Chemistry

Chemistry is a versatile subject area, and pursuing 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 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. Particular strengths of this department include surface and interface chemistry; photochemistry; lipids and membranes, 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's degree recipients to pursue advanced degrees in the field of chemistry and related disciplines . Chemistry or biochemistry provides the strongest preparation for graduate studies or professional school in 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 choice of both degree programs and some additional courses.

DEGREE PROGRAMS

The Department of Chemistry offers undergraduate degrees in both the College of Arts and Sciences and the Rossin 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 Chemistry, and the B.S. in Pharmaceutical Chemistry. In addition, an interdepartmental B.S. in Biochemistry in collaboration with the Department of Biological Sciences is offered. A B.S. in Chemistry is also available for students in the College of Engineering and Applied Sciences

In the College of Arts and Sciences, the traditional degree approved by the American Chemical Society is offered; the B.S. degree in the College of Engineering is the ACS approved degree and is identical in terms of degree program requirements, but the college level requirements are different. All B.S. programs share several common "core" chemistry courses, and have similar collateral science requirements,. although the options differ depending on the specific degree program chosen. The B.S. programs are pre-professional in nature, and students planning to attend graduate school in chemistry or an allied science should elect the ACS approved 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. degrees, a regular non-ACS approved B.S. Chemistry program is available in the College of Arts and Sciences. Students may transfer from a B.S. program to a B.A. program easily, but the reverse is more difficult, considering both the number of required chemistry courses and the more restrictive collateral courses in Mathematics and Physics. 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 CHM 307 Advanced Inorganic Chemistry as an additional course, and by taking additional 300-level chemistry courses.

The Department of Chemistry also offers a Ph.D. in Chemistry for qualified students. More information is found on the Graduate Tab.

CHEMISTRY DEGREES 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. The B.S. in Biochemistry degree is an interdepartmental degree offered with the Department of Biological Sciences. The B.S. in Chemistry degree has two tracks: 1) the American Chemical Society (ACS) approved B.S. in Chemistry and 2) the non-ACS approved B.S. in Chemistry that requires fewer credits. All degree programs require appropriate Mathematics and Physics collateral courses, and some require one or more Programming course(s). Each student will need to meet with a first-year advisor and then with a major advisor (once the student has declared their major) to establish an academic plan.

Common "core" Chemistry courses

The following courses are required for ANY of the undergraduate degree programs administered by the Department of Chemistry (not Biochemistry). One of the general chemistry sequences is taken in the first year, with organic chemistry in the second year. Most of the required chemistry courses are at the 300 level and are distributed between the third and fourth years.

Select one of the following:		8
CHM 040 & CHM 041	Honors General Chemistry I and Honors General Chemistry II	
or		
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	4
CHM 112 & CHM 113	Organic Chemistry II and Organic Chemistry Laboratory II	4
CHM 332	Analytical Chemistry	3
Concentrations (see below)		3-8
CHM 307	Advanced Inorganic Chemistry	3
CHM 351	Professional Development Seminar	2
Total Credits		**27-32**

Collateral requirements

The B.S. in Chemistry degree programs require Path A below for the collateral requirements. The B.S. in Pharmaceutical Chemistry, the B.A. in Chemistry, and the B.S. in Biochemistry require EITHER Path A or Path B. A course from Path A may replace one in Path B, but the opposite is not true. Thus, it is suggested that students consider the MATH 021, 022, 023 sequence if a B.S. in Chemistry degree program is one of their options.

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 003	Introduction to Programming, Part A	
Total Credits		**27**

Path B

MATH 051	Survey of Calculus I	4
MATH 052	Survey of Calculus II	3
MATH 043	Survey of Linear Algebra	3
PHY 010 & PHY 012	General Physics I and Introductory Physics Laboratory I	5
PHY 013 & PHY 022	General Physics II and Introductory Physics Laboratory II	4
Total Credits		**19**

SPECIALIZATIONS

The ACS-approved B.S. in Chemistry is the "gold standard" and is the strongest degree program to prepare for graduate work in Chemistry or a closely related field. The table directly below lists the course requirements for the two B.S. degrees.

B.S. Chemistry (ACS certified Degree)

