Chemistry

Chemistry is a versatile subject area and the pursuit of a career in chemistry can be a most intellectually satisfying experience. No other basic science touches and shapes as many aspects of modern society as does chemistry. The study of chemistry has provided solutions to complex problems and has improved the quality of all phases of human life from soft contact lenses and synthetic blood to longer-lasting paint and alternative fuels. A particular strength of this department is in surface and interface chemistry, which bridges many areas of modern science and technology.

Chemists at all levels of education find a market for their skills and knowledge in many employment areas. Chemists provide the technical backbone for the manufacturing industries (pharmaceuticals, plastics, paper, semiconductor electronics technology, and agriculture), for service industries (clinical and forensic laboratories, academe, environmental protection, and information science) and for governmental positions in regulatory agencies and in science policy analyses. Many chemists are employed in nontraditional areas, such as patent law, insurance underwriting, sales, product management, journalism, and even banking.

The alluring challenge of chemistry inspires many bachelor degree recipients to study for advanced degrees within the discipline of chemistry and in other areas, as well. Chemistry or biochemistry is the strongest preparation for graduate studies or for professional school in the health-related disciplines (medicine, pharmacology, and biochemistry), and for other science programs (materials science, polymers, biotechnology, environmental studies, and mineralogy).

The study of chemistry opens doors to satisfying careers, to a stimulating view of the world, and to a professional life in which one’s natural tendency to ask “Why?” can lead to personally rewarding endeavors. The undergraduate curriculum in chemistry contains many of the prerequisites for biology, earth and environmental sciences, materials science, molecular biology, physics, and chemical engineering. This allows students to transfer credits among these majors through the sophomore year.

Chemistry students have the opportunity to design their undergraduate curricula for specialization in a variety of fields through the ChemFlex curriculum.

THE CHEMFLEX CURRICULUM

The Department of Chemistry offers degrees in both the College of Arts and Sciences and the College of Engineering and Applied Sciences. Students in the College of Arts and Sciences have three options: the B.S. in Chemistry, the B.A. in Chemical Engineering, and the B.S. in Pharmaceutical Chemistry. In addition we offer an interdepartmental B.S. in Biochemistry in collaboration with the Department of Biological Sciences. For students in the College of Engineering and Applied Sciences we offer the B.S. in Chemistry.

In the College of Arts and Sciences, the traditional degree certified by the American Chemical Society is offered; the B. S. degree in the College of Engineering is very similar to the certified degree. All B. S. programs have a Common Chemistry Core and similar collateral science requirements. These programs are pre-professional in nature, and students planning to attend graduate school in chemistry or an allied science should elect the B. S. program in the college to which they have been admitted. The traditional B. A. Program in the College of Arts and Sciences is not a pre-professional program and may be elected by students who do not plan to do graduate work in chemistry or allied sciences but who desire a stronger background in chemistry than is provided by a chemistry minor.

In addition to the traditional certified B. S degree and B. A. degree, the B. A. and B. S. Chemistry programs in the College of Arts and Sciences feature an alternative flexible curriculum, called ChemFlex, which enables a student to concentrate in a specific area. The concentrations possible for the B. S. are Physical/Analytical, Polymers, and Materials. The B. A. has two areas of concentration: Business and the Health Professions. All concentrations in ChemFlex share a Common Chemistry Core; all students complete the core and then follow one of two paths (Path A or Path B) as outlined in the following lists.

Students may transfer from a B. S. program to a B. A. program easily, but the reverse is more difficult. Students in a B. A. program who make the decision to attend graduate school in chemistry or allied sciences can achieve a minimum preparation for this transition by electing 307 Advanced Inorganic Chemistry.

DEPARTMENT MODERN LANGUAGE AND LITERATURE REQUIREMENT

The modern foreign language requirement is met by one of three options:

1. Completion of the second semester of a modern foreign language;
2. Certification of language equivalent to this level taken in high school;
3. Substitution of six credits of science electives. If science electives are chosen, the non-science distribution requirement must still be met.

Professors. Gregory S Ferguson, PhD (Cornell University); Robert A. Flowers, II, PhD (Lehigh University); Ned D. Heindel, PhD (University of Delaware); Steven L. Regen, PhD (Massachusetts Institute of Technology); John D. Simon, PhD (Harvard University); David A. Vicic, PhD (University of Rochester)

Associate Professors. Kerney Jebrell Glover, PhD (University of California San Diego); Kai Manfred Martin Landskron, PhD (University of Munich); James E. Roberts, PhD (Northwestern University); Dmitri V. Vezenov, PhD (Harvard University)

Assistant Professors. Mark Shio-Yih Chen, PhD (Harvard University); Heather Jaeger, PhD (University Georgia Athens); Marcos Pires, PhD (Purdue University); Damien Thevenin, PhD (University of Delaware); Nathan Wittenberg, PhD (The Pennsylvania State University); Xiaoji G. Xu, PhD (University of British Columbia)

Professors Of Practice. Suzanne Marie Fernandez, PhD (University of Utah); Andy W. Ho, PhD (Harvard University); Rebecca S. Miller, PhD (Duke University)

Emeriti. Jack A. Alhadeff, PhD (Oregon Health Science University); Natalie M. Foster, PhD (Lehigh University); Kamil Klier, PhD (Acad Sciences Czech Republic); John W. Larsen, PhD (Purdue University Calumet); Joseph R. Merkel, PhD (University of Maryland College Park); Fortunato J. Micale, PhD (Lehigh University); Keith J. Schray, PhD (The Pennsylvania State University); Gary W. Simmons, PhD (University of Virginia); Robert S. Sprague, PhD (University of Illinois Urbana); James E. Sturm, PhD (University of Notre Dame); Daniel Zeroka, PhD (University of Pennsylvania)

DEGREES IN THE COLLEGE OF ARTS AND SCIENCES

In the College of Arts and Sciences the Chemistry Department offers three degrees: a B.S. in Chemistry, a B.A. in Chemistry and a B.S. in Pharmaceutical Chemistry with an interdepartmental B.S. degree.

The ChemFlex Curriculum allows the flexibility for a student to develop a concentration in a specific area if he/she wishes to do so. The specific concentrations are noted in the following Table.

Table: ChemFlex Curriculum Overview

<table>
<thead>
<tr>
<th>Specialization Requirements</th>
<th>B.S. Chemistry (ACS)</th>
<th>B.S. Chemistry Analytical/Physical</th>
<th>B.S. Chemistry Polymers</th>
<th>B.S. Chemistry Materials</th>
<th>B.A. Chemistry</th>
<th>B.A. Chemistry Business</th>
<th>B.A. Chemistry Health Professions</th>
<th>B.S. Pharmaceutical Chemistry</th>
<th>B.S. Biochemistry (interdepartmental degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Chemistry Core</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
<td>1, 2, 3 or 4</td>
</tr>
<tr>
<td>Courses required for specific concentration</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
With regard to the B.S. in Pharmaceutical Chemistry, the pharmaceutical industry is focused on exploring the biochemistry of disease and designing or finding drugs to cure or ameliorate disease. Biochemists, organic chemists, biologists, and chemical engineers collaborate to achieve this end. The majority of chemists hired today go into the pharmaceutical industry. The B.S. in Pharmaceutical Chemistry is a chemistry degree option which focuses on core chemistry, biochemistry, and molecular biology to prepare students for careers in this field. Since it is a highly interdisciplinary field it requires chemistry, biochemistry, and molecular biology to prepare students for careers in this field. Since it is a highly interdisciplinary field it requires the breadth of knowledge offered by this degree program.

**Freshman chemistry courses**
The freshman courses CHM 030 and CHM 040 have similar course content. If both courses are taken, only credit for CHM 040, the more advanced course, will be awarded.

