CHEMISTRY

Courses offered by the Department of Chemistry are listed under the subject code CHEM on the Stanford Bulletin's ExploreCourses web site.

Chemistry is about the nature of matter, how to make it, how to measure it, how to model it. In that sense chemistry really matters; it is essential to explaining all the real world. It holds the key to making new drugs, creating new materials, and understanding and controlling material properties of all sorts. It is no wonder then that chemistry is called the "Central Science". Traditionally, it is divided into subdisciplines, such as organic, inorganic, physical, biological, theoretical, and analytical, but these distinctions blur as it is increasingly appreciated how all of science, let alone chemistry, is interconnected.

A deeper understanding of chemistry enables students to participate in research and studies involving biotechnology, nanotechnology, catalysis, human health, materials, earth and environmental sciences, and more. Together, faculty, graduate and undergraduate students actively work together within our department developing new probes of biological molecules, modeling protein folding and reactivity, manipulating carbon nanotubes, developing new oxidation and polymerization catalysts, and synthesizing organic molecules to probe ion-channels. The overarching theme of these pursuits is a focus at the atomic and molecular levels, whether this concerns probing the electronic structure and reactivity of molecules as small as dihydrogen or synthesizing large polymer assemblies. The ability to synthesize new molecules and materials and to modify existing biological structures allows the properties of complex systems to be analyzed and harnessed with huge benefit to both the scientific community and society at large.

Undergraduate Program

Mission

The mission of the undergraduate program in Chemistry is to provide students with foundational knowledge in the subdisciplines of chemistry as well as depth in one or more advanced areas, including cutting-edge research. Introductory course work allows students to gain hands-on experience with chemical phenomena, gather data, and propose models and explanations for their observations, thus participating in the scientific process from the start. In advanced labs and lectures, students build an in-depth knowledge of the molecular principles of chemistry empowering them to become molecular engineers comfortable with the methodologies necessary to solve complex problems and effectively articulate their ideas to the scientific community. Ultimately the analytical thinking and problem solving skills developed within the chemistry major make students successful candidates for a wide range of careers in chemistry and beyond, including engineering, teaching, consulting, medicine, law, science writing, and science policy.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to:

1. demonstrate the knowledge and skills required to solve problems in the synthesis, measurement, and modeling of chemical systems.
2. apply this set of chemical knowledge and skills to analyze scientific data, evaluate and interpret its significance, and articulate conclusions supportable by the data.
3. be able to construct a scientific hypothesis and devise appropriate experiments to test and evaluate this hypothesis
4. communicate scientific research effectively in written and spoken form.

Graduate Program

The University's basic requirements for the M.S. and Ph.D. degrees are discussed in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)" section of this bulletin.

Learning Outcomes (Graduate)

The purpose of the master's program is to further develop knowledge and skills in Chemistry and to prepare students for a professional career or doctoral studies. This is achieved through completion of courses, in the primary field as well as related areas, and experience with independent work and specialization.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research and analysis in the field of chemistry. Through completion of advanced course work and rigorous skills training, the doctoral program prepares students to make original contributions to the knowledge of chemistry and to interpret and present the results of such research.

Fellowships and Scholarships

In addition to University and school fellowships and scholarships open to properly qualified students, there are several department fellowships in chemistry awarded based on merit. Teaching assistantships and research assistantships are provided to eligible graduate students. Teaching assistantships beyond the required quarters are available for those interested. Graduate fellowships, scholarships, and teaching assistantships are administered through the Department of Chemistry student services office.

Teaching Credentials

The requirements for certification to teach chemistry in the secondary schools of California may be ascertained by consulting the section on credentials under the "School of Education (http://exploredegrees.stanford.edu/schoolofeducation)" section of this bulletin and the Credential Administrator of the School of Education.

Chemical Physics

Students with an exceptionally strong background in physics and mathematics may, with special arrangement, pursue a program of studies in chemical physics.

Bachelor of Science in Chemistry

Entrance Preparation

Entrance credit in the preparatory subjects of chemistry, physics, and especially mathematics provides flexibility in creating a four-year schedule for students intending to major in Chemistry.

Degree Requirements

Additional information on the undergraduate program can be found on the Department of Chemistry web site beginning with the section on Requirements for the B.S. Degree (http://chemistry.stanford.edu/undergradprograms/requirements-bs-degree). All degree courses must be taken for a letter grade.

Lab Courses

Lab courses have a mandatory, non-refundable fee. Students who have not yet taken a lab course must purchase a department-approved lab coat and safety glasses. The department makes these available for purchase at the lowest possible price during the first few days of each quarter.

Chemistry Option

Requirements for students choosing the Chemistry Option:

		Units
Select one of the following:		5-10
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	
CHEM 31X	Chemical Principles Accelerated	
Required Chemistry Courses		
CHEM 33	Structure and Reactivity	5
CHEM 35	Synthetic and Physical Organic Chemistry	5
CHEM 130	Organic Chemistry Laboratory	3
CHEM 131	Organic Polyfunctional Compounds	3
CHEM 132	Synthesis Laboratory	3
CHEM 134	Analytical Chemistry Laboratory	5
CHEM 151	Inorganic Chemistry I	4
CHEM 153	Inorganic Chemistry II	3
CHEM 171	Physical Chemistry I	4
CHEM 173	Physical Chemistry II	3
CHEM 174	Electrochemical Measurements Lab	3
CHEM 175	Physical Chemistry III	3
CHEM 176	Spectroscopy Laboratory	3
Mathematics or CME		
MATH 19	Calculus	3
MATH 20	Calculus	3
MATH 21	Calculus	4
Select one of the following series:		
Series A		10
MATH 51	Linear Algebra and Differential Calculus of Several Variables	
MATH 53	Ordinary Differential Equations with Linear Algebra	
Series B		15
CME 100	Vector Calculus for Engineers	
CME 102	Ordinary Differential Equations for Engineers	
CME 104	Linear Algebra and Partial Differential Equations for Engineers	
Physics Required Courses		
PHYSICS 41	Mechanics	4
PHYSICS 42	Classical Mechanics Laboratory	1
PHYSICS 43	Electricity and Magnetism	4
PHYSICS 44	Electricity and Magnetism Lab	1
Total Units		97-102

Biological Chemistry Option

Requirements for students choosing the Biological Chemistry Option.