CHM 040	Honors General Chemistry I	4
or CHM 030	Introduction to Chemical Principles	
CHM 041	Honors General Chemistry II	4
or CHM 031	Chemical Equilibria in Aqueous Systems	
CHM 110 & CHM 111	Organic Chemistry I and Organic Chemistry Laboratory I	4
CHM 112 & CHM 113	Organic Chemistry II and Organic Chemistry Laboratory II	4
CHM 307	Advanced Inorganic Chemistry	3
CHM 332	Analytical Chemistry	3
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
CHM 351	Professional Development Seminar	2
CHM 371	Elements of Biochemistry I	3
CHM 375	Research Chemistry Laboratory	2
Advanced Chemistry Elective Requirement		
Select one course from two of the three areas listed below:		6
Analytical Chemistry (CHM 350) [1]		
CHM 336	Clinical Chemistry	
CHM 356	Spectral Analysis	
CHM 388	Polymer Characterization	
Biochemistry (CHM 350) [1]		
CHM 323	Chemical Biology	
CHM 362	Molecular Biophysics	
CHM 365	Protein Separation & Biophysical Analysis	
CHM 372	Elements of Biochemistry II	
CHM 373	Lipids and Membranes	
CHM 377	Biochemistry Laboratory	
Inorganic Chemistry (CHM 350) [1]		
CHM 305	Organometallic Chemistry	
CHM 337	Crystallography and Diffraction	
CHM 340	Solid-State Chemistry	
CHM 364	Bioinorganic Chemistry	
Collateral Requirements		
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
Select one from the following:		2-4
ENGR 010	Applied Engineering Computer Methods	
CSE 003	Introduction to Programming, Part A	
CSE 007	Introduction to Programming	
Total Credits		**76-78**

[1]

CHM 350 may be applied to any one of the three areas, provided it is for a 3 credit lecture course and the particular section has been identified to fit into one of these three areas based on course content. CHM 350 may be repeated for credit if a different topic is offered, and if appropriate, a second CHM 350 section may count under a different area.

B.S. Chemistry- Analytical/Physical Concentration

CHM 040	Honors General Chemistry I	4
or CHM 030	Introduction to Chemical Principles	
CHM 041	Honors General Chemistry II	4
or CHM 031	Chemical Equilibria in Aqueous Systems	
CHM 110 & CHM 111	Organic Chemistry I and Organic Chemistry Laboratory I	4
CHM 112 & CHM 113	Organic Chemistry II and Organic Chemistry Laboratory II	4
CHM 307	Advanced Inorganic Chemistry	3
CHM 332	Analytical Chemistry	3
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
CHM 351	Professional Development Seminar	2
Collateral Requirements		
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
Select one of the following:		2-4
ENGR 010	Applied Engineering Computer Methods	
CSE 003	Introduction to Programming, Part A	
CSE 007	Introduction to Programming	
Total Credits		**65-67**

B. A. Chemistry

The B.A. in Chemistry program is sometimes chosen as a second major to pair with another major in a single B.A. degree. It is less rigorous than either track under the B.S. in Chemistry degree. Note that the choices in the collateral courses clearly indicate either Path A or Path B may be chosen for the non-chemistry required courses.

CHM 040	Honors General Chemistry I	4
or CHM 030	Introduction to Chemical Principles	
CHM 041	Honors General Chemistry II	4
or CHM 031	Chemical Equilibria in Aqueous Systems	

CHM 110 & CHM 111	Organic Chemistry I and Organic Chemistry Laboratory I	4
CHM 112 & CHM 113	Organic Chemistry II and Organic Chemistry Laboratory II	4
Select one of the follwoing:		3
CHM 194	Physical Chemistry for Biological Sciences	
CHM 342	Thermodynamics & Kinetics	
CHM 307	Advanced Inorganic Chemistry	3
CHM 332	Analytical Chemistry	3
CHM 343	Physical Chemistry Laboratory	2
CHM 351	Professional Development Seminar	2
Advanced CHM elective (300 Level)		**3**
Select one of the following:		
CHM 305	Organometallic Chemistry	
CHM 323	Chemical Biology	
CHM 334	Advanced Chemistry Laboratory I	
CHM 336	Clinical Chemistry	
CHM 337	Crystallography and Diffraction	
CHM 340	Solid-State Chemistry	
CHM 341	Molecular Structure, Bonding and Dynamics	
CHM 346	Photochemistry of Consequence	
CHM 350	Special Topics	
CHM 356	Spectral Analysis	
CHM 357	Organic Reaction Mechanisms	
CHM 358	Advanced Organic Chemistry	
CHM 362	Molecular Biophysics	
CHM 364	Bioinorganic Chemistry	
CHM 365	Protein Separation & Biophysical Analysis	
CHM 371	Elements of Biochemistry I	
CHM 372	Elements of Biochemistry II	
CHM 373	Lipids and Membranes	
CHM 375	Research Chemistry Laboratory	
CHM 376	Advanced Research Chemistry Laboratory	
CHM 377	Biochemistry Laboratory	
CHM 388	Polymer Characterization	
CHM 391	Colloid and Surface Chemistry	
CHM 393	Physical Polymer Science	
CHM 394	Organic Polymer Science I	
Collateral Requirements		**19-21**
MATH 021	Calculus I	
or MATH 051	Survey of Calculus I	
MATH 022	Calculus II	
or MATH 052	Survey of Calculus II	
MATH 205	Linear Methods	
or MATH 043	Survey of Linear Algebra	
PHY 011	Introductory Physics I	
or PHY 010	General Physics I	
PHY 012	Introductory Physics Laboratory I	
PHY 021	Introductory Physics II	
or PHY 013	General Physics II	
PHY 022	Introductory Physics Laboratory II	
Total Credits		**51-53**

B.S. Pharmaceutical Chemistry

The B.S. in Pharmaceutical Chemistry requires some Biological Sciences courses as background for entry into the field. As a consequence, there are fewer Chemistry courses, and they are tailored to the requirements of the pharmaceutical industry. Note that the flexibility in the collateral requirements is the same as for the B.A. degree.