**Common Chemistry Core**
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 030 &amp; CHM 031</td>
<td>Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems</td>
</tr>
<tr>
<td>CHM 110 &amp; CHM 111</td>
<td>Organic Chemistry I and Organic Chemistry Laboratory I</td>
</tr>
<tr>
<td>CHM 112 &amp; CHM 113</td>
<td>Organic Chemistry II and Organic Chemistry Laboratory II</td>
</tr>
<tr>
<td>CHM 332</td>
<td>Analytical Chemistry</td>
</tr>
</tbody>
</table>

**Collateral Requirement - Path A**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 307</td>
<td>Advanced Inorganic Chemistry</td>
</tr>
</tbody>
</table>

**Specialization Courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 334</td>
<td>Advanced Chemistry Laboratory I</td>
</tr>
<tr>
<td>CHM 335</td>
<td>Advanced Chemistry Laboratory II</td>
</tr>
<tr>
<td>CHM 341</td>
<td>Molecular Structure, Bonding and Dynamics</td>
</tr>
<tr>
<td>CHM 342</td>
<td>Thermodynamics &amp; Kinetics</td>
</tr>
<tr>
<td>CHM 343</td>
<td>Physical Chemistry Laboratory</td>
</tr>
<tr>
<td>CHM 371</td>
<td>Elements of Biochemistry I</td>
</tr>
</tbody>
</table>

**Advanced Chemistry Elective Requirement**
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 358</td>
<td>Advanced Organic Chemistry</td>
</tr>
<tr>
<td>CHM 372</td>
<td>Elements of Biochemistry II</td>
</tr>
<tr>
<td>CHM 376</td>
<td>Advanced Research Chemistry Laboratory</td>
</tr>
<tr>
<td>CHM 391</td>
<td>Colloid and Surface Chemistry</td>
</tr>
<tr>
<td>CHE 392</td>
<td>Introduction to Polymer Science</td>
</tr>
<tr>
<td>CHM 393</td>
<td>Physical Polymer Science</td>
</tr>
<tr>
<td>CHM 394</td>
<td>Organic Polymer Science I</td>
</tr>
<tr>
<td>PHY 363</td>
<td>Physics of Solids</td>
</tr>
</tbody>
</table>

**Common Core**
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 040 &amp; CHM 041</td>
<td>Concepts, Models and Experiments I and Concepts, Models and Experiments II</td>
</tr>
<tr>
<td>CHM 030 &amp; CHM 031</td>
<td>Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems</td>
</tr>
<tr>
<td>CHM 110 &amp; CHM 111</td>
<td>Organic Chemistry I and Organic Chemistry Laboratory I</td>
</tr>
<tr>
<td>CHM 112 &amp; CHM 113</td>
<td>Organic Chemistry II and Organic Chemistry Laboratory II</td>
</tr>
<tr>
<td>CHM 332</td>
<td>Analytical Chemistry</td>
</tr>
</tbody>
</table>

**SPECIALIZATIONS**

**B.S. Chemistry - Analytical/Physical Concentration**

**Common Core**
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 040 &amp; CHM 041</td>
<td>Concepts, Models and Experiments I and Concepts, Models and Experiments II</td>
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<tr>
<td>CHM 030 &amp; CHM 031</td>
<td>Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems</td>
</tr>
<tr>
<td>CHM 110 &amp; CHM 111</td>
<td>Organic Chemistry I and Organic Chemistry Laboratory I</td>
</tr>
<tr>
<td>CHM 112 &amp; CHM 113</td>
<td>Organic Chemistry II and Organic Chemistry Laboratory II</td>
</tr>
<tr>
<td>CHM 332</td>
<td>Analytical Chemistry</td>
</tr>
</tbody>
</table>

**Collateral Requirement - Path A**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 201</td>
<td>Technical Writing</td>
</tr>
<tr>
<td>CHM 301</td>
<td>Chemistry Seminar</td>
</tr>
<tr>
<td>CHM 307</td>
<td>Advanced Inorganic Chemistry</td>
</tr>
</tbody>
</table>

or CSE 002 | Fundamentals of Programming |

**Specialization Courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 334</td>
<td>Advanced Chemistry Laboratory I</td>
</tr>
<tr>
<td>CHM 335</td>
<td>Advanced Chemistry Laboratory II</td>
</tr>
<tr>
<td>CHM 341</td>
<td>Molecular Structure, Bonding and Dynamics</td>
</tr>
<tr>
<td>CHM 342</td>
<td>Thermodynamics &amp; Kinetics</td>
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<tr>
<td>CHM 343</td>
<td>Physical Chemistry Laboratory</td>
</tr>
<tr>
<td>CHM 371</td>
<td>Elements of Biochemistry I</td>
</tr>
</tbody>
</table>

**Advanced Chemistry Elective Requirement**
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 358</td>
<td>Advanced Organic Chemistry</td>
</tr>
<tr>
<td>CHM 372</td>
<td>Elements of Biochemistry II</td>
</tr>
<tr>
<td>CHM 376</td>
<td>Advanced Research Chemistry Laboratory</td>
</tr>
<tr>
<td>CHM 391</td>
<td>Colloid and Surface Chemistry</td>
</tr>
<tr>
<td>CHE 392</td>
<td>Introduction to Polymer Science</td>
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</tr>
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<td>PHY 363</td>
<td>Physics of Solids</td>
</tr>
</tbody>
</table>

**Common Core**
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 040</td>
<td>Honors General Chemistry I</td>
</tr>
<tr>
<td>CHM 041</td>
<td>Honors General Chemistry II</td>
</tr>
<tr>
<td>CHM 030 &amp; CHM 031</td>
<td>Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems</td>
</tr>
</tbody>
</table>

**Total Credits**

- Path A: 28-33
- Path B: 27

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1 Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.

2 CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.
CHM 110 Organic Chemistry I and Organic Chemistry Laboratory I 4
CHM 111 & CHM 112 Organic Chemistry II and Organic Chemistry Laboratory II 4
CHM 332 Analytical Chemistry 3
See Concentrations - Physical chemistry 3-8
CHM 201 Technical Writing 1 2
CHM 301 Chemistry Seminar 2 1
CHM 307 Advanced Inorganic Chemistry 3

Collateral Requirement - Path A
MATH 021 Calculus I 4
MATH 022 Calculus II 4
MATH 023 Calculus III 4
MATH 205 Linear Methods 3
PHY 011 & PHY 012 Introductory Physics I and Introductory Physics Laboratory I 5
PHY 021 & PHY 022 Introductory Physics II and Introductory Physics Laboratory II 5
ENGR 010 Applied Engineering Computer Methods 2
or CSE 002 Fundamentals of Programming

Specialization Courses
CHM 334 Advanced Chemistry Laboratory I 3
CHM 335 Advanced Chemistry Laboratory II 3
CHM 341 Molecular Structure, Bonding and Dynamics 3
CHM 342 Thermodynamics & Kinetics 3
CHM 343 Physical Chemistry Laboratory 2

Total Credits 69-74

1 Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.
2 CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.

B.S. Chemistry - Polymers Concentration

Common Core
Select one of the following: 8
CHM 040 Honors General Chemistry I & CHM 041 Honors General Chemistry II
CHM 030 Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems & CHM 031
See Concentrations - Physical chemistry 3-8
CHM 201 Technical Writing 1 2
CHM 301 Chemistry Seminar 2 1
CHM 307 Advanced Inorganic Chemistry 3

Collateral Requirement - Path A
MATH 021 Calculus I 4
MATH 022 Calculus II 4
MATH 023 Calculus III 4
MATH 205 Linear Methods 3
PHY 011 & PHY 012 Introductory Physics I and Introductory Physics Laboratory I 5
PHY 021 & PHY 022 Introductory Physics II and Introductory Physics Laboratory II 5
ENGR 010 Applied Engineering Computer Methods 2
or CSE 002 Fundamentals of Programming

Specialization Courses
CHM 334 Advanced Chemistry Laboratory I 3
CHM 335 Advanced Chemistry Laboratory II 3
CHM 341 Molecular Structure, Bonding and Dynamics 3
CHM 342 Thermodynamics & Kinetics 3
CHM 343 Physical Chemistry Laboratory 2

Total Credits 72-77

1 Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.
2 CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.