Select one of the following:		5-10
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	
CHEM 31X	Chemical Principles Accelerated	
Required Chemistry and Biology courses		
CHEM 33	Structure and Reactivity	5
CHEM 35	Synthetic and Physical Organic Chemistry	5
CHEM 130	Organic Chemistry Laboratory	3
CHEM 131	Organic Polyfunctional Compounds	3
CHEM 132	Synthesis Laboratory	3
CHEM 134	Analytical Chemistry Laboratory	5
CHEM 151	Inorganic Chemistry I	4
CHEM 171	Physical Chemistry I	4
CHEM 173	Physical Chemistry II	3
CHEM 176	Spectroscopy Laboratory	3
CHEM 181	Biochemistry I	3
CHEM 183	Biochemistry II	3
CHEM 184	Biological Chemistry Laboratory	3
CHEM 185	Biophysical Chemistry	3
BIO 42	Cell Biology and Animal Physiology	5
Mathematics or CME		
MATH 19	Calculus	3
MATH 20	Calculus	3
MATH 21	Calculus	4
Select one of the following Series:		
Series A		10
MATH 51	Linear Algebra and Differential Calculus of Several Variables	
MATH 53	Ordinary Differential Equations with Linear Algebra	
Series B		15
CME 100	Vector Calculus for Engineers	
CME 102	Ordinary Differential Equations for Engineers	
CME 104	Linear Algebra and Partial Differential Equations for Engineers	
Required Physics Courses		
PHYSICS 41	Mechanics	4
PHYSICS 42	Classical Mechanics Laboratory	1
PHYSICS 43	Electricity and Magnetism	4
PHYSICS 44	Electricity and Magnetism Lab	1
Elective		3-4
Select one graduate-level elective course related to your biochemical interests.		
CHEM 221	Advanced Organic Chemistry	
CHEM 223	Advanced Organic Chemistry	
CHEM 225	Advanced Organic Chemistry	
CHEM 227	Therapeutic Science at the Chemistry - Biology Interface (strongly recommended)	
CHEM 235	Applications of NMR Spectroscopy	
CHEM 255	Advanced Inorganic Chemistry	
CHEM 271	Advanced Physical Chemistry	
CHEM 277	Materials Chemistry and Physics (not offered 2016-17)	
CHEM 297	Bio-Inorganic Chemistry	
BIO 214	Advanced Cell Biology	
BIO 230	Molecular and Cellular Immunology	
BIO 232	Advanced Imaging Lab in Biophysics	
BIOC 241	Biological Macromolecules	
BIOE 214	Representations and Algorithms for Computational Molecular Biology	
BIOE 224	Probes and Applications for Multi-modality Molecular Imaging of Living Subjects	
BIOE 300A	Molecular and Cellular Bioengineering	
BIOE 335	Molecular Motors I	
BIOPHYS 232	Advanced Imaging Lab in Biophysics	
BIOPHYS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
CSB 220	Chemistry of Biological Processes	
CSB 260	Concepts and Applications in Chemical Biology	

For further information on the undergraduate program, see the Department of Chemistry (http://chemistry.stanford.edu/undergraduate-programs) web site.

Chemistry Major Schedule

Below are possible schedules for the traditional concentration and the biological chemistry concentration, each followed by an accelerated schedule.

Schedule for Traditional Concentration

First Year	Units		
	Autumn	Winter	Spring
Chemical Principles I (CHEM 31A)	5		
Calculus (MATH 19)	3		
Chemical Principles II (CHEM 31B)		5	
Calculus (MATH 20)		3	
Structure and Reactivity (CHEM 33)			5
Calculus (MATH 21)			4
Year Total:	8	8	9

Second Year	Units		
	Autumn	Winter	Spring
Synthetic and Physical Organic Chemistry (CHEM 35)	5		
Linear Algebra and Differential Calculus of Several Variables (MATH 51)	5		
Organic Chemistry Laboratory (CHEM 130)		3	
Organic Polyfunctional Compounds (CHEM 131)		3	
Mechanics (PHYSICS 41)		4	
Classical Mechanics Laboratory (PHYSICS 42)		1	
Analytical Chemistry Laboratory (CHEM 134)			5
Electricity and Magnetism (PHYSICS 43)			4
Electricity and Magnetism Lab (PHYSICS 44)			1
Year Total:	10	11	10

Third Year	Units		
	Autumn	Winter	Spring
Synthesis Laboratory (CHEM 132)		3	
Inorganic Chemistry I (CHEM 151)		4	
Physical Chemistry I (CHEM 171)			4
Ordinary Differential Equations with Linear Algebra (MATH 53)			5
Year Total:		7	9

Fourth Year	Units		
	Autumn	Winter	Spring
Physical Chemistry II (CHEM 173)	3		
Electrochemical Measurements Lab (CHEM 174)	3		
Physical Chemistry III (CHEM 175)		3	
Spectroscopy Laboratory (CHEM 176)		3	
Inorganic Chemistry II (CHEM 153)			3
Year Total:	6	6	3

Total Units in Sequence:	87

Accelerated Schedule for the Traditional Concentration

First Year	Units		
	Autumn	Winter	Spring
Chemical Principles Accelerated (CHEM 31X)	5		
Linear Algebra and Differential Calculus of Several Variables (MATH 51)	5		
Structure and Reactivity (CHEM 33)		5	
Mechanics (PHYSICS 41)		4	
Classical Mechanics Laboratory (PHYSICS 42)		1	
Synthetic and Physical Organic Chemistry (CHEM 35)			5
Electricity and Magnetism (PHYSICS 43)			4
Electricity and Magnetism Lab (PHYSICS 44)			1
Year Total:	10	10	10

Second Year	Units		
	Autumn	Winter	Spring
Organic Chemistry Laboratory (CHEM 130)	3		
Organic Polyfunctional Compounds (CHEM 131)	3		
Ordinary Differential Equations with Linear Algebra (MATH 53)	5		
Synthesis Laboratory (CHEM 132)		3	
Inorganic Chemistry I (CHEM 151)		4	
Analytical Chemistry Laboratory (CHEM 134)			5
Physical Chemistry I (CHEM 171)			4
Year Total:	11	7	9

Third Year	Units		
	Autumn	Winter	Spring
Physical Chemistry II (CHEM 173)	3		
Electrochemical Measurements Lab (CHEM 174)	3		
Physical Chemistry III (CHEM 175)		3	
Spectroscopy Laboratory (CHEM 176)		3	
Inorganic Chemistry II (CHEM 153)			3
Year Total:	6	6	3

Total Units in Sequence:	72

Schedule for Biological Chemistry Concentration

First Year	Units		
	Autumn	Winter	Spring
Chemical Principles I (CHEM 31A)	5		
Calculus (MATH 19)	3		
Chemical Principles II (CHEM 31B)		5	
Calculus (MATH 20)		3	
Structure and Reactivity (CHEM 33)			5
Calculus (MATH 21)			4
Year Total:	8	8	9

Second Year	Units		
	Autumn	Winter	Spring
Synthetic and Physical Organic Chemistry (CHEM 35)	5		
Linear Algebra and Differential Calculus of Several Variables (MATH 51)	5		
Organic Chemistry Laboratory (CHEM 130)		3	
Organic Polyfunctional Compounds (CHEM 131)		3	
Cell Biology and Animal Physiology (BIO 42)		5	
Analytical Chemistry Laboratory (CHEM 134)			5
Ordinary Differential Equations with Linear Algebra (MATH 53)			5
Year Total:	10	11	10

Third Year	Units		
	Autumn	Winter	Spring
Synthesis Laboratory (CHEM 132)		3	
Inorganic Chemistry I (CHEM 151)		4	
Mechanics (PHYSICS 41)		4	
Classical Mechanics Laboratory (PHYSICS 42)		1	
Physical Chemistry I (CHEM 171)			4
Electricity and Magnetism (PHYSICS 43)			4
Electricity and Magnetism Lab (PHYSICS 44)			1
Year Total:		12	9

Fourth Year	Units		
	Autumn	Winter	Spring
Physical Chemistry II (CHEM 173)	3		
Biochemistry I (CHEM 181)	3		
Spectroscopy Laboratory (CHEM 176)		3	
Biochemistry II (CHEM 183)		3	
Biological Chemistry Laboratory (CHEM 184)			3
Biophysical Chemistry (CHEM 185)			3
Therapeutic Science at the Chemistry - Biology Interface (CHEM 227)			3
Year Total:	6	6	9