CHM 040	Honors General Chemistry I	4
or CHM 030	Introduction to Chemical Principles	
CHM 041	Honors General Chemistry II	4
or CHM 031	Chemical Equilibria in Aqueous Systems	
CHM 110 & CHM 111	Organic Chemistry I and Organic Chemistry Laboratory I	4
CHM 112 & CHM 113	Organic Chemistry II and Organic Chemistry Laboratory II	4
Select one of the following:		3
CHM 194	Physical Chemistry for Biological Sciences	
CHM 342	Thermodynamics & Kinetics	
CHM 307	Advanced Inorganic Chemistry	3
CHM 332	Analytical Chemistry	3
CHM 351	Professional Development Seminar	2
CHM 358	Advanced Organic Chemistry	3
CHM 371	Elements of Biochemistry I	3
CHM 372	Elements of Biochemistry II	3
Advanced CHM Elective (300 Level)		**3**
Select one of the following:		
CHM 305	Organometallic Chemistry	
CHM 323	Chemical Biology	
CHM 334	Advanced Chemistry Laboratory I	
CHM 336	Clinical Chemistry	
CHM 337	Crystallography and Diffraction	
CHM 340	Solid-State Chemistry	
CHM 341	Molecular Structure, Bonding and Dynamics	
CHM 346	Photochemistry of Consequence	
CHM 350	Special Topics	
CHM 356	Spectral Analysis	
CHM 357	Organic Reaction Mechanisms	
CHM 362	Molecular Biophysics	
CHM 364	Bioinorganic Chemistry	
CHM 365	Protein Separation & Biophysical Analysis	
CHM 373	Lipids and Membranes	
CHM 375	Research Chemistry Laboratory	
CHM 376	Advanced Research Chemistry Laboratory	
CHM 377	Biochemistry Laboratory	
CHM 388	Polymer Characterization	
CHM 391	Colloid and Surface Chemistry	
CHM 393	Physical Polymer Science	
CHM 394	Organic Polymer Science I	
Biological Sciences		
BIOS 041 & BIOS 042	Introduction to Cellular and Molecular Biology and Introduction to Cellular and Molecular Biology Laboratory	4
BIOS 115	Genetics	3
Collateral Requirements		**19-21**
MATH 012	Basic Statistics and Data Science [1]	
MATH 021	Calculus I	
or MATH 051	Survey of Calculus I	
MATH 022	Calculus II	
or MATH 052	Survey of Calculus II	
MATH 205	Linear Methods	
or MATH 043	Survey of Linear Algebra	
PHY 011	Introductory Physics I	

or PHY 010	General Physics I	
PHY 012	Introductory Physics Laboratory I	
PHY 021	Introductory Physics II	
or PHY 013	General Physics II	
PHY 022	Introductory Physics Laboratory II	
Total Credits		**65-67**

1

MATH 012 may be substituted by any statistics course with the approval of the department chair.

PATH A SCHEDULE MODEL FOR THE B.S. IN CHEMISTRY DEGREE PROGRAMS

The strongest background includes Honors Chemistry (CHM 040 & 041) and the higher-level Mathematics and Physics courses. The sequence below provides one pathway to achieve all required courses in the proper sequence. Although this pathway is ideal, many students start with different courses in their first year. It is possible to change into a B.S. in Chemistry degree program in a later semester, but consultation with a Major Advisor will be required. If a B.S. in Chemistry degree program is one of your options, stay in the MATH 021, 022, 023 sequence, and take Physics 011 and 021 instead of the "lower-level" sequences (MATH 051 & 052, Physics 010 & 013).

First Year	CR
College Seminar	3-4
CHM 040	4
CHM 041	4
MATH 021	4
MATH 022	4
PHY 011	4
PHY 012	1
WRT 001	3
WRT 002	3
	30-31

Second Year	CR
CHM 110 & CHM 111	4
CHM 112 & CHM 113	4
PHY 021 & PHY 022	5
MATH 023	4
MATH 043	3
ENGR 010 or CSE 012	2
distribution requirements - free electives	9
	31

Total Credits: 61-62

Note that some concentrations would insert courses such as MATH 012, BIOS 041/BIOS 042 (B.S. Pharmaceutical Chemistry or B.S. in Biochemistry), etc., which may require moving some courses to later years. The non-B.S. in Chemistry degree programs can substitute the lower level MATH and PHYSICS courses as well.

In the junior and senior year 30-32 credits towards the major should be taken.