B.A. Chemistry

Common Core
Select one of the following: 8
CHM 040 Concepts, Models and Experiments I & CHM 041 Concepts, Models and Experiments II
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 030 &amp; CHM 031</td>
<td>Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems</td>
<td>8</td>
</tr>
<tr>
<td>CHM 110 &amp; CHM 111</td>
<td>Organic Chemistry I and Organic Chemistry Laboratory I</td>
<td>3</td>
</tr>
<tr>
<td>CHM 112 &amp; CHM 113</td>
<td>Organic Chemistry II and Organic Chemistry Laboratory II</td>
<td>3</td>
</tr>
<tr>
<td>CHM 332</td>
<td>Analytical Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>CHM 301</td>
<td>Chemistry Seminar</td>
<td>1</td>
</tr>
<tr>
<td>CHM 307</td>
<td>Advanced Inorganic Chemistry</td>
<td>3</td>
</tr>
</tbody>
</table>

**Collateral Requirement**

Select one of the following:

**Path A**

- MATH 021: Calculus I
- MATH 022: Calculus II
- MATH 023: Calculus III
- MATH 205: Linear Methods
- PHY 011 & PHY 012: Introductory Physics I and Introductory Physics Laboratory I
- PHY 021 & PHY 022: Introductory Physics II and Introductory Physics Laboratory II
- ENGR 010: Applied Engineering Computer Methods

or CSE 002: Fundamentals of Programming

**Path B**

- MATH 051: Survey of Calculus I
- MATH 052: Survey of Calculus II
- MATH 043: Survey of Linear Algebra
- PH 010 & PH 012: General Physics I and Introductory Physics Laboratory I
- PH 013 & PH 022: General Physics II and Introductory Physics Laboratory II

**Specialization Courses**

Select one of the following:

- CHM 341: Molecular Structure, Bonding and Dynamics
- CHM 342: Thermodynamics & Kinetics
- CHM 194: Physical Chemistry for Biological Sciences
- CHM 343: Physical Chemistry Laboratory
- ECO 001: Principles of Economics
- BUS 125: Behavioral Skills Workshop
- BUS 126: Information Analysis and Financial Decision Making I
- BUS 127: Information Analysis and Financial Decision Making II
- BUS 225: Developing, Producing, and Marketing Products and Services I
- BUS 226: Developing, Producing, and Marketing Products and Services II
- BUS 326: Business Strategy
- MATH 012: Basic Statistics

**Total Credits**

57-71

1. Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.
2. CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.
3. MATH 012 may be substituted by any statistics course.

**B.A. Chemistry - Business Concentration**

**Common Core**

Select one of the following:

- CHM 030 & CHM 031: Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems
- CHM 110 & CHM 111: Organic Chemistry I and Organic Chemistry Laboratory I
- CHM 112 & CHM 113: Organic Chemistry II and Organic Chemistry Laboratory II
- CHM 332: Analytical Chemistry
- CHM 201: Technical Writing

**Total Credits**

1. Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.
2. CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.

**B.A. Chemistry - Health Professions Concentration**

**Common Core**

Select one of the following:

- CHM 030 & CHM 031: Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems
- CHM 110 & CHM 111: Organic Chemistry I and Organic Chemistry Laboratory I
- CHM 112 & CHM 113: Organic Chemistry II and Organic Chemistry Laboratory II
- CHM 332: Analytical Chemistry
- CHM 201: Technical Writing

**Total Credits**

1. Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.
2. CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.
CHM 332 Analytical Chemistry 3
See Concentrations - Physical chemistry 3-8
CHM 201 Technical Writing 1 2
CHM 301 Chemistry Seminar 2 1
CHM 307 Advanced Inorganic Chemistry 3

Collateral Requirement
Select one of the following: 19-28
Path A
MATH 021 Calculus I
MATH 022 Calculus II
MATH 023 Calculus III
MATH 205 Linear Methods
PHY 011 Introductory Physics I
& PHY 012 and Introductory Physics Laboratory I
PHY 021 Introductory Physics II
& PHY 022 and Introductory Physics Laboratory II
ENGR 010 Applied Engineering Computer Methods
or CSE 002 Fundamentals of Programming
Path B
MATH 051 Survey of Calculus I
MATH 052 Survey of Calculus II
MATH 043 Survey of Linear Algebra
PHYS 01 General Physics I
& PHYS 012 and Introductory Physics Laboratory I
PHYS 013 General Physics II
& PHYS 022 and Introductory Physics Laboratory II

Specialization Courses
CHM elective 3
Select one of the following: 3
CHM 341 Molecular Structure, Bonding and Dynamics
CHM 342 Thermodynamics & Kinetics
CHM 194 Physical Chemistry for Biological Sciences
CHM 343 Physical Chemistry Laboratory 2
BIOS 115 Biology Core II: Genetics
& BIOS 116 and Biology Core II: Genetics Laboratory
BIOS 041 Biotechnology Core I: Cellular and Molecular Biology
& BIOS 042 and Molecular Biology Core I: Cellular and Molecular Lab
MATH 012 Basic Statistics 3

Additional courses in BioS are recommended.

Total Credits 67-81
1 Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.
2 CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.
3 MATH 012 may be substituted by any statistics course.

B.S. Pharmaceutical Chemistry

Common Core
Select one of the following: 8
CHM 040 Concepts, Models and Experiments I
& CHM 041 and Concepts, Models and Experiments II
CHM 030 Introduction to Chemical Principles
& CHM 031 and Chemical Equilibria in Aqueous Systems
CHM 110 Organic Chemistry I
& CHM 111 and Organic Chemistry Laboratory I
CHM 112 Organic Chemistry II
& CHM 113 and Organic Chemistry Laboratory II
CHM 332 Analytical Chemistry 3
See Concentrations - Physical Chemistry 3-8
CHM 201 Technical Writing 1 2
CHM 301 Chemistry Seminar 2 1
CHM 307 Advanced Inorganic Chemistry 3

Collateral Requirement
Select one of the following: 19-28
Path A
MATH 021 Calculus I
MATH 022 Calculus II
MATH 023 Calculus III
MATH 205 Linear Methods
PHY 011 Introductory Physics I
& PHY 012 and Introductory Physics Laboratory I
PHY 021 Introductory Physics II
& PHY 022 and Introductory Physics Laboratory II
ENGR 010 Applied Engineering Computer Methods
or CSE 002 Fundamentals of Programming
Path B
MATH 051 Survey of Calculus I
MATH 052 Survey of Calculus II
MATH 043 Survey of Linear Algebra
PHY 01 General Physics I
& PHY 012 and Introductory Physics Laboratory I
PHY 013 General Physics II
& PHY 022 and Introductory Physics Laboratory II

Specialization Courses
Select one of the following: 3
CHM 194 Physical Chemistry for Biological Sciences
CHM 341 Molecular Structure, Bonding and Dynamics
CHM 342 Thermodynamics & Kinetics
CHM 358 Advanced Organic Chemistry 3
CHM 371 Elements of Biochemistry I 1-3
CHM 372 Elements of Biochemistry II 3
Advanced CHM Electives 3
BIOS 041 Biotechnology Core I: Cellular and Molecular Biology
& BIOS 042 and Molecular Biology Core I: Cellular and Molecular Lab
BIOS 115 Biotechnology Core II: Genetics
MATH 012 Basic Statistics 3

Total Credits 71-87
1 Other writing intensive courses may be substituted with the approval of the advisor but any substitute course should have a science focus.
2 CHM 301 may be substituted by any course having a major presentation component with the approval of the major advisor.
3 MATH 012 may be substituted by any statistics course.