Total Units in Sequence:	98

Accelerated Schedule for the Biological Chemistry Concentration

First Year	Units		
	Autumn	Winter	Spring
Chemical Principles Accelerated (CHEM 31X)	5		
Linear Algebra and Differential Calculus of Several Variables (MATH 51)	5		
Structure and Reactivity (CHEM 33)		5	
Mechanics (PHYSICS 41)		4	
Classical Mechanics Laboratory (PHYSICS 42)		1	
Synthetic and Physical Organic Chemistry (CHEM 35)			5
Electricity and Magnetism (PHYSICS 43)			4
Electricity and Magnetism Lab (PHYSICS 44)			1
Year Total:	10	10	10

Second Year	Units		
	Autumn	Winter	Spring
Organic Chemistry Laboratory (CHEM 130)	3		
Organic Polyfunctional Compounds (CHEM 131)	3		
Ordinary Differential Equations with Linear Algebra (MATH 53)	5		
Synthesis Laboratory (CHEM 132)		3	
Inorganic Chemistry I (CHEM 151)		4	
Cell Biology and Animal Physiology (BIO 42)		5	
Analytical Chemistry Laboratory (CHEM 134)			5
Physical Chemistry I (CHEM 171)			4
Year Total:	11	12	9

Third Year	Units		
	Autumn	Winter	Spring
Physical Chemistry II (CHEM 173)	3		
Biochemistry I (CHEM 181)	3		
Spectroscopy Laboratory (CHEM 176)		3	
Biochemistry II (CHEM 183)		3	
Biological Chemistry Laboratory (CHEM 184)			3
Biophysical Chemistry (CHEM 185)			3
Therapeutic Science at the Chemistry - Biology Interface (CHEM 227)			3
Year Total:	6	6	9

Total Units in Sequence:	83

Related Courses

Courses offered by other departments that may be of interest to Chemistry majors include:

		Units
BIO 41	Genetics, Biochemistry, and Molecular Biology	5
BIO 42	Cell Biology and Animal Physiology	5
BIO 43	Plant Biology, Evolution, and Ecology	5
CHEMENG 20	Introduction to Chemical Engineering	4
CHEMENG 120A	Fluid Mechanics	4
CHEMENG 120B	Energy and Mass Transport	4
CHEMENG 130	Separation Processes	3
CS 106A	Programming Methodology (recommended for students planning graduate study)	3-5
CS 106B	Programming Abstractions (recommended for students planning graduate study)	3-5
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	4
MATH 106	Functions of a Complex Variable	3
MATH 109	Applied Group Theory	3
MATH 113	Linear Algebra and Matrix Theory	3
MATH 131P	Partial Differential Equations	3
MATSCI 151	Microstructure and Mechanical Properties	4
PHYSICS 110	Advanced Mechanics	4
STATS 110	Statistical Methods in Engineering and the Physical Sciences	4-5
STATS 116	Theory of Probability	3-5

American Chemical Society (ACS) Certification

Students who wish to be certified as having met the minimum requirements of the American Chemical Society for professional training must complete, in addition to the above requirements:

		Units
CHEM 181	Biochemistry I	3
CHEM 190	Advanced Undergraduate Research	4

Honors Program

A bachelor’s degree in Chemistry with honors is available to those students interested in chemical research. Admission to the honors program requires a grade point average (GPA) of 3.3 in science courses and an overall GPA of 3.0 in all University courses. Beyond the standard B.S. course requirements for each track, 9 units of research credit and 9 units of course work need to be completed during the junior and senior academic years. A thesis, approved by the honors adviser, must be completed during the senior year. The theses must be submitted to the research adviser, at least one week before the end of regular classes in Spring Quarter, and must be completed by May 15 to be considered for the Firestone or Golden award. The use of a single course for multiple requirements for honors, major, minor, or coterminal requirements is not allowed. Students who wish to be admitted to the honors program should register with the student services manager in the Mudd Chemistry Building in Spring Quarter of their junior year.

CHEM 190 Advanced Undergraduate Research research units towards honors may be completed, after being accepted into the program, in any laboratory within Chemistry or with courtesy faculty in Chemistry. Other chemical research can be approved through a formal petitioning of the Undergraduate Studies Committee. At least 3 units must be completed during the senior year. Participation in a summer research program in an academic setting between junior and senior years may be used in lieu of 3 units of CHEM 190 Advanced Undergraduate Research. For each quarter, a progress report reflecting the units undertaken is required. This report must be signed by the honors adviser, and filed in the department student services office before the last day of finals in the quarter during which the research is performed.

The 9 units of course work for honors must be completed from courses approved by the Undergraduate Studies Committee and taken for a letter grade. At least six of these units need to be taken from the following CHEM courses:

		Units
CHEM 153	Inorganic Chemistry II	3
CHEM 174	Electrochemical Measurements Lab	3
CHEM 175	Physical Chemistry III	3
CHEM 181	Biochemistry I	3
CHEM 183	Biochemistry II	3
CHEM 184	Biological Chemistry Laboratory	3
CHEM 185	Biophysical Chemistry	3
CHEM 221	Advanced Organic Chemistry	3
CHEM 223	Advanced Organic Chemistry	3
CHEM 225	Advanced Organic Chemistry	3
CHEM 235	Applications of NMR Spectroscopy	3
CHEM 251	Advanced Inorganic Chemistry	3
CHEM 255	Advanced Inorganic Chemistry	3

CHEM 271	Advanced Physical Chemistry	3
CHEM 273	Advanced Physical Chemistry	3
CHEM 275	Advanced Physical Chemistry	3
CHEM 297	Bio-Inorganic Chemistry	3

Minor in Chemistry

Courses required for a minor must be taken for a letter grade and all courses below are required:

		Units
CHEM 33	Structure and Reactivity	5
CHEM 35	Synthetic and Physical Organic Chemistry	5
CHEM 130	Organic Chemistry Laboratory	3
CHEM 131	Organic Polyfunctional Compounds	3
CHEM 134	Analytical Chemistry Laboratory	5
CHEM 151	Inorganic Chemistry I	4
CHEM 171	Physical Chemistry I	4
Total Units		29

Master of Science in Chemistry

The Master of Science is available only to current Ph.D. students or as part of a coterminal program. Applicants for the M.S. degree in Chemistry are required to complete, in addition to the requirements for the bachelor's degree, a minimum of 45 graduate-level units and a M.S. thesis. Of the 45 units, approximately two-thirds must be in the department and must include at least 12 units of graduate level lecture courses exclusive of the thesis.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken three quarters prior to the first graduate quarter, or later, are eligible for consideration for transfer to the graduate career. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

		Units
Of the 12 units, at least 6 units must be from:		
CHEM 221	Advanced Organic Chemistry	3
CHEM 223	Advanced Organic Chemistry	3
CHEM 225	Advanced Organic Chemistry	3
CHEM 227	Therapeutic Science at the Chemistry - Biology Interface	3
CHEM 235	Applications of NMR Spectroscopy	3
CHEM 251	Advanced Inorganic Chemistry	3
CHEM 253	Advanced Inorganic Chemistry	3
CHEM 255	Advanced Inorganic Chemistry	3
CHEM 271	Advanced Physical Chemistry	3
CHEM 273	Advanced Physical Chemistry	3
CHEM 275	Advanced Physical Chemistry	3
CHEM 277	Materials Chemistry and Physics	3
CHEM 297	Bio-Inorganic Chemistry	3

Doctor of Philosophy in Chemistry Process to Candidacy

Graduate students are eligible to become formal candidates for the Ph.D. degree after taking the department placement examinations, satisfactory completion of most of the formal lecture course requirements, and satisfactory progress on a dissertation research project. There is no foreign language requirement for the Ph.D. degree. Admission to candidacy for the Ph.D. degree must be done before June of the second year of graduate registration.