PATH B SCHEDULE MODEL FOR THE B.S. IN PHARMACEUTICAL CHEMISTRY AND BIOCHEMISTRY DEGREES

First Year	CR
College Seminar	3-4
CHM 040	4
CHM 041	4
MATH 051	4
MATH 052	3
PHY 010	4
PHY 012	1
WRT 001	3
WRT 002	3
	29-30

Second Year	CR
CHM 110 & CHM 111	4
CHM 112 & CHM 113	4
PHY 013 & PHY 022	4
MATH 043	3
distribution requirements - free electives	15
	30

Total Credits: 59-60

Note that some concentrations would insert courses such as MATH 012, BIOS 041/BIOS 042(B.S. Pharmaceutical Chemistry or B.S. in Biochemistry), etc., which may require moving some courses to later years. The non-B.S. in chemistry degree programs can substitute the lower level MATH and PHYSICS courses.

In the junior and senior year 30-32 credits towards the major should be taken.

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

Summary of Requirements

The Chemistry and collateral courses for the ACS Approved Degree in Chemistry are identical in both colleges in terms of the specific courses required. The B.S. in Chemistry degree in the Rossin College of Engineering and Applied Sciences requires both the higher level MATH and PHYSICS courses (MATH 21, 22, & 23, PHYS 11 & 21), but the college distribution requirements are different from those in the College of Arts and Sciences.

College distribution	24
Physics, math, and computing	28
Chemistry	46
Unrestricted electives	25
Total Credits	**123**

CHM 040	Honors General Chemistry I	4
or CHM 030	Introduction to Chemical Principles	
CHM 041	Honors General Chemistry II	4
or CHM 031	Chemical Equilibria in Aqueous Systems	
CHM 110 & CHM 111	Organic Chemistry I and Organic Chemistry Laboratory I	4
CHM 112 & CHM 113	Organic Chemistry II and Organic Chemistry Laboratory II	4
CHM 307	Advanced Inorganic Chemistry	3
CHM 332	Analytical Chemistry	3
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
CHM 351	Professional Development Seminar	2
CHM 371	Elements of Biochemistry I	3
CHM 375	Research Chemistry Laboratory	2

Advanced Chemistry Elective Requirement		
Select one course from two of the three areas listed below:		6
Analytical Chemistry (CHM 350) [1]		
CHM 336	Clinical Chemistry	
CHM 356	Spectral Analysis	
CHM 388	Polymer Characterization	
Biochemistry (CHM 350) [1]		
CHM 323	Chemical Biology	
CHM 362	Molecular Biophysics	
CHM 365	Protein Separation & Biophysical Analysis	
CHM 372	Elements of Biochemistry II	
CHM 373	Lipids and Membranes	
Inorganic Chemistry (CHM 350) [1]		
CHM 305	Organometallic Chemistry	
CHM 337	Crystallography and Diffraction	
CHM 340	Solid-State Chemistry	
CHM 364	Bioinorganic Chemistry	
Collateral Requirements		
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
Select one from the following:		2-4
ENGR 010	Applied Engineering Computer Methods	
CSE 003	Introduction to Programming, Part A	
CSE 007	Introduction to Programming	
Total Credits		**76-78**

1

CHM 350 may be applied to any one of the three areas, provided it is for a 3 credit lecture course and the particular section has been identified to fit into one of these three areas based on course content. CHM 350 may be repeated for credit if a different topic is offered, and if appropriate, a second CHM 350 section may count under a different area.

ACCELERATED COMBINED B.S. - M.S. DEGREE OPTIONS IN CHEMISTRY

Individual degree paths can be designed to earn either the B.S. or both BS. and M.S. degrees in Chemistry over a reduced or accelerated time frame. A discussion with the Chemistry faculty advisor during the first academic year is required to successfully complete any of the following options:

1. If you have more than 20 credits total of AP or transfer courses, it may be possible to earn the B.S. in three years and the M.S. in four. This path may require up to two summers of courses and/or research for most students.
2. If you have 30 or more AP or transfer credits, the B.S. degree must be completed in three years, and up to two summers of courses and/or research may be required.
3. If you have limited or no AP or transfer credits, then two paths are available: A) A five-year path is possible with one summer of research work after the B.S. degree is finished in four years. B) A five-year path may be possible if courses are excluded from the undergraduate degree (possibly requiring course overloads), and one summer of research is generally required, but support is not guaranteed.

Accelerated B.S. degree options are also possible for some students. See the Chemistry faculty advisor to develop a customized program for your situation. A discussion as early as possible is best for determining which options may be suitable.

B.S. IN BIOCHEMISTRY

An interdepartmental B.S. in Biochemistry major is offered in the College of Arts and Sciences. Faculty in both Chemistry and Biological Sciences serve as advisors depending on student interest. Refer to the department's respective website for more details on major advisors. Please see the section on Biochemistry (http://catalog.lehigh.edu/coursesprogramsandcurricula/artsandsciences/biochemistry/) for details of the major.