MODEL ROSTER WHEN PATH A IS FOLLOWED

First Year CR
College Seminar 3-4
CHM 040 4
CHM 041 4
ENGL 001 3
ENGL 002 3
MATH 021 4
MATH 022 4
PHY 011 4
PHY 012 1

30-31
Unrestricted electives 25

Total Credits 123

Model Roster

First Year

First Semester CR Second Semester CR
ENGL 001 3 ENGL 002 3
MATH 021 4 MATH 022 4
ENGR 010 2 ENGR 005 2
Select one of the following: 4-5 Select one of the following: 4-5
CHM 030 1 4 CHM 030 1 4
PHY 011 5 PHY 011 5
& PHY 012 1 & PHY 012 1

22-23

Second Year

First Semester CR Second Semester CR
CHM 110 4 CHM 112 4
& CHM 111 4 & CHM 113 4
PHY 021 5 MATH 205 3
& PHY 022 4 MATH 023 4
MATH 023 4 ECO 001 4
modern foreign language requirement (See details in introduction) 4 Humanities/Social Science requirement 4

Third Year

First Semester CR Second Semester CR
Select one of the following: 2-3 Select one of the following: 6
CHM 307 2 CHM 335 6
& CHM 335 6
CHM 201 2 CHM 342 5
& CHM 343 5
Or approved writing-intensive course 3 modern foreign language requirement 4

CHM 332 6 free electives 4
& CHM 334 4
CHM 341 3
Distribution requirement/ elective 4
modern foreign language requirement (See details in introduction) 4

24-25

Fourth Year

First Semester CR Second Semester CR
CHM 301 1 Advanced chemistry elective 3
CHM 371 3 free electives 11
Advanced chemistry elective 3
Distribution requirement 7

Total Credits 147-150

1 Required natural science courses, one taken fall semester and the other taken in spring.
2 Note: It is recommended that, where possible, students planning to major in chemistry take CHM 040 in the fall semester and CHM 041 in the spring semester of the freshman year. For such students the elective in the spring semester is displaced to a subsequent semester. The CHM 030/CHM 031 sequence may be substituted.

Total Credits: 61-62

Note that some concentrations would insert courses such as MATH 012, BIOS 041/BIOS 042 (B.S. Pharmaceutical Chemistry), ECO 001 (B.A.-Business), etc.

junior year/senior year (30-32 credits)

Student will need to meet with major advisor in order to formulate courses to be taken.

MODEL ROSTER WHEN PATH B IS FOLLOWED

First Year CR
College Seminar 3-4
CHM 040 4
CHM 041 4
ENGL 001 3
ENGL 002 3
MATH 051 4
MATH 052 3
PHY 010 4
PHY 012 1

29-30

Second Year CR
CHM 110 4
& CHM 111 4
CHM 112 4
& CHM 113 4
PHY 013 4
& PHY 022 4
MATH 043 3
distribution requirements - free electives 15

Total Credits: 59-60

Note that some concentrations would insert courses such as MATH 012, BIOS 041/BIOS 042 (B.S. Pharmaceutical Chemistry), ECO 001 (B.A.-Business), etc.

junior year/senior year (30-32 credits)

Student will need to meet with major advisor in order to formulate courses to be taken.

B.S. DEGREE IN CHEMISTRY, COLLEGE OF ENGINEERING & APPLIED SCIENCE

Summary of Requirements

College distribution 24
Physics, math, and computing 28
Chemistry 46

Total Credits

123
The following information on admissions, proficiency examinations and other policies applies to both the master of science and doctor of philosophy degrees in chemistry.

Admission to graduate study in chemistry assumes that a student has met, or is willing to meet though further study, minimum undergraduate requirements for a bachelor's degree in chemistry. This would include (beyond two semesters of introductory chemistry) two semesters of organic chemistry, two semesters of physical chemistry, two semesters of analytical chemistry and one semester of inorganic chemistry. A promising student whose degree is in a field related to chemistry (e.g., biology, chemical engineering) may be admitted to graduate study in chemistry provided that any deficiencies in basic chemistry preparation are made up in the first year of graduate study, noting that some of the courses required for this may not carry graduate credit.

The chemistry department administers proficiency examinations at the advanced undergraduate level in analytical, biochemistry, inorganic, organic and physical chemistry to all regular graduate students at the time of matriculation. Each student is required to take three examinations. Information regarding material to be covered on these examinations will be sent to each student several months in advance of matriculation. It is expected that each student will prepare diligently for these tests. A student who performs well on one or more of these tests has an opportunity to take advanced level and special topics courses at an earlier than normal time and may in fact begin graduate research during the first year. A Ph.D. candidate must show proficiency in three areas and an M.S. candidate in two areas within the first year in residence. A student who fails one or more of the proficiency examinations will meet with Professor Miller, faculty graduate administrator, to determine an appropriate course of action in light of the exam performance, projected major and degree aspiration. Two optional routes are available for demonstration of proficiency. (1) The student through self-study and auditing of appropriate courses may prepare for a retaking of a proficiency examination at the beginning of the second semester in residence. (2) Alternatively, the student may enroll in appropriate 400 level courses during the first year in residence. A grade of B- or better in an appropriate 400 level course will be considered equivalent to passing the proficiency examination in that area. Courses taken as a means of demonstrating proficiency will be acceptable for the M.S. or Ph.D. graduate program.

**Master of Science in Chemistry degree**

There are no other specifically required courses for the M.S. degree, allowing each student to design a curriculum that fits their needs and interests. Normally, work for the master's degree can be completed in 18 calendar months of full-time study.

The Master of Science in Chemistry degree requires a total of 30 credits.

Select one of the following options:

<table>
<thead>
<tr>
<th>Option</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option A</strong></td>
<td></td>
</tr>
<tr>
<td>A minimum of 30 course credits</td>
<td>30</td>
</tr>
<tr>
<td><strong>Option B</strong></td>
<td></td>
</tr>
<tr>
<td>A minimum of 27 course credits</td>
<td>27</td>
</tr>
<tr>
<td>CHM 421 Chemistry Research (literature review paper)</td>
<td></td>
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<tr>
<td><strong>Option C</strong></td>
<td></td>
</tr>
<tr>
<td>A minimum of 24 course credits</td>
<td>24</td>
</tr>
<tr>
<td>CHM 421 Chemistry Research (experimental research)</td>
<td></td>
</tr>
</tbody>
</table>

Each option requires:

- A minimum of 18 credits at the 400 level (15 of which must be in chemistry)

| Total Credits | 30 |

**Doctor of Philosophy Degree**

Completion of a doctor of philosophy degree program normally requires a minimum of four years fulltime work after entrance with a bachelor's degree. There are few specific course credit requirements...
for the Ph.D.; however, approved degree programs generally have at least 24 hours of course work (including any applied toward a master’s degree) and 6 credits of research. Thus, the program consists of approximately one-third formal course work and two-thirds independent study and research. There is a two-credit seminar requirement (CHM 481). After Ph.D. proficiency has been established and the research advisor selected (this must be done by the end of the first year in residence), the major hurdles are the doctoral examination in the student’s area of concentration. This exam must be passed by the end of 2 1/2 years of residence. If this hurdle is surmounted, the remaining time is spent completing (and ultimately defending) the dissertation research under the guidance of the research advisor and the dissertation committee.

### CURRENT RESEARCH PROJECTS
Current research projects of interest are listed below.

#### Analytical Chemistry
NMR studies of organic solids and polymers; electrochemical reduction and oxidation mechanisms of organic compounds; development of novel immunoassays.

#### Biochemistry
Membrane protein interactions; structural characterization of membrane proteins; production of membrane proteins; biophysical characterization of membrane proteins; medicinal assay development; medical diagnostics; cryogenics; microfluids; biomaterials; multidrug resistance; selective drug delivery; anti-cancer therapy; antibiotic drug discovery; cell surface remodeling; immunotherapy; activity based probes; fluorescence assay development.