Placement Examinations

Each new graduate student must take placement examinations upon entrance. These consist of three written examinations of two hours each in the fields of inorganic, organic, and physical chemistry, and cover such material as ordinarily is given in a rigorous one-year undergraduate course in each of these subjects. Students concentrating in biophysical chemistry or chemical physics must take examinations in biophysical or chemical physics, physical chemistry, and organic or inorganic chemistry. Students concentrating in chemical biology must take examinations in biophysical, organic chemistry, and physical chemistry or inorganic chemistry. All placement examinations are given the week before instruction begins in Autumn Quarter, and must be taken at that time. Each new graduate student meets with a member of the graduate study committee to define a program of courses based on results of the placement examinations.

General Requirements

After taking the departmental placement examinations, students select a research adviser by interviewing members of the Chemistry faculty. An Application to Start Research form is submitted to the Department as research begins under the supervision of the adviser. All students in good standing are required to start research by the end of February, during Winter Quarter of the first year of graduate registration.

Candidates for the Ph.D. degree are required to participate continually in the department colloquium (CHEM 300 Department Colloquium) and in the division seminar of the major subject (CHEM 229 Organic Chemistry Seminar, CHEM 259 Inorganic Chemistry Seminar, or CHEM 279 Physical Chemistry Seminar).

Candidates for advanced degrees must have a minimum grade point average (GPA) of 3.0 for all Chemistry lecture courses as well as for all courses taken during graduate study. Required courses must be taken for a letter grade. Most course work ends in the second year of studies, and students will then focus on full-time dissertation research.

Students may major in organic, chemical biology, physical, biophysical, chemical physics, or inorganic chemistry. All graduate students are required to take six graduate-level lecture courses (course numbers greater than 199) of at least 3 units each in chemistry or related disciplines (e.g., biochemistry, electrical engineering, mathematics, chemical engineering, chemical and systems biology, physics, materials science), to be selected in consultation with their research adviser and the Graduate Study Committee. All six courses must be taken for a letter grade. At least three of the six courses should be taken within the Chemistry Department. A minimum of four courses should be completed by the end of the first year.

Course Requirements

		Units
Students majoring in organic chemistry or chemical biology must complete:		
CHEM 231	Organic Chemistry Seminar Presentation (Autumn, Winter, and Spring of the second year)	1
CHEM 233A	Creativity in Organic Chemistry (Research Progress)	1
CHEM 233B	Creativity in Organic Chemistry (Research Progress)	1
CHEM 233C	Creativity in Organic Chemistry (Research Progress)	1
Students majoring in physical or biophysical chemistry or chemical physics must complete:		
CHEM 271	Advanced Physical Chemistry (in the first year)	3
CHEM 273	Advanced Physical Chemistry (in the first year)	3
CHEM 275	Advanced Physical Chemistry (in the first year)	3
CHEM 278A	Research Progress in Physical Chemistry	1
CHEM 278B	Research Progress in Physical Chemistry	1
Students majoring in inorganic chemistry must complete:		
CHEM 258A	Research Progress in Inorganic Chemistry	1
CHEM 258B	Research Progress in Inorganic Chemistry (Seminar Presentation)	1
CHEM 258C	Research Progress in Inorganic Chemistry (Research Proposal)	1

Continuous enrollment in CHEM 301 Research in Chemistry is expected after the student has chosen a research supervisor.

Post-Candidacy

Before candidates may request scheduling of the University oral examination, clearance must be obtained from the dissertation adviser and an academic review meeting made with the Student Services Manager for the Department of Chemistry.

During the period in which a dissertation is being read by members of the faculty, candidates must be available for personal consultation until the dissertation has received final department approval.

Ph.D. Minor in Chemistry

Candidates for the Ph.D. degree in other departments who wish to obtain a minor in chemistry must complete, with a GPA of 3.0 or higher, 20 graduate-level units in Chemistry including four lecture courses of at least three units each.

Emeriti: (Professors) Hans C. Andersen, John I. Brauman, James P. Collman, Wray H. Huestis, Robert Pecora, John Ross

Chair: Keith O. Hodgson

Vice Chair: T. Daniel P. Stack

Professors: Carolyn R. Bertozzi, Steven G. Boxer, Hongjie Dai, Michael D. Fayer, Keith O. Hodgson, Chaitan Khosla, Eric T. Kool, Todd J. Martínez, W. E. Moerner, Vijay S. Pande, Edward I. Solomon, Barry M. Trost, Robert M. Waymouth, Paul A. Wender, Richard N. Zare

Associate Professors: Christopher E. D. Chidsey, Bianxiao Cui, Justin Du Bois, T. Daniel P. Stack

Assistant Professors: Noah Z. Burns, Lynette Cegelski, Matthew Kanan, Hemamala Karunadasa, Thomas E. Markland, Yan Xia

Courtesy Professors: Zhenan Bao, Stacey F. Bent, James K. Chen, Karlene A. Cimprich, Curtis W. Frank, Daniel Herschlag, Thomas J. Wandless

Courtesy Associate Professors: Yi Cui, Jianghong Rao

Lecturers: Charles Cox, Megan McClory, Jennifer Schwartz Poehlmann, Heidi Vollmer-Snarr

Courses

CHEM 1. Introduction to Organic Chemistry. 4 Units.
First lecture class in summer organic intensive designed for those entering the medical field. Introduction to molecular structure and reactivity of functional groups. Explore chemical reactivity in the context of kinetics and thermodynamics. Prerequisite: College level general chemistry or an AP Chemistry score of 5.

CHEM 1L. Organic Chemistry Lab I. 2 Units.
Hands on exploration of laboratory reactions & phenomena discussed in Chem 1. Learn techniques for separation of compounds: distillation, extraction and chromatography (TLC, GCMS) while investigating the nature and properties of organic compounds such as boiling points, polarity, solubility and chirality. Prerequisite: Chem 33 (or course equivalent) or Chem 1 co-requisite.

CHEM 2. Organic Chemistry of Carbonyl Containing Molecules. 4 Units.
Second lecture class in the summer organic intensive series focusing on the synthesis and reactivity of small molecules, with particular emphasis on those that possess the carbonyl functional group. Discuss the importance of the carbonyl functional group to biochemistry. Prerequisite: Chem 33 or Chem 1 or equivalent.

CHEM 2L. Organic Chemistry Lab II. 2 Units.
Provides hands on experience with modern chemical methods for preparative and analytical chemistry including GCMS, UV-VIS and IR spectroscopy. Learn how chemoselectivity of reactions can be acheived, synthesize bioactive molecules such as pain relievers, and explore how sunscreens can be made more effective. Prerequisite: Chem 1L. Co-requisite: Chem 2.

CHEM 3. Organic Chemistry of Biomolecules. 4 Units.
Third lecture class in summer organic intensive focusing on the structure and reactivity of a class of larger molecules, the biomolecules. Topics covered of interest to biochemistry include aromatic compounds, amines and heterocycles, amino acids, proteins, polysaccharides, nucleic acids and polymers. Prerequisite: Chem 35 or Chem 2 or course equivalent.