MINOR IN CHEMISTRY

A minor in chemistry may be achieved by completing the following requirements:

CHM 031	Chemical Equilibria in Aqueous Systems [1]	4
or CHM 041	Honors General Chemistry II	
CHM 110 & CHM 111	Organic Chemistry I and Organic Chemistry Laboratory I	4
CHM 332	Analytical Chemistry	3
CHM 342	Thermodynamics & Kinetics [2]	3
CHM 343	Physical Chemistry Laboratory [3]	2
Total Credits		**16**

1 Prerequisite of (CHM 030 or CHM 040) and corequisite of (MATH 21 or MATH 31 or MATH 51 or MATH 76)

2. Prerequisites of (CHM 031 or CHM 041) and MATH 021 or MATH 51) and (MATH 022 or MATH 32 or MATH 52) and (PHY 013 or PHY 021).

3. Prerequisite of CHM 342.

4. Students who wish to minor in chemistry but whose major program requires more than one of the above courses may achieve the minor with substitutions approved by the department chair.

GRADUATE PROGRAMS IN CHEMISTRY

The Department of Chemistry offers graduate studies leading to a Doctor of Philosophy degree in Chemistry.

Admission to graduate study in chemistry assumes that a student has met, or is willing to meet through further study, minimum undergraduate requirements for a bachelor's degree in chemistry or biochemistry. 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 undergraduate level upon matriculation to Lehigh. Information on the 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 Ph.D. candidate must show proficiency in the areas tested. An incoming student who fails one or more of the examinations will have one additional opportunity to demonstrate proficiency by re-taking the examination(s). The student is highly encouraged to meet with the Graduate Advising Director to determine the best course of action in light of the exam performance and projected area of study. The student may prepare for the examination(s) by self-study and enrolling in the appropriate course.

Doctor of Philosophy Degree

Completion of a doctor of philosophy degree program normally requires a minimum of four years of full time 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 26 hours of course work. A minimum of 15 credits must be obtained in the Department of Chemistry. Thus, the program consists of approximately one-third formal course work and two-thirds independent study and research. There is a one-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 semester in residence), the major hurdle is the general 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.

Chemistry, PhD

Course Work		18
CHM 421	Chemistry Research	6
CHM 481	Chemistry Seminar	1
Total Credits [1]		26

1

A minimum of 15 credits must be obtained in the Department of Chemistry.

CURRENT RESEARCH PROJECTS

Current research projects of interest are listed below.

Analytical Chemistry

Analytical Chemistry develops and applies techniques to measure and interpret the composition, structure, and dynamics of matter with precision and accuracy. Ongoing work in our department includes Biosensors; microfluidic platforms; electroanalytical chemistry; optical spectroscopy; optical microscopy; scanning probe microscopy; mass spectrometry.

Biochemistry

Biochemistry investigates the molecular mechanisms of life by integrating chemical principles to understand the structure, function, and interactions of biological macromolecules at the cellular and molecular levels. Research in our department spans a diverse range of topics, including Membrane protein interactions; structural characterization of membrane proteins; production of membrane proteins; biophysical characterization of membrane proteins; biomaterials; selective drug delivery; anti-cancer therapy;; immunotherapy; nucleic acid chemistry; enzymology; DNA repair mechanisms and diseases; Translesion synthesis.

Inorganic Chemistry

Inorganic Chemistry investigates the properties and reactivity of metals, minerals, and coordination compounds, often exploring their roles in catalysis, materials, and biological systems. Areas of emphasis include Synthesis, characterization, and reactivity of transition metal complexes and nano particles; coordination chemistry and molecular self-assembly at metal surfaces and semi-metal surfaces; electrochemistry at metal, semi-metal, and oxide-coated 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

Materials and Polymer Chemistry focuses on the design, synthesis, and characterization of functional materials and macromolecules with applications in energy, healthcare, electronics, and sustainability. Research efforts span 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; characterization of semiconducting material

Organic Chemistry

Organic Chemistry explores the structure, reactivity, and synthesis of carbon-based compounds, driving advances in fields ranging from pharmaceuticals to materials science. Projects in this area include Chemical models for biochemical reactions; chemistry of monolayers and organized molecule assemblages; drug carriers; synthetic ion conductors; organometallic reaction mechanisms; organofluorine chemistry; protein folding and renaturation; molecular recognition; calorimetry; electrochemical studies of electron transfer reactions; synthetic methods development.

Physical Chemistry

Physical Chemistry aims to describe and rationalize fundamental physical processes that occur within and between molecules and material systems. Experimental physical chemistry in the Department uses femtosecond ultra-fast spectroscopy; transient absorption spectroscopy; and time-resolved photoluminescence along with other techniques to study a wide-range of photoinduced chemical transformations, including isomerization reactions, proton-coupled electron transfer reactions, and charge transfer in energy-related materials. Computational projects focus on understanding how atom positions in molecules and materials lead to the quantum mechanical electronic structure.