#### Inorganic Chemistry
Synthesis, characterization, and reactivity of transition metal complexes and nanoparticles; coordination chemistry and molecular self-assembly at metal surfaces; electrochemistry at metal and metal-oxide electrodes; synthesis and characterization of mesoporous solids from transition metal and main-group element precursors; applications of mesoporous solids for carbon sequestration; formation of multilayered thin films of inorganic and organic-inorganic hybrid materials; and application of lanthanide catalysis in organic synthesis.

#### Materials and Polymer Chemistry
Inorganic and organometallic chemistry in the synthesis of thin-film materials; synthesis at and dynamics of polymer interfaces; acoustic, optical, permeability, dielectric and mechanical behavior of thin films; laser light scattering and small-angle X-ray scattering studies on polymer solutions; polyelectrolytes and ion-containing solutions; nanofabrications in polymer systems; organic-inorganic hybrid solid state materials; synthesis and characterization of novel mesoporous materials.

#### Organic Chemistry
Synthesis of medicinal agents, correlation of molecular structure with pharmacological behavior; chemical models for biochemical reactions; chemistry of monolayers and organized molecule assemblages; drug carriers; synthetic ion conductors; Langmuir-Blodgett films; organometallic reaction mechanisms; organofluorine chemistry; protein folding and renaturation; molecular recognition; calorimetry; electrochemical studies of electron transfer reactions; synthetic methods development.

#### Physical Chemistry
Chemistry at surfaces and interfaces of catalysts, alloys, electrodes, thin films, and biosensors using an array of surface sensitive methods: spectroscopic ellipsometry, scanning probe microscopy, angle resolved X-ray photoelectron spectroscopy, electrochemistry; intermolecular interactions in soft matter; single-molecule force spectroscopy; chemically sensitive imaging at nanoscale; development of optics-based tools for chemical analysis; femtosecond ultrafast spectroscopy; investigation of charge transfer in energy materials; development of instrumentation and experimental methodologies for the cryogenic spectroscopy of ions; deposition of ions into solid rare-gas matrices; ion-ion and ion-molecule reactions in matrices; freeze-frame spectroscopy – utilizing kinetic control inherent to cryogenic spectroscopy to elucidate reaction mechanisms (in particular of nanocatalysis with metal clusters) in step-wise fashion.

### Computational Chemistry
Characterization of electronic properties and structures of molecules, molecular complexes, and extended systems from ab initio methods; development of quantum-classical methods for non-adiabatic dynamics; real-time simulations of non-radiative relaxation and electron-hole recombination in semiconducting nanocrystals; charge and energy transfer rates and mechanisms in metal-organic hybrid polymers.

### MAJOR INSTRUMENTATION
Chemistry research spans all areas: analytical, biochemistry, inorganic, organic, and physical. Special equipment available for graduate research in chemistry is as follows.

#### Research facilities
LC/MS/MS, GC-MS, MALDI-TOF-MS, HPLCs, GCs, ultracentrifuges, cold rooms, cell disintegrator, zone and disc electrophoresis apparatus, column chromatograph, autoclave, freezers (-80C), rotary evaporator, Milli-Q water purification system, shaking heated water baths, spectropolarimeter with circular dichroism capability.


#### Spectrometers
UV/visible double beam automated, fluorescence, UV/visible/near IR, Fourier transform IR with diffuse reflectance, photoacoustic and attenuated reflectance capability, and GC mass spectrometers.

Surface analysis facilities – rotating anode high-sensitivity high-energy resolution ESCA with imaging capability (ESCA is equipped with automated angular data acquisition). Surface science facility – Low energy electron diffraction (LEED), photoelectron spectroscopy for submicron particle analysis. Ellipsimeter, contact angle capabilities, gas adsorption apparatus (BET), atomic force microscope, instructional scanning tunneling microscope, and light scanning. Microcalorimeter (flowing with UV and refractive index detectors), differential scanning calorimeter (DSC).

#### Courses

<table>
<thead>
<tr>
<th>CHM 030 Introduction to Chemical Principles</th>
<th>4 Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>An introduction to important topics in chemistry: atomic structure, properties of matter, chemical reactions, energy, structure and bonding in organic and inorganic compounds, chemical equilibrium. The course features a lecture tightly linked to a three-hour studio experience that combines laboratory work and recitation.</td>
<td>Attribute/Distribution: NS</td>
</tr>
</tbody>
</table>
CHM 031 Chemical Equilibria in Aqueous Systems 4 Credits
An introduction to: intermolecular forces and their influence on physical properties and phase behavior; chemical kinetics; thermodynamics in chemical systems; and electrochemistry. The course includes a detailed treatment of equilibria in aqueous solutions, including acid-base, precipitation-solubility, metal-ligand, oxidation-reduction and distribution equilibria. The laboratory work emphasizes the qualitative and quantitative analysis of equilibria in aqueous media. Three lectures and one three-hour laboratory period.
Prerequisites: (CHM 030 or CHM 040) and (MATH 021 or MATH 031 or MATH 051 or MATH 076)
Can be taken Concurrently: MATH 021, MATH 031, MATH 051, MATH 076
Attribute/Distribution: NS

CHM 040 Honors General Chemistry I 4 Credits
A first-semester course in chemistry for students planning to major in chemistry, biochemistry, chemical engineering, materials science, or other chemistry-related fields. Chemical and physical properties, structures, bonding concepts, and quantitative analysis. Laboratory includes synthesis, separation and analysis procedures; computer applications to chemistry. Three lectures, one laboratory.
Attribute/Distribution: NS

CHM 041 Honors General Chemistry II 4 Credits
Continuation of Chemistry 40. Three lectures, one laboratory.
Prerequisites: (CHM 040 or CHM 030) and (MATH 021 or MATH 031 or MATH 051)
Attribute/Distribution: NS

CHM 110 Organic Chemistry I 3 Credits
Systematic survey of the typical compounds of carbon, their classification, and general relations; study of synthetic reactions.
Prerequisites: CHM 031 or CHM 041
Attribute/Distribution: NS

CHM 111 Organic Chemistry Laboratory I 1 Credit
Preparation of pure organic compounds. Modern techniques of characterization.
Prerequisites: CHM 110
Can be taken Concurrently: CHM 110
Attribute/Distribution: NS

CHM 112 Organic Chemistry II 3 Credits
Continuation of CHM 110.
Prerequisites: CHM 110
Attribute/Distribution: NS

CHM 113 Organic Chemistry Laboratory II 1 Credit
Continuation of Organic Chemistry Laboratory I.
Prerequisites: CHM 111 and CHM 112
Can be taken Concurrently: CHM 111, CHM 112
Attribute/Distribution: NS

CHM 177 Introduction to Research 1-2 Credits
For advanced freshmen and sophomore chemistry majors. Consent of department chair required.
Repeat Status: Course may be repeated.
Attribute/Distribution: NS

CHM 194 Physical Chemistry for Biological Sciences 3 Credits
The principles and applications of physical chemical concepts to systems of biological interest, including the gas laws, thermodynamics of metabolic reactions, colligative properties, electrochemical equilibria, reaction kinetics and enzyme catalysis, and transport of macromolecules and viruses.
Prerequisites: (CHM 030 or CHM 040) and (CHM 031 or CHM 041)
Attribute/Distribution: NS

CHM 201 Technical Writing 2 Credits
Principal types of written communications used by professional chemists including informative abstracts, research proposals, progress reports, executive summaries for nonchemist decision makers and proper written experimental procedures, tables, schemes and figures. Must have junior standing in chemistry major.
Attribute/Distribution: ND

CHM 250 Special Topics 1-4 Credits
Selected topics in chemistry.
Repeat Status: Course may be repeated.
Attribute/Distribution: NS

CHM 300 Apprentice Teaching 3 Credits
Repeat Status: Course may be repeated.

CHM 301 Chemistry Seminar 1 Credit
A course designed for seniors will involve the literature research of a topic of the student’s choosing followed by a 35 minute oral presentation to the class and professor. Must have senior standing.