CHEM 3L. Organic Chemistry Lab III. 2 Units.
Advanced organic lab course that introduces multi-step synthesis, NMR spectroscopy, and polymer chemistry. Learn how to use modern analytical and spectroscopic techniques to determine the structure of organic compounds. Prerequisite: Chem 2L or course equivalent.

CHEM 4. Biochemistry: Chemistry of Life. 4 Units.
A four-week intensive biochemistry course from a chemical perspective. The chemical basis of life, including the biomolecular chemistry of amino acids, proteins, carbohydrates, lipids, and nucleic acids, as well as enzyme kinetics and mechanisms, thermodynamics, and core metabolism, control, and regulation. Recitation includes group work on case studies that support the daily lecture material. Prerequisites: CHEM 33, 35, 131 or 1 year of organic chemistry; Math 19, 20, 21 or 41, 42 or 1 year of single variable calculus.

CHEM 10. Exploring Research and Problem Solving Across the Sciences. 2 Units.
Development and practice of critical problem solving and study skills using wide variety of scientific examples that illustrate the broad yet integrated nature of current research. Student teams will have the opportunity to explore and present on topics revolving around five central issues: energy, climate change, water resources, medicine, and food & nutrition from a chemical perspective. Course offered in August prior to start of fall quarter.

CHEM 25N. Science in the News. 3 Units.
Preference to freshmen. Possible topics include: diseases such as avian flu, HIV, and malaria; environmental issues such as climate change, atmospheric pollution, and human population; energy sources in the future; evolution; stem cell research; nanotechnology; and drug development. Focus is on the scientific basis for these topics as a basis for intelligent discussion of societal and political implications. Sources include the popular media and scientific media for the nonspecialist, especially those available on the web.

CHEM 26N. The What, Why, How and wow's of Nanotechnology. 3 Units.
Preference to freshmen. Introduction to nanotechnology with discussion of basic science at the nanoscale, its difference from molecular and macroscopic scales, and implications and applications. Developments in nanotechnology in the past two decades, from imaging and moving single atoms on surfaces to killing cancer cells with nanoscale tools and gadgets.

CHEM 27N. Light and Life. 3 Units.
Preference given to freshman. Light plays a central role in many biological processes and color affects everything in our world. This includes familiar processes such as photosynthesis and vision, but also proton pumps in the organisms that make the Bay purple, green fluorescent protein (GFP), the light from fireflies, the blue and red light receptors responsible for directing how plants grow, the molecules responsible for fall colors, and repair enzymes such as DNA photolyase (this year¿s Nobel prize). Light is also used to interrogate (e.g. super-resolution microscopy, last year¿s Nobel prize) and manipulate (optogenetics) biological systems. Light causes sunburn, but can also be used in combination with special molecules to treat diseases. We will discuss the nature of light, how it is measured, how it is generated in the laboratory, how molecules are excited, and how one measures the fate of this excitation. Chem 31X or 31A preferred, but not required.

CHEM 28N. Science Innovation and Communication. 3 Units.
Preference to freshmen. The course will explore evolutionary and revolutionary scientific advances; their consequences to society, biotechnology, and the economy; and mechanisms for communicating science to the public. The course will engage academic and industrial thought leaders and provide an opportunity for students to participate in communicating science to the public.

CHEM 31A. Chemical Principles I. 5 Units.
For students with moderate or no background in chemistry. Stoichiometry; periodicity; electronic structure and bonding; gases; enthalpy; phase behavior. Emphasis is on skills to address structural and quantitative chemical questions; lab provides practice. Recitation.

CHEM 31AC. Problem Solving in Science. 1 Unit.
Development and practice of critical problem solving skills using chemical examples. Limited enrollment. Prerequisite: consent of instructor. Corequisite: CHEM 31A.

CHEM 31B. Chemical Principles II. 5 Units.
Chemical equilibrium; acids and bases; oxidation and reduction reactions; chemical thermodynamics; kinetics. Lab. Prerequisite: CHEM 31A.

CHEM 31BC. Problem Solving in Science. 1 Unit.
Development and practice of critical problem solving skills using chemicalnexamples. Students should also be concurrently enrolled in the parent course 31B. Limited enrollment and with permission of the instructor.

CHEM 31X. Chemical Principles Accelerated. 5 Units.
Accelerated; for students with substantial chemistry background. Chemical equilibria concepts, equilibrium constants, acids and bases, chemical thermodynamics, quantum concepts, models of ionic and covalent bonding, atomic and molecular orbital theory, periodicity, and bonding properties of matter. Recitation. Prerequisites: AP chemistry score of 5 or passing score on chemistry placement test, and AP Calculus AB score of 4 or Math 20 or Math 41. Recommended: high school physics.

CHEM 33. Structure and Reactivity. 5 Units.
Organic chemistry, functional groups, hydrocarbons, stereochemistry, thermochemistry, kinetics, chemical equilibria. Recitation. Prerequisite: 31A,B, or 31X, or an AP Chemistry score of 5.

CHEM 33C. Problem Solving in Science. 1 Unit.
Development and practice of critical problem solving skills using chemical examples. Limited enrollment. Prerequisite: consent of instructor. Corequisite: CHEM 33.

CHEM 35. Synthetic and Physical Organic Chemistry. 5 Units.
The structure and reactivity of mono- and polyfunctionalized molecules; retrosynthetic analysis and multi-step chemical synthesis. Course will emphasize deductive logic and reasoning skills through conceptual learning. Students gain an appreciation for the profound impact of organic chemistry on humankind in fields ranging from biology and medicine to gastronomy, agriculture, and materials science. A three hour lab section provides hands on experience with modern chemical methods for preparative and analytical chemistry. Prerequisite: Chem 33.

CHEM 110. Directed Instruction/Reading. 1-2 Unit.
Undergraduates pursue a reading program under supervision of a faculty member in Chemistry; may also involve participation in lab. Prerequisites: superior work in 31A,B, 31X, or 33; and consent of instructor.

CHEM 111. Exploring Chemical Research at Stanford. 1 Unit.
Preference to freshmen and sophomores. Department faculty describe their cutting-edge research and its applications.

CHEM 130. Organic Chemistry Laboratory. 3 Units.
Intermediate organic chemistry laboratory, including synthesis and spectroscopy. Nobel prize winning reactions and characterization techniques, such as Diels-Alder and modified Wittig reactions, as well as IR, NMR, and GCMS; Biodiesel synthesis and lipid characterization. Prerequisite: Chem 35 taken in Aut 2014-15 or later, or Chem 35 and 36. Corequisite: 131.

CHEM 131. Organic Polyfunctional Compounds. 3 Units.
Aromatic compounds, polysaccharides, amino acids, proteins, natural products, dyes, purines, pyrimidines, nucleic acids, and polymers. Prerequisite: 35.

CHEM 132. Synthesis Laboratory. 3 Units.
Focus is on longer syntheses with an emphasis upon using metal catalysts. Emphasis will be on complete characterization of final products using chromatographic and spectroscopic methods. Concludes with an individual synthesis project. Prerequisites: 35, 130.

CHEM 134. Analytical Chemistry Laboratory. 5 Units.
Classical analysis methods, statistical analyses, chromatography, and spectroscopy will be covered with an emphasis upon quantitative measurements and data analysis. WIM course with full lab reports and oral communication. Concludes with student-developed quantitative project. Prerequisite: Chem 35.