Major Instrumentation

Major Instrumentation supports cutting-edge research across all areas of chemistry by providing access to advanced analytical and characterization tools. Special equipment available for graduate research in chemistry is as follows.

Research facilities

GC-MS, MALDI-TOF-MS, HPLCs, GCs, ultracentrifuges, cold rooms, hot room, cell ultrasonic disintegrator, fast protein liquid chromatography, microplate reader, gel imaging systems , autoclave, freezers (-80C), rotary vaporator, Milli-Q water purification system, temperature-controlled shaking incubators, spectropolarimeter with circular dichroism capability. Cell culture facilities – complete with biosafety hood, fluorescence microscope, and incubators..

Electron optical facilities – transmission electron microscopy with x-ray fluorescence analysis capability, scanning electron microscope, and scanning electron microprobe. Gas chromatographs. Liquid chromatographs – high performance for analytical and preparative work. NMR spectrometers – 400 MHz for both solids and solutions, and 500 MHz for solutions with an enhanced sensitivity multinuclear cyroprobe. Photochemistry equipment – lamps and filters for selected wavelength work. Polarographs, chronopotentiometers, electrophoresis apparatus, electrochemical impedance, electrochemical scanning tunneling microscope, potentiostats, and rotating disk electrode. Portable data interface (8-channel 50 KHz), digital readout polarimeter, Vibron elastoviscometers, differential refractometer.

Spectrometers

UV/visible double beam automated, steady-state and lifetime 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), photocorrelation spectroscopy for submicron particle analysis. Ellipsometer, 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). The goniometer equipped with correlator for DLS and SLS measurements.

Courses

CHM 007 Preparation for General Chemistry 2 Credits
Intensive review of fundamental concepts in chemistry, including chemical equations, stoichiometry, dimensional analysis, and significant figures, with an emphasis on developing problem solving skills. This course is for students who need to take CHM 30 or 40, but who require additional preparation in chemistry.

CHM 030 Introduction to Chemical Principles 0,4 Credits
An introduction to important topics in chemistry: atomic structure, properties of matter, chemical reactions, energy, structure and bonding in organic and inorganic compounds. The course features a lecture tightly linked to a three-hour studio experience that combines laboratory work and recitation.
Attribute/Distribution: LS, NS, NW, Q

CHM 031 Chemical Equilibria in Aqueous Systems 0,4 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 075)
Can be taken Concurrently: MATH 021, MATH 031, MATH 051, MATH 075
Attribute/Distribution: NS, NW, Q

CHM 040 Honors General Chemistry I 0,4 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 and one three-hour laboratory period.
Attribute/Distribution: LS, NS, NW, Q

CHM 041 Honors General Chemistry II 0,4 Credits
Continuation of Chemistry 40. Three lectures and one three-hour laboratory period.
Prerequisites: (CHM 040 or CHM 030) and (MATH 021 or MATH 031 or MATH 051 or MATH 075)
Can be taken Concurrently: MATH 021, MATH 031, MATH 051, MATH 075
Attribute/Distribution: NS, NW, Q

CHM 091 Special Topics 1-4 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.
Attribute/Distribution: NS, NW

CHM 110 Organic Chemistry I 0,3 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 031 or CHM 041 or CHM 110
Can be taken Concurrently: CHM 110
Attribute/Distribution: NS, Q

CHM 112 Organic Chemistry II 0,3 Credits
Continuation of CHM 110.
Prerequisites: (CHM 031 or CHM 041) and CHM 110
Attribute/Distribution: NS

CHM 113 Organic Chemistry Laboratory II 1 Credit
Continuation of Organic Chemistry Laboratory I.
Prerequisites: (CHM 030 or CHM 040) and (CHM 031 or CHM 041) and CHM 110 and CHM 111 and CHM 112
Can be taken Concurrently: CHM 112
Attribute/Distribution: NS, Q

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, NW, Q

CHM 191 Special Topics 1-4 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.
Attribute/Distribution: NS, NW

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, Q

CHM 291 Special Topics 1-4 Credits
Intensive study of a topic of special interest not covered in other courses.
Repeat Status: Course may be repeated.
Attribute/Distribution: NS, NW

CHM 300 Apprentice Teaching 1-4 Credits
Supervised participation in various aspects of the teaching of a course. Consent of instructor, department chairperson, and permission of the Dean required.
Repeat Status: Course may be repeated.