CHM 307 Advanced Inorganic Chemistry 3 Credits
Introduction to transition metal complexes; theories of bonding; kinetics and mechanisms of transition metal complex reactions; selected aspects of organometallic chemistry; bioinorganic chemistry.
Prerequisites: CHM 341 or CHM 194
Can be taken Concurrently: CHM 341, CHM 194
Attribute/Distribution: NS

CHM 332 Analytical Chemistry 3 Credits
Theory and practice of chemical analysis. Principles of quantitative separations and determinations; theory and application of selected optical and electrical instruments in analytical chemistry; interpretation of numerical data, design of experiments, solute distribution in separation methods.
Prerequisites: (CHM 031 or CHM 041) and CHM 110
Attribute/Distribution: NS

CHM 334 Advanced Chemistry Laboratory I 3 Credits
Exploration of synthetic methods and analysis techniques for inorganic and organic compounds. Determination of product structures and quantitative analysis using modern chemical analysis techniques, including NMR, GC-MS, GC, HPLC, FT-IR, and XPS.
Prerequisites: (CHM 110 and CHM 111 and CHM 112 and CHM 113 and CHM 332)
Can be taken Concurrently: CHM 332
Attribute/Distribution: NS

CHM 335 Advanced Chemistry Laboratory II 3 Credits
Content related to CHM 334.
Prerequisites: (CHM 334)

CHM 336 Clinical Chemistry 3 Credits
Applications of analytical chemistry to clinical problems. Discussion of methods in common use and the biochemical/medical significance of the results.
Prerequisites: CHM 332 or CHM 112
Attribute/Distribution: NS

CHM 337 Crystallography and Diffraction 3 Credits
Introduction to crystal symmetry, point groups, and space groups. Emphasis on materials characterization by X-ray diffraction and electron diffraction. Specific topics include crystallographic notation, stereographic projections, orientation of single crystals, textures, phase identification, quantitative analysis, stress measurement, electron diffraction, ring and spot patterns, convergent beam electron diffraction (CBED), and space group determination. Applications in mineralogy, metallurgy, ceramics, microelectronics, polymers, and catalysts. Lectures and laboratory work. Prerequisites may be waived if student has senior standing in chemistry.
Prerequisites: MAT 203 or EES 131
Attribute/Distribution: NS

CHM 341 Molecular Structure, Bonding and Dynamics 3 Credits
Nature of chemical bonding as related to structure and properties of molecules and extended systems. Quantum chemistry of atoms and molecules applied to chemical transformations and spectroscopic transitions. Symmetry analysis and selections rules. Interpretation of electronic, vibrational and rotational spectra.
Prerequisites: (MATH 022 or MATH 096 or MATH 032) and (PHY 011 or PHY 013) and (CHM 031 or CHM 041)
Attribute/Distribution: NS
CHM 342 Thermodynamics & Kinetics 3 Credits  
Development of the principles of classical and statistical thermodynamics and their application to chemical systems. In classical thermodynamics emphasis will be on systems in which composition is of major concern: solutions, chemical and phase equilibria. Kinetic theory of gases; chemical reaction kinetics; chemical reaction dynamics.  
**Prerequisites:** (CHM 031 or CHM 041) and (PHY 013 or PHY 021) and (MATH 022 or MATH 023)

CHM 343 Physical Chemistry Laboratory 2 Credits  
Laboratory studies that illustrate and extend the various fields of study in experimental physical chemistry as discussed in CHM 341 and CHM 342. This course fulfills the junior year writing intensive course requirement in CAS.  
**Prerequisites:** (CHM 194 or CHE 210) or (CHM 341 and CHM 342)  
**Can be taken Concurrently:** CHM 342  
**Attribute/Distribution:** NS

CHM 350 Special Topics 1-3 Credits  
Selected advanced topics in chemistry.  
**Repeat Status:** Course may be repeated.  
**Attribute/Distribution:** NS

CHM 358 Advanced Organic Chemistry 3 Credits  
Reaction mechanism types and supporting physical-chemical data. Classes of mechanisms include elimination, substitution, rearrangement, oxidation-reduction, enolate alkylations, and others. Must have completed one year of organic chemistry.  
**Prerequisites:** CHM 112  
**Attribute/Distribution:** NS

CHM 371 (BIOS 371) Elements of Biochemistry I 3 Credits  
A general study of carbohydrates, proteins, lipids, nucleic acids and other biological substances and their importance in life processes. Protein and enzyme chemistry are emphasized. Must have completed one year of organic chemistry.  
**Prerequisites:** CHM 112 or CHM 031  
**Attribute/Distribution:** NS

CHM 372 (BIOS 372) Elements of Biochemistry II 3 Credits  
Dynamic aspects of biochemistry: enzyme reactions including energetics, kinetics and mechanisms, metabolism of carbohydrates, lipids, proteins and nucleic acids, photosynthesis, electron transport mechanisms, coupled reactions, phosphorylations, and the synthesis of biological macromolecules.  
**Prerequisites:** (BIOS 371 or CHM 371) and BIOS 041  
**Attribute/Distribution:** NS

CHM 375 Research Chemistry Laboratory 1-3 Credits  
An introduction to independent study or laboratory investigation under faculty guidance. Consent of instructor required.  
**Repeat Status:** Course may be repeated.  
**Attribute/Distribution:** NS

CHM 376 Advanced Research Chemistry Laboratory 1-6 Credits  
Advanced independent study or laboratory investigation under faculty guidance. Consent of faculty research supervisor.  
**Repeat Status:** Course may be repeated.  
**Attribute/Distribution:** NS

CHM 377 (BIOS 377) Biochemistry Laboratory 3 Credits  
Laboratory studies of the properties of chemicals of biological origin and the influence of chemical and physical factors on these properties. Laboratory techniques used for the isolation and identification of biochemicals.  
**Prerequisites:** (BIOS 371 or CHM 371) and (BIOS 031 or BIOS 041)  
**Can be taken Concurrently:** BIOS 371, CHM 371  
**Attribute/Distribution:** NS

CHM 388 (CHE 388, MAT 388) Polymer Synthesis and Characterization Laboratory 3 Credits  
Techniques include: free radical and condensation polymerization; molecular weight distribution by gel chromatography; crystallinity and order by differential scanning calorimetry; pyrolysis and gas chromatography; dynamic mechanical and dielectric behavior; morphology and microscopy; surface properties.  
**Prerequisites:** (CHM 341 or CHE 210 or CHM 342) and CHM 110  
**Attribute/Distribution:** NS

CHM 389 Honors Project 1-6 Credits  
**Repeat Status:** Course may be repeated.

CHM 391 (CHE 391) Colloid and Surface Chemistry 3 Credits  
Physical chemistry of everyday phenomena. Intermolecular forces and electrostatic phenomena at interfaces, boundary tensions and films at interfaces, mass and charge transport in colloidal suspensions, electrostatic and London forces in disperse systems, gas adsorption and heterogeneous catalysis.  
**Prerequisites:** CHM 342  
**Attribute/Distribution:** NS

CHM 393 (CHE 393, MAT 393) Physical Polymer Science 3 Credits  
Structural and physical aspects of polymers (organic, inorganic, natural). Molecular and atomic basis for polymer properties and behavior. Characteristics of glassy, crystalline, and paracrystal-line states (including viscoelastic and relaxation behavior) for single-and multi-component systems. Thermodynamics and kinetics of transition phenomena. Structure, morphology, and behavior. Must have senior level standing in CHE, CHEM, or MAT.  
**Attribute/Distribution:** NS

CHM 394 (CHE 394) Organic Polymer Science I 3 Credits  
Organic chemistry of synthetic high polymers. Polymer nomenclature, properties, and applications. Functionality and reactivity or monomers and polymers. Mechanism and kinetics of step-growth and chain-growth polymerization in homogenous and heterogenous media. Brief description of emulsion polymerization, ionic polymerization, and copolymerization. Must have completed one year of physical chemistry and one year of organic chemistry.  
**Prerequisites:** CHM 112 or CHM 342  
**Attribute/Distribution:** NS

CHM 400 First Year Graduate Student Seminar 0 Credits  
First year graduate student seminar course and introduction to research. Topics include: research opportunities in the department, introduction to instrumentation facilities, ethics in science, use of library facilities, effective teaching methods.