CHEM 137. Special Topics in Synthesis. 3 Units.
The course covers the basic toolbox for construction of more complex structures for function, largely directed towards molecules of biological relevance. The focus will be the ability to perform structural changes efficiently in order to enable the design of the best structure for a function. The concepts of catalytic processes are at the heart of the how small molecule drug discovery is performed. Fundamentals of the pertinent catalytic processes are discussed. The inter-relationship of synthetic chemistry and pharmaceuticals is emphasized. See more at: http://library.stanford.edu/guides/chem-137-special-topics-organic-chemistry#sthash.vi9khNU5.dpuf. Prerequisite CHEM 35.

CHEM 141. The Chemical Principles of Life I. 4 Units.
This is the first course in a two-quarter sequence (Chem 141/143), which will examine biological science through the lens of chemistry. In this sequence students will gain a qualitative and quantitative understanding of the molecular logic of cellular processes, which include expression and transmission of the genetic code, enzyme kinetics, biosynthesis, energy storage and consumption, membrane transport, and signal transduction. Connections to foundational principles of chemistry will be made through structure-function analyses of biological molecules. Integrated lessons in structural, mechanistic, and physical chemistry will underscore how molecular science and molecular innovation have impacted biology and medicine. Prerequisites: CHEM 35, MATH 21 or equivalent.

CHEM 143. The Chemical Principles of Life II. 4 Units.
This is the second course in a two-quarter sequence (Chem 141/143), which will continue the discussion of biological science through the lens of chemistry. In this sequence students will gain a qualitative and quantitative understanding of the molecular logic of cellular processes, which include expression and transmission of the genetic code, enzyme kinetics, biosynthesis, energy storage and consumption, membrane transport, and signal transduction. Connections to foundational principles of chemistry will be made through structure-function analyses of biological molecules. Integrated lessons in structural, mechanistic, and physical chemistry will underscore how molecular science and molecular innovation have impacted biology and medicine. Prerequisite: Chem 141.

CHEM 150. Single-Crystal X-ray Diffraction. 3 Units.
Practical X-ray crystallography for small molecule compounds, which will emphasize crystal growth, measurement strategies, structure solution and refinement, and report generation. Example structures will include absolute configuration of organic compounds (with the heaviest atom being oxygen), metal containing complexes, disordered small molecules and twinning. Students will learn how to get from a new compound to a single crystal, and then to a cif-file ready for publication submission. They will gain knowledge of the underlying theory and concepts for each step of structure determination.
Same as: CHEM 250

CHEM 151. Inorganic Chemistry I. 4 Units.
Theories of electronic structure, stereochemistry, and symmetry properties of inorganic molecules. Topics: ionic and covalent interactions, electron-deficient bonding, and molecular orbital theories. Emphasis is on the chemistry of the metallic elements. An introduction to the Gaussian program will be covered in the discussion sections, used for electronic calculations in the computer and problem set exercises. Prerequisites: 35. Recommended: 171.

CHEM 153. Inorganic Chemistry II. 3 Units.
The theoretical aspects of inorganic chemistry. Group theory; many-electron atomic theory; molecular orbital theory emphasizing general concepts and group theory; ligand field theory; application of physical methods to predict the geometry, magnetism, and electronic spectra of transition metal complexes. Prerequisites: 151, 173.

CHEM 155. Advanced Inorganic Chemistry. 3 Units.
Chemical reactions of organotransition metal complexes and their role in homogeneous catalysis. Analogous patterns among reactions of transition metal complexes in lower oxidation states. Physical methods of structure determination. Prerequisite: one year of physical chemistry.
Same as: CHEM 255

CHEM 171. Physical Chemistry I. 4 Units.
Laws of thermodynamics, properties of gases, phase transitions and phase equilibrium, chemical equilibrium, chemical kinetics, reaction rate, thermal motion and energy barriers, kinetic molecular models. The MATLAB programming language with hands-on experiences will be introduced in discussion sections and used for simulations of chemical systems. Prerequisites: CHEM 33; PHYS 41; either CME 100 or MATH 51.

CHEM 173. Physical Chemistry II. 3 Units.
Introduction to quantum chemistry: the basic principles of wave mechanics, the harmonic oscillator, the rigid rotator, infrared and microwave spectroscopy, the hydrogen atom, atomic structure, molecular structure, valence theory. Prerequisites: CHEM 171; CME 102, 104 or MATH 53; PHYSICS 41, 43.

CHEM 174. Electrochemical Measurements Lab. 3 Units.
Introduction to modern electrochemical measurement in a hands-on, laboratory setting. Students assemble and use electrochemical cells including indicator, reference, working and counter electrodes, with macro, micro and ultramicro geometries, salt bridges, ion-selective membranes, electrometers, potentiostats, galvanostats, and stationary and rotated disk electrodes. The later portion of the course will involve a student-generated project to experimentally characterize some electrochemical system. Prerequisites: 134, 171, MATH 51, PHYSICS 44 or equivalent.
Same as: CHEM 274

CHEM 175. Physical Chemistry III. 3 Units.
Molecular theory of kinetics and statistical mechanics: transport and reactions in gases and liquids, ensembles and the Boltzmann distribution law, partition functions, molecular simulation, structure and dynamics of liquids. Diffusion and activation limited reactions, potential energy surfaces, collision theory, transition-state theory and Marcus theory of reaction rates. Prerequisites: 171, 173.

CHEM 176. Spectroscopy Laboratory. 3 Units.
Use of spectroscopic instrumentation to obtain familiarity with important types of spectrometers and spectroscopic method and to apply them to study molecular properties and physical chemical time-dependent processes. Spectrometers include electronic ultraviolet/visible absorption, fluorescence, Raman, Fourier transform infrared, and nuclear magnetic resonance. Prerequisite: 173.

CHEM 181. Biochemistry I. 3 Units.
Structure and function of major classes of biomolecules, including proteins, carbohydrates and lipids. Mechanistic analysis of properties of proteins including catalysis, signal transduction and membrane transport. Students will also learn to critically analyze data from the primary biochemical literature. Satisfies Central Menu Area 1 for Bio majors. Prerequisites: CHEM 35, 131, and 135 or 171.
Same as: CHEMENG 181, CHEMENG 281

CHEM 183. Biochemistry II. 3 Units.
Focus on metabolic biochemistry: the study of chemical reactions that provide the cell with the energy and raw materials necessary for life. Topics include glycolysis, gluconeogenesis, the citric acid cycle, oxidative phosphorylation, photosynthesis, the pentose phosphate pathway, and the metabolism of glycogen, fatty acids, amino acids, and nucleotides as well as the macromolecular machines that synthesize RNA, DNA, and proteins. Medical relevance is emphasized throughout. Satisfies Central Menu Area 1 for Bio majors. Prerequisite: CHEM 181 or CHEM 143 or CHEMENG 181/281.
Same as: CHEMENG 183, CHEMENG 283

CHEM 184. Biological Chemistry Laboratory. 3 Units.
Modern techniques in biological chemistry including protein purification, characterization of enzyme kinetics, heterologous expression of His-tagged fluorescent proteins, site-directed mutagenesis, and single-molecule fluorescence microscopy. Prerequisite: 181.

CHEM 185. Biophysical Chemistry. 3 Units.
Primary literature based seminar/discussion course covering classical and contemporary papers in biophysical chemistry. Topics include: protein structure and stability, folding, single molecule fluorescence and force microscopy, simulations, ion channels, GPCRs, and ribosome structure/function. Course is restricted to undergraduates. Prerequisites: 171 and 181, with 173 strongly recommended.