CHM 305 Organometallic Chemistry 3 Credits
The chemistry of compounds containing bonds between carbon and the transition metals. Topics include the synthesis, characterization, and electronic structure of organometallic compounds, and mechanistic studies of their reactions. A description of common ligands and their bonding is covered, as well as applications of organometallic chemistry in organic synthesis and catalysis.
Prerequisites: CHM 112
Attribute/Distribution: NS

CHM 307 Advanced Inorganic Chemistry 3 Credits
Introduction to transition metal complexes; theories of bonding; kinetics and mechanisms of transition metal complex reactions; and selected aspects of organometallic chemistry. .
Prerequisites: CHM 031 or CHM 041
Attribute/Distribution: NS, NW, Q

CHM 323 Chemical Biology 3 Credits
Chemical biology is a discipline at the interface of organic and biological chemistry. It entails the design, synthesis, and evaluation of probes, substrates, and materials for the study of biological systems using chemical principles. Chemical biology can also take inspiration from biological systems for the design and synthesis of novel molecules and materials for non-biological applications. The class is designed to be an introduction to chemical biology for upper-level undergraduates and graduate students.
Prerequisites: CHM 112 and (BIOS 371 or CHM 371)

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, Q

CHM 334 Advanced Chemistry Laboratory I 0,3 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 Electrochemistry.
Prerequisites: (CHM 110 and CHM 111 and CHM 112 and CHM 113 and CHM 332)
Can be taken Concurrently: CHM 332
Attribute/Distribution: Q, W

CHM 335 Advanced Chemistry Laboratory II 0,3 Credits
Continuation of CHM 334.
Prerequisites: (CHM 334)
Attribute/Distribution: Q, W

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 031 or CHM 041 or CHM 332 or CHM 112
Attribute/Distribution: NS, Q

CHM 337 Crystallography and Diffraction 3 Credits
Introduction to crystal symmetry, point groups, and space groups. Emphasis on materials characterization by Xray 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: CHM 031 or CHM 041 or MAT 203 or EES 131
Attribute/Distribution: NS

CHM 340 Solid-State Chemistry 3 Credits
This solid state chemistry course will introduce students into symmetry of extended solids, X-ray crystallography of solids, crystal structures, band theory, electronic and ionic conductivity in solids, defects in solids, silicate chemistry and nanoporous solids.
Prerequisites: CHM 031 or CHM 041
Attribute/Distribution: NS, NW, Q

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 023 or MATH 033) and (PHY 021 or PHY 013) and (CHM 031 or CHM 041)
Attribute/Distribution: NS, Q

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 032 or MATH 052)
Attribute/Distribution: Q

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.
Prerequisites: CHM 031 or CHM 041 or CHM 194 or CHE 210 or CHM 342
Attribute/Distribution: NS, W, WRIT

CHM 346 Photochemistry of Consequence 3 Credits
Photochemistry involves using photons (light from the sun) to drive critical chemical reactions and is attractive because of its application to solar energy. Fundamental processes in photochemistry will be covered . Topics will include: energy transfer, electron transfer, proton-coupled electron transfer processes and their applications to biological systems.
Prerequisites: CHM 031 or CHM 041
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 351 Professional Development Seminar 2 Credits
Topics for the developing professional chemist include lab safety, using a laboratory notebook, searching the scientific literature, reading and writing scientific papers, ethics, and developing both a poster and an oral presentation. Students will present their own poster and a short talk on the same subject. Each student will write his/her own resume and participate in a mock interview session.
Attribute/Distribution: NS

CHM 356 Spectral Analysis 3 Credits
Use of data from nuclear magnetic residence, 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.
Prerequisites: CHM 112

CHM 357 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.
Prerequisites: CHM 112

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 362 Molecular Biophysics 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.
Prerequisites: BIOS 371 or CHM 371
Attribute/Distribution: NS

CHM 364 Bioinorganic Chemistry 3 Credits
This course will cover inorganic chemistry as it relates to biology, with emphasis on how metal ions and cofactors are employed by biological systems. Topics will include metalloproteins, metal cofactors, and metals in medicine. Experimental methods used to study bioinorganic chemistry will also be discussed.
Prerequisites: CHM 371 or BIOS 371
Attribute/Distribution: NS

CHM 365 Protein Separation & Biophysical Analysis 3 Credits
Laboratory studies of techniques and principles used for the isolation, characterization, and biophysical analysis of proteins.
Prerequisites: BIOS 371 or CHM 371
Attribute/Distribution: NS

CHM 371 (BIOS 371) Elements of Biochemistry I 0,3 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
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 473 or ((BIOS 371 or CHM 371) and BIOS 041)
Attribute/Distribution: NS

CHM 373 Lipids and Membranes 3 Credits
The study of lipids and lipid membranes similar to those found in mammalian cells including methods of synthesis, surface activity, bilayer and micellar structures, lipid mixing, fluidity, permeability and membrane stability. Special emphasis will be given to the current evidence for and against the lipid raft hypothesis.
Prerequisites: BIOS 372 or CHM 372
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, Q