CHM 405 Organometallic Chemistry 3 Credits  
The chemistry of compounds containing carbon to metal bonds. Among topics covered are the following: organic compounds of the representative elements from Group I to IV; the chemistry of ferrocene and related pi-bonded organometallic complexes; metal carbonyl and nitrosyl complexes; dioxygen and dinitrogen complexes; organic synthesis utilizing organometallic catalysts.

CHM 407 Advanced Inorganic Chemistry 3 Credits  
Introduction to transition metal complexes; theories of bonding; kinetics and mechanisms of transition metal complex reactions; selected aspects of organometallic chemistry; bio-inorganic chemistry. Must have completed one semester of physical chemistry and have CAS graduate student status.

CHM 421 Chemistry Research 1-6 Credits  
Research in one of the following fields of chemistry: analytical, inorganic, organic, physical, polymer, biochemistry.

CHM 423 Bio-Organc Chemistry 3 Credits  
An examination of biochemistry on the basis of organic chemical principles. Emphasis on reaction mechanisms of biochemical transformations and methods for elucidation of these mechanisms, i.e., kinetics, isotope effects, exchange techniques, inhibition studies, substrate analog effects and organic model studies.
CHM 424 Medicinal and Pharmaceutical Chemistry 3 Credits
Principles of drug design, structure-activity relationships in antibacterial, antimalarial, antiinflammatory and psychoactive drugs; synthesis and modes of action of pharmacologically active agents of pharmaceutical importance.
Prerequisites: CHM 358

CHM 425 Pharmaceutical Regulatory Affairs 1: Drug Discovery to Approval 3 Credits
Coverage includes the stages of the drug approval process and how these relate to the laboratory activities that provide the scientific basis of the New Drug Application (NDA). Lectures treat drug discovery, chemical process development of the active pharmaceutical ingredient (API), and pharmaceutical process development of the drug product. Regulatory issues in screening and testing, the management of the preclinical trials, and the management of clinical trials will be covered.
Attribute/Distribution: NS

CHM 426 Principles of statistical mechanics to chemical problems. A study of the techniques for evaluating the properties of matter in bulk from the properties of molecules and their interactions.

CHM 427 Thermodynamics & Kinetics 3 Credits
Development of the principles of classical and statistical thermodynamics and their applications to chemical systems. In classical thermodynamics, emphasis will be on systems in which composition is of major concern: solutions, chemical and phase equilibria. Kinetic theory of gases; chemical reaction kinetics. Must have CAS graduate student status. This course cannot be taken by students who have already taken CHM 342.

CHM 428 Pharmaceutical Regulatory Affairs-II: Biomarkers for Pharmaceutics and Diagnostics: Laws & Regulation 3 Credits
For decades diagnostic products and technologies have been used to monitor or detect a variety of indicators for disease and infection. Each year, over 4,000 devices are reviewed by the U.S. Food & Drug Administration for safety and efficacy before being allowed to enter the marketplace. Today, regulations have set in motion the use of Biomarkers as a key element for new pharmaceutical development. Biomarkers in a way similar to Diagnostic markers will become a method to demonstrate safety and efficacy of experimental drugs during human trials. This course will review the history of Biomarker and medical device law and regulations in the United States. It will also define the current scientific requirements for Biomarkers to meet the new regulations. Case studies will be used to educate participants on the use of Biomarkers in pharmaceutical development as well as Design Controls, Quality System Regulations, Manufacturing Requirements for diagnostic testing technologies. Specific examples include Nucleic Acid Diagnostics, Cardiovascular Stents, Drug Delivery, Cancer Diagnostics, and Consumer Self-Testing. Students will also use knowledge gained to prepare class presentations to address current issues within the field. This course is one of four courses required to fulfill the requirements for a Certificate in Regulatory Affairs. It may be applied as a 400-level credit in the Masters of Chemistry degree program.
Attribute/Distribution: NS

CHM 430 Chemical and Biochemical Separations 3 Credits
Theory and applications of equilibrium and nonequilibrium separation techniques at both the analytical and preparative levels. Solvent and buffer extractions, chromatographic separations (e.g., thin layer, partition, gas liquid, gel filtration, ion exchange, affinity, supercritical fluid), electrophoretic separations (e.g., gel, capillary, isoelectric focusing, immunoelectrophoresis), centrifugal separations (e.g., differential, velocity sedimentation, density gradient) and other separation methods (e.g., dialysis, ultrafiltration). Examples will focus on biological applications.

CHM 431 Contemporary Topics in Analytical Chemistry 1 Credit
Discussion of the current literature in analytical chemistry, including spectroscopy, separations, and electrochemistry. Students find current papers and lead discussions.
Repeat Status: Course may be repeated.

CHM 432 Chemometrics 3 Credits
Mathematical and statistical methods for experimental design, calibration, signal resolution, and instrument control and optimization.

CHM 434 Advanced Topics in Spectroscopy 3 Credits
Fundamentals of interactions of electromagnetic radiation with matter: electronic, vibrational, scattering based spectroscopies, instrumentation and signal processing. Advanced applications to the analysis of molecular structure and chemical processes including surface analysis, time-resolved spectroscopies, and ultrasonic spectroscopic techniques.

CHM 436 Special Topics in Analytical Chemistry 1-3 Credits
Topics of contemporary interest in analytical chemistry.
Repeat Status: Course may be repeated.

CHM 437 (BIOS 437) Pathophysiological Chemistry 3 Credits
Biochemical basis of human diseases involving abnormal metabolism of proteins, nucleic acids, carbohydrates, and lipids. Emphasis on the correlation of the clinical presentation of disease processes seen as physiological dysfunctions with clinical laboratory methods. Lectures, student presentations, and clinical case discussions. Must have completed one semester of biochemistry.

CHM 442 Pharmaceutical Regulatory Affairs 3: Analytical Methods, Validation, and Data Manipulation 3 Credits
A review of the FDA guidance and common industry practices. A presentation of the more user-friendly and higher accuracy analytical methods, which are supplanting traditional analyses. Lectures will cover the eight fundamentals of analytical method validation: accuracy, linearity, precision, limits of detection, selectivity, limits of quantification, specificity, and ruggedness of method. In addition, the student will be taught what to do when the results do not meet the Acceptance Criteria. Lectures also cover evaluation of data streams for supporting conclusions.

CHM 443 (MAT 443) Solid-State Chemistry 3 Credits
Crystal structure, diffraction in crystals and on surfaces, bonding and energy spectra in solids dielectrics, surface states and surface fields in crystals. Must have completed one course in linear algebra and one course in quantum mechanics.

CHM 444 Molecular Structure, Bonding and Dynamics 3 Credits
Nature of chemical bonding as related to structure and properties of molecules and extended systems. Quantum chemistry of atoms and molecules applied to chemical transformations and spectroscopic transitions. Symmetry analysis and selection rules. Interpretation of electronic, vibrational and rotational spectra. Must have CAS graduate student status.

CHM 452 Advanced Organic Chemistry 3 Credits
Reaction mechanism types and supporting physical chemical data. Classes of mechanisms include elimination, substitution, rearrangement, oxidation reduction, enolate alkylations, and others. Must have completed one year of organic chemistry and have CAS graduate student status.