CHEM 187B. Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery. 1 Unit.
This course provides an overview of the biosynthesis of the five major classes of small molecule natural products, including polyketides, nonribosomal peptides, terpene/isoprenoid scaffolds, alkaloids, and phenylpropanoids. Focus will be on the chemical logic for bond-forming chemical steps in each natural product class and the kinds of enzyme catalysts required to effect complexity-generating molecular scaffolds. This short course runs for the first five weeks of the quarter, from January through the second week of February. Prerequisite: Chem 181 or equivalent.
Same as: CHEM 287B

CHEM 190. Advanced Undergraduate Research. 1-5 Unit.
Limited to undergraduates who have completed Chem 35 and/or Chem 134, or by special arrangement with a faculty member. May be repeated 8 times for a max of 27 units. Prerequisite: 35 or 134. Corequisite: 300.

CHEM 196. Creating New Ventures in Engineering and Science-based Industries. 3 Units.
Open to seniors and graduate students interested in the creation of new ventures and entrepreneurship in engineering and science intensive industries such as chemical, energy, materials, bioengineering, environmental, clean-tech, pharmaceuticals, medical, and biotechnology. Exploration of the dynamics, complexity, and challenges that define creating new ventures, particularly in industries that require long development times, large investments, integration across a wide range of technical and non-technical disciplines, and the creation and protection of intellectual property. Covers business basics, opportunity viability, creating start-ups, entrepreneurial leadership, and entrepreneurship as a career. Teaching methods include lectures, case studies, guest speakers, and individual and team projects.
Same as: CHEM 296, CHEMENG 196, CHEMENG 296

CHEM 200. Research and Special Advanced Work. 1-15 Unit.
Qualified graduate students undertake research or advanced lab work not covered by listed courses under the direction of a member of the teaching staff. For research and special work, students register for 200.

CHEM 221. Advanced Organic Chemistry. 3 Units.
Physical organic chemistry: molecular structures, bonding, and non-covalent interactions; thermodynamic and kinetic understanding of reactivity and reaction mechanism. Prerequisites: 137, 175.

CHEM 223. Advanced Organic Chemistry. 3 Units.
Continuation of 221. Modern synthetic organic chemistry with an emphasis on structure, reactivity, and stereocontrol. Prerequisite: 221 or consent of instructor.

CHEM 225. Advanced Organic Chemistry. 3 Units.
Continuation of 223. Organic reaction science with an emphasis on mechanistic organic and organometallic chemistry, new synthetic methods, selectivity analysis, strategies for the design and synthesis of complex molecules, concepts for innovative problems solving and how to put these skills together in the generation of impactful ideas and proposals directed at solving problems in science. Prerequisite: 223 or consent of instructor.

CHEM 225T. Advanced Organic Chemistry. 3 Units.
Organic reactions, new synthetic methods with special attention to catalysis and atom economy, selectivity analysis, and exercises in the syntheses of complex molecules.

CHEM 227. Therapeutic Science at the Chemistry - Biology Interface. 3 Units.
Explores the design and enablement of new medicines that were born from a convergence of concepts and techniques from chemistry and biology. Topics include fundamental methods for biomolecule synthesis and engineering and application to hybrid chemical/biologic drugs, as well as modern approaches for target discovery and validation. Prerequisite: One year of undergraduate organic chemistry, as well as familiarity with concepts in biochemistry and molecular biology.

CHEM 229. Organic Chemistry Seminar. 1 Unit.
Required of graduate students majoring in organic chemistry. Students giving seminars register for 231.

CHEM 231. Organic Chemistry Seminar Presentation. 1 Unit.
Required of graduate students majoring in organic chemistry for the year in which they present their organic seminar. Second-year students must enroll all quarters.

CHEM 233A. Creativity in Organic Chemistry. 1 Unit.
Required of second- and third-year Ph.D. candidates in organic chemistry. The art of formulating, writing, and orally defending a research progress report (A) and two research proposals (B, C). Second-year students register for A and B; third-year students register for C. A: Aut, B: Spr, C: Spr.

CHEM 233B. Creativity in Organic Chemistry. 1 Unit.
Required of second- and third-year Ph.D. candidates in organic chemistry. The art of formulating, writing, and orally defending a research progress report (A) and two research proposals (B, C). Second-year students register for A and B; third-year students register for C. A: Aut, B: Spr, C: Spr.

CHEM 233C. Creativity in Organic Chemistry. 1 Unit.
Required of second- and third-year Ph.D. candidates in organic chemistry. The art of formulating, writing, and orally defending a research progress report (A) and two research proposals (B, C). Second-year students register for A and B; third-year students register for C. A: Aut, B: Spr, C: Spr.

CHEM 235. Applications of NMR Spectroscopy. 3 Units.
The uses of NMR spectroscopy in chemical and biochemical sciences, emphasizing data acquisition for liquid samples and including selection, setup, and processing of standard and advanced experiments.

CHEM 250. Single-Crystal X-ray Diffraction. 3 Units.
Practical X-ray crystallography for small molecule compounds, which will emphasize crystal growth, measurement strategies, structure solution and refinement, and report generation. Example structures will include absolute configuration of organic compounds (with the heaviest atom being oxygen), metal containing complexes, disordered small molecules and twinning. Students will learn how to get from a new compound to a single crystal, and then to a cif-file ready for publication submission. They will gain knowledge of the underlying theory and concepts for each step of structure determination.
Same as: CHEM 150

CHEM 251. Advanced Inorganic Chemistry. 3 Units.
Primarily intended for first-year graduate students, as a review of some of the basic concepts in inorganic chemistry. Specific topics covered will include: symmetry, group theory, electronic structure of molecules and solids, and reactivity of coordination complexes. Prerequisite: Advanced undergraduate-level inorganic chemistry.

CHEM 253. Advanced Inorganic Chemistry. 3 Units.
Electronic structure and physical properties of transition metal complexes. Ligand field and molecular orbital theories, magnetism and magnetic susceptibility, electron paramagnetic resonance including hyperfine interactions and zero field splitting and electronic absorption spectroscopy including vibrational interactions. Prerequisite: 153 or the equivalent.

CHEM 255. Advanced Inorganic Chemistry. 3 Units.
Chemical reactions of organotransition metal complexes and their role in homogeneous catalysis. Analogous patterns among reactions of transition metal complexes in lower oxidation states. Physical methods of structure determination. Prerequisite: one year of physical chemistry.
Same as: CHEM 155

CHEM 258A. Research Progress in Inorganic Chemistry. 1 Unit.
Required of all second-, third-, and fourth-year Ph.D. candidates in inorganic chemistry. Students present their research progress in written and oral forms (A); present a seminar in the literature of the field of research (B); and formulate, write, and orally defend a research proposal (C). Second-year students register for A; third-year students register for B; fourth-year students register for C.

CHEM 258B. Research Progress in Inorganic Chemistry. 1 Unit.
Required of all second-, third-, and fourth-year Ph.D. candidates in inorganic chemistry. Students present their research progress in written and oral forms (A); present a seminar in the literature of the field of research (B); and formulate, write, and orally defend a research proposal (C). Second-year students register for A; third-year students register for B; fourth-year students register for C.