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, Q

CHM 377 (BIOS 377) Biochemistry Laboratory 0,3 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 Characterization 3 Credits
Description of molecular weight measurements using dilute solutions (solution viscosity, size exclusion chromatography, osmotic pressure, and light scattering). Introduction to polymer thermal analysis techniques such as differential scanning calorimetry (DSC) , dynamic mechanical analysis (DMA), and thermomechanical analyzer (TMA). Discussion of structure and morphology of polymers and polymer blends using nuclear magnetic resonance (NMR), infrared spectroscopy (IR), Raman spectroscopy, UV analysis, transmission electron microscopy (TEM), scanning electron microscopy (SEM), atomic force microscopy (AFM). Crystallinity measurements using SANS, SAXS, and WAXS.
Prerequisites: MAT 033 or MAT 204 or MAT 392 or MAT 393

CHM 389 Honors Project 1-6 Credits
Opportunity for Chemistry majors to pursue an Honors Project. Consent of instructor required.
Repeat Status: Course may be repeated.
Attribute/Distribution: Q, W

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. Available to graduate and undergraduate students (with senior level standing) in CHE, CHEM or MAT.

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 031 or CHM 041 or CHM 110 or CHM 112 or CHM 342 or CHE 210
Attribute/Distribution: NS, Q

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. Course may be repeated.
Repeat Status: Course may be repeated.

CHM 405 Organometallic Chemistry 3 Credits
The chemistry of compounds containing bonds between carbon and the transition metals. Topics include the synthesis, characterization, and electronic structure of organometallic compounds, and mechanistic studies of their reactions. A description of common ligands and their bonding is covered, as well as applications of organnometallic chemistry in organic synthesis and catalysis.

CHM 407 Advanced Inorganic Chemistry 3 Credits
Introduction to transition metal complexes; theories of bonding; kinetics and mechanisms of transition metal complex reactions; and selected aspects of organometallic 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. A maximum of 6 credits total may be earned. Consent of the instructor is required.
Repeat Status: Course may be repeated.

CHM 423 Chemical Biology 3 Credits
Chemical biology is a discipline at the interface of organic and biological chemistry. It entails the design, synthesis, and evaluation of probes, substrates, and materials for the study of biological systems using chemical principles. Chemical biology can also take inspiration from biological systems for the design and synthesis of novel molecules and materials for non-biological applications. The class is designed to be an introduction to chemical biology for upper-level undergraduates and graduate students.

CHM 426 Statistical Thermodynamics 3 Credits
Principles and applications 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 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 ultrasensitive 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 438 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. Must have CAS graduate student status.

CHM 443 (MAT 443) Solid-State Chemistry 3 Credits
This solid state chemistry course will introduce students into symmetry of extended solids, X-ray crystallography of solids, crystal structures, band theory, electronic and ionic conductivity in solids, defects in solids, silicate chemistry and nonoporous solids.

CHM 444 Molecular Structure, Bonding and Dynamics 0,3 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. Must have CAS graduate student status.

CHM 446 Photochemistry of Consequence 3 Credits
Photochemistry involves using photons (light from the sun) to drive critical chemical reactions and is attractive because of its application to solar energy. Fundamental processes in photochemistry will be covered. Topics will include: energy transfer, electron transfer, proton-coupled electron transfer processes and their applications to biological systems.

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
Intensive survey of modern synthetic organic chemistry from a mechanistic standpoint. Classical Namereactions, olefin synthesis, organometallic reagents in synthesis, Woodward-Hoffmann rules, electrocyclic processes, enolate chemistry, and related reactions.
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 464 Bioinorganic Chemistry 3 Credits
This course will cover inorganic chemistry as it relates to biology, with emphasis on how metal ions and cofactors are employed by biological systems. Topics will include metalloproteins, metal cofactors, and metals in medicine. Experimental methods used to study bioinorganic chemistry will also be discussed.

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 472 (BIOS 472) Lipids and Membranes 3 Credits
The study of lipids and lipid membranes similar to those found in mammalian cells including methods of synthesis, surface activity, bilayer and micellar structures, lipid mixing, fluidity, permeability and membrane stability. Special emphasis will be given to the current evidence for and against the lipid raft hypothesis.
Prerequisites: BIOS 372 or CHM 372

CHM 473 (BIOS 473) Principles of Biochemistry I 3 Credits
Study of proteins, carbohydrates, lipids, nucleic acids and other biological substances. Protein and enzyme chemistry are emphasized. Must have completed one year each of general chemistry and organic chemistry.

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 481 Chemistry Seminar 1 Credit
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 mechanicial behavior.

CHM 483 (CHE 483, MAT 483, PSE 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, PSE 485) Polymer Blends 3 Credits
Synthesis, morphology, and mechanical behavior of polymer blends. Polymer/polymer miscibility and thermodynamics of mixing of polymer/solvent and polymer/polymer blends. Prediction of miscibility using various theoretical models and methods that can be used to help enhance miscibility (H bonding etc.). Methods to enhance the compatibility of polymer/polymer blends (e.g., block copolymers, ternary addition, IPNs), etc.). Types of polymer blends. Must have completed any introductory polymer course or equivalent.

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. Topic changes almost every time it is offered.
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-Newtownian 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.