CHM 453 Heterocyclic Compounds 3 Credits
An intensive study of the syntheses, reactions and properties of heteroaromatic compounds including derivatives of thiophene, pyrrole, furan, indole, pyridine, quinoline, the azoles and the diazines all considered from the viewpoint of modern theories of structure and reaction mechanisms.
Prerequisites: CHM 358 or CHM 452

CHM 455 Organic Reactions 3 Credits
Prerequisites: or CHM 452, CHM 358 or CHM 452
CHM 456 Spectral Analysis 3 Credits
Use of data from nuclear magnetic resonance, infrared, ultraviolet, and mass spectrometric techniques for the determination of structure of organic compounds. Emphasis on information from one- and two-dimensional proton and carbon NMR, and a mechanistic interpretation of data from mass spectrometry.

CHM 457 Organic Reaction Mechanisms 3 Credits
Intensive in class problem solving that involves the formulation of reasonable reaction mechanisms for complex multistep pathways, i.e., organic transformations that proceed via highly energetic intermediates such as carbocations, carbanions, free radicals, carbenes, and nitrenes.

CHM 458 Topics in Organic Chemistry 1-3 Credits
An intensive study of limited areas in organic chemistry.
Repeat Status: Course may be repeated.

CHM 462 3 Credits
This course focuses on the physical tools that exist to obtain information about biological macromolecules, with an emphasis on spectroscopic and imaging techniques, e.g., circular dichroism, fluorescence spectroscopy, FRET, BRET, calorimetry, analytical ultracentrifugation, X-ray crystallography, electron microscopy, dynamic light scattering, surface plasmon resonance). Lectures and discussion of research articles are used to illustrate the use of the different tools and methods.

CHM 463 Pharmaceutical Regulatory Affairs 4: Commercial Production, Validation, and Process Qualification 3 Credits
This course covers the scientific principles and the registry requirements for polymeric implants, controlled-release drug depot units, pumps, point-of-care testing kits, contrast media for MRI, x-ray, and ultrasound and all FDA controlled products not defined as therapeutic pharmaceuticals.

CHM 465 Protein Separation & Biophysical Analysis 3 Credits
Laboratory studies of techniques and principles used for the isolation, characterization, and biophysical analysis of proteins.
Attribute/Distribution: NS

CHM 467 (BIOS 467) Principles of Nucleic Acid Structure 3 Credits
An examination of the principles underlying nucleic acid structure including stereochemistry, electrostatics, hydration, torsional constraints, sequence specific effects, and interaction with nuclear proteins. Special emphasis will be placed on DNA structure. Must have completed one year of biochemistry and one year of physical chemistry or have consent of the department chair.

CHM 468 (BIOS 468) Principles of Protein Structure 3 Credits
An examination of the principles underlying protein structure including stereochemistry, prefered tertiary structures, protein homology, excluded volume effects, time dependent structural fluctuations, and prediction of protein structure from sequence information. Must have completed one year of biochemistry and one year of physical chemistry or consent of department required.

CHM 469 (BIOS 469) Biochemical Problem Solving I 1 Credit
Applications of material covered in BIOS/CHM 371 including techniques used in research.

CHM 470 (BIOS 470) Biochemical Problem Solving II 1 Credit
Applications of concepts covered in BIOS/CHM 372 including techniques used in research.

CHM 472 (BIOS 472) Lipids and Membranes 3 Credits
Structure, physical properties and functions of lipids and their biological aggregates. Techniques for studying lipid assemblies, enzymes which act on lipids, membrane proteins and lipoproteins will also be discussed. Consent of department chair. Prerequisites: BIOS 372 or CHM 372

CHM 474 Pharmaceutical Regulatory Affairs 5: Pharmaceuticals 3 Credits
This course covers the development of therapeutic products subsequent to the initial discovery of the active pharmaceutical ingredient (API) through to the final dosage form. Both small molecule drugs and biotechnological pharmaceuticals will be included. Issues of API formulation, choice of excipients, control of release, target specificity, mode of delivery, drug-drug interactions, and product stabilization will be addressed with special reference to the regulatory issues involved at that stage of drug development. This course builds upon a foundation in organic, analytical, and biochemistry.

CHM 475 Advanced Topics in Chemistry 1 Credit
Audiovisual courses in topics such as acid-base theory, NMR, chromatography, electroanalytical chemistry and mass-spectroscopy interpretation; course material obtained from the American Chemical Society.
Repeat Status: Course may be repeated.

CHM 477 (BIOS 477) Topics In Biochemistry 1-3 Credits
Selected areas of biochemistry, such as mechanisms of enzyme action, new developments in the chemistry of lipids, nucleic acids, carbohydrates and proteins. Must have completed one semester of biochemistry.
Repeat Status: Course may be repeated.

CHM 479 (BIOS 479) Biochemical Techniques 3 Credits
Laboratory studies of the techniques and principles involved in the isolation, identification, and biochemical transformation of carbohydrates, lipids, nucleic acids and proteins.

CHM 480 (BIOS 480) Advanced Biochemical Preparations 1-3 Credits
An advanced laboratory course in the preparation, isolation, purification, and identification of biochemically produced materials. Emphasis is placed on materials and procedures of current interest in biochemistry. Must have completed two semesters of biochemistry.

CHM 481 Chemistry Seminar 1-6 Credits
Student presentations on current research topics in the student’s discipline but not on subjects close to the thesis. A one-hour presentation and attendance at other presentations are required for credit.
Repeat Status: Course may be repeated.

CHM 482 (CHE 482, MAT 482) Mechanical Behaviors of Polymers 3 Credits
Mechanical behavior of polymers. Characterization of experimentally observed viscoelastic response of polymeric solids with the aid of mechanical model analogs. Topics include time-temperature superposition, experimental characterization of large deformation and fracture processes, polymer adhesion, and the effects of fillers, plasticizer, moisture, and aging on mechanical behavior.

CHM 483 (CHE 483) Emulsion Polymers 3 Credits
Fundamental concepts important in manufacture, characterization, and application of polymer latexes. Topics include colloidal stability, polymerization mechanisms and kinetics, reactor design, characterization of particle surfaces, latex rheology, morphology considerations, polymerization with functional groups, film formation and various application problems.

CHM 485 (CHE 485, MAT 485) Polymer Blends and Composites 3 Credits
Synthesis, morphology, and mechanical behavior of polymer blends and composites. Mechanical blends block and graft copolymers, interpenetrating polymer networks, polymer impregnated solids and fiber and particulate-reinforce polymers are emphasized.

CHM 487 Topics in Colloid and Surface Chemistry 3 Credits
Applications of colloid chemistry; special topics in surface chemistry. Lectures and seminar.
Repeat Status: Course may be repeated.

CHM 488 Advanced Topics in Physical Chemistry 1-3 Credits
Advanced topics in physical chemistry, such as photochemistry and molecular beam dynamics, Fourier transform spectroscopy, kinetics of rapid reactions, theory of magnetic resonance, liquids and solutions.
Repeat Status: Course may be repeated.
CHM 489 Organic Polymer Science II 3 Credits
Continuation of CHM 394. Theory and mechanism of ionic vinyladdition chaingrowth polymerization. Chain copolymerization by radical and ionic mechanism. Mechanism of ring-opening polymerization, stereochemistry of polymerization including ionic, coordination, and Ziegler-Natta mechanisms. Reactions of polymers, including crosslinking, reaction of functional groups, graft and block copolymers, and polymer carriers and supports.

CHM 490 Thesis 1-6 Credits
Repeat Status: Course may be repeated.

CHM 492 (CHE 492, MAT 492) Topics in Polymer Science 3 Credits
Intensive study of topics selected from areas of current research interest such as morphology and mechanical behavior, thermodynamics and kinetics of crystallization, new analytical techniques, molecular weight distribution, non-Newtonian flow behavior, second-order transition phenomena, novel polymer structures. Credit above three hours is granted only when different material is covered.

CHM 494 Quantum Chemistry 3 Credits
Principles and applications of quantum mechanics to chemical problems. Applications to chemical bonding, molecular structure, reactivity and spectroscopy.

CHM 499 Dissertation 1-15 Credits
Repeat Status: Course may be repeated.