CHEM 258C. Research Progress in Inorganic Chemistry. 1 Unit.
Required of all second-, third-, and fourth-year Ph.D. candidates in inorganic chemistry. Students present their research progress in written and oral forms (A); present a seminar in the literature of the field of research (B); and formulate, write, and orally defend a research proposal (C). Second-year students register for A; third-year students register for B; fourth-year students register for C.

CHEM 259. Inorganic Chemistry Seminar. 1 Unit.
Required of graduate students majoring in inorganic chemistry.

CHEM 271. Advanced Physical Chemistry. 3 Units.
The principles of quantum mechanics. General formulation, mathematical methods, and applications of quantum theory. Exactly solvable problems and approximate methods including time independent perturbation theory and the variational method. Time dependent methods including exactly solvable problems, time dependent perturbation theory, and density matrix formalism. Different representations of quantum theory including the Dirac, Schrödinger, matrix, and density matrix methods. Absorption and emission of radiation Angular momentum. Atomic energy calculations and simple molecular structure methods. Prerequisite: 175 or equivalent course.

CHEM 273. Advanced Physical Chemistry. 3 Units.
Statistical mechanics is a fundamental bridge that links microscopic world of quantum mechanics to macroscopic thermodynamic properties. We discuss the principles and methods of statistical mechanics from the ensemble point of view. Applications include statistical thermodynamics, quantum systems, heat capacities of gases and solids, chemical equilibrium, pair correlation functions in liquids, and phase transitions. Prerequisite: 271.

CHEM 274. Electrochemical Measurements Lab. 3 Units.
Introduction to modern electrochemical measurement in a hands-on, laboratory setting. Students assemble and use electrochemical cells including indicator, reference, working and counter electrodes, with macro, micro and ultramicro geometries, salt bridges, ion-selective membranes, electrometers, potentiostats, galvanostats, and stationary and rotated disk electrodes. The later portion of the course will involve a student-generated project to experimentally characterize some electrochemical system. Prerequisites: 134, 171, MATH 51, PHYSICS 44 or equivalent.
Same as: CHEM 174

CHEM 275. Advanced Physical Chemistry. 3 Units.
Covering angular momentum theory with a special emphasis on scattering dynamics and the interaction of radiation and matter. Recommended: Chem 273 and either Chem 271 or Physics 230.

CHEM 277. Materials Chemistry and Physics. 3 Units.
Topics: structures and symmetries and of solid state crystalline materials, chemical applications of group theory in solids, quantum mechanical electronic band structures of solids, phonons in solids, synthesis methods and characterization techniques for solids including nanostructured materials, selected applications of solid state materials and nanostructures. May be repeated for credit.

CHEM 278A. Research Progress in Physical Chemistry. 1 Unit.
Required of all second- and third-year Ph.D. candidates in physical and biophysical chemistry and chemical physics. Second-year students present their research progress and plans in brief written and oral summaries (A); third-year students prepare a written progress report (B). A: Win, B: Win.

CHEM 278B. Research Progress in Physical Chemistry. 1 Unit.
Required of all second- and third-year Ph.D. candidates in physical and biophysical chemistry and chemical physics. Second-year students present their research progress and plans in brief written and oral summaries (A); third-year students prepare a written progress report (B). A: Win, B: Win.

CHEM 279. Physical Chemistry Seminar. 1 Unit.
Required of graduate students majoring in physical chemistry. May be repeated for credit.

CHEM 280. Single-Molecule Spectroscopy and Imaging. 3 Units.
Theoretical and experimental techniques necessary to achieve single-molecule sensitivity in laser spectroscopy: interaction of radiation with spectroscopic transitions; systematics of signals, noise, and signal-to-noise; modulation and imaging methods; and analysis of fluctuations; applications to modern problems in biophysics, cellular imaging, physical chemistry, single-photon sources, and materials science. Prerequisites: 271, previous or concurrent enrollment in 273.

CHEM 287B. Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery. 1 Unit.
This course provides an overview of the biosynthesis of the five major classes of small molecule natural products, including polyketides, nonribosomal peptides, terpene/isoprenoid scaffolds, alkaloids, and phenylpropanoids. Focus will be on the chemical logic for bond-forming chemical steps in each natural product class and the kinds of enzyme catalysts required to effect complexity-generating molecular scaffolds. This short course runs for the first five weeks of the quarter, from January through the second week of February. Prerequisite: Chem 181 or equivalent.
Same as: CHEM 187B

CHEM 291. Introduction to Nuclear Magnetic Resonance. 3 Units.
Introduction to quantum and classical descriptions of NMR; analysis of pulse sequences and nuclear spin coherences via density matrices and the product operator formalism; NMR spectrometer design; Fourier analysis of time-dependent observable magnetization; NMR relaxation in liquids and solids; NMR strategies for biological problem solving. Prerequisite: Chem 173.

CHEM 296. Creating New Ventures in Engineering and Science-based Industries. 3 Units.
Open to seniors and graduate students interested in the creation of new ventures and entrepreneurship in engineering and science intensive industries such as chemical, energy, materials, bioengineering, environmental, clean-tech, pharmaceuticals, medical, and biotechnology. Exploration of the dynamics, complexity, and challenges that define creating new ventures, particularly in industries that require long development times, large investments, integration across a wide range of technical and non-technical disciplines, and the creation and protection of intellectual property. Covers business basics, opportunity viability, creating start-ups, entrepreneurial leadership, and entrepreneurship as a career. Teaching methods include lectures, case studies, guest speakers, and individual and team projects.
Same as: CHEM 196, CHEMENG 196, CHEMENG 296

CHEM 297. Bio-Inorganic Chemistry. 3 Units.
Overview of metal sites in biology. Metalloproteins as elaborated inorganic complexes, their basic coordination chemistry and bonding, unique features of the protein ligand, and the physical methods used to study active sites. Active site structures are correlated with function. Prerequisites: 153 and 173, or equivalents.
Same as: BIOPHYS 297

CHEM 299. Teaching of Chemistry. 1-3 Unit.
Required of all teaching assistants in Chemistry. Techniques of teaching chemistry by means of lectures and labs.

CHEM 300. Department Colloquium. 1 Unit.
Required of graduate students. May be repeated for credit.

CHEM 301. Research in Chemistry. 2 Units.
Required of graduate students who have passed the qualifying examination. Open to qualified graduate students with the consent of the major professor. Research seminars and directed reading deal with newly developing areas in chemistry and experimental techniques. May be repeated for credit. Search for adviser name on Axess.

CHEM 390. Curricular Practical Training for Chemists. 1 Unit.
For Chemistry majors who need work experience as part of their program of study. Confer with Chem student services office for signup.

CHEM 459. Frontiers in Interdisciplinary Biosciences. 1 Unit.
Students register through their affiliated department; otherwise register for CHEMENG 459. For specialists and non-specialists. Sponsored by the Stanford BioX Program. Three seminars per quarter address scientific and technical themes related to interdisciplinary approaches in bioengineering, medicine, and the chemical, physical, and biological sciences. Leading investigators from Stanford and the world present breakthroughs and endeavors that cut across core disciplines. Pre-seminars introduce basic concepts and background for non-experts. Registered students attend all pre-seminars; others welcome. See http://biox.stanford.edu/courses/459.html. Recommended: basic mathematics, biology, chemistry, and physics.
Same as: BIO 459, BIOC 459, BIOE 459, CHEMENG 459, PSYCH 459

CHEM 802. TGR Dissertation. 0 Units.
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