

Key to Course Listings

Catalog numbers are part of a University-wide numbering system. Generally, courses numbered 100 to 199 are introductory, 200-299 are intermediate, and 300-499 are advanced (upper-level).

Reorganized or renumbered courses are denoted by a parenthetical number in boldface following the course number. When renumbering or reorganization has left the SUBJECT unchanged, only the previous catalog number is given; if the SUBJECT has also changed, the previous SUBJECT name and course number appear. A reorganized or renumbered course cannot be repeated for credit without special permission.

Cross-listed courses are sponsored by more than one department or program and may be elected in any of the participating units. Cross-listings appear in boldface and are denoted by a slash between the participating units.

Course titles appear in boldface after the catalog number.

Prerequisites appear in italics after the course title. Some prerequisites are advisory. They suggest the assumed background or level of academic experience, and students should be guided by these statements. Some prerequisites are mandatory and are enforced at the point of registration. The *Course Guide* and the *LS&A Bulletin* indicate the cases when prerequisites are enforced.

Prerequisites are of three types:

- *Courses*. Unless otherwise stated, the phrase "or equivalent" may be considered an implicit part of the prerequisite for any course. When a student has satisfactorily completed a course(s) at the required level of competency and when that course is believed to be substantially equivalent to one listed as a prerequisite, the student must consult the instructor or department. If equivalency is determined to have been satisfied, election may be approved by issuance of electronic permission.
- *Class standing* (first year, sophomore, junior, senior). A course might be appropriate for "first and second year students only," or for "juniors and seniors."
- *Permission of instructor*. The phrase "or permission of instructor" may be considered an implicit part of the statement of prerequisites for any course. When permission is a stated requirement, or when a student does not have the stated prerequisite for a course but can give evidence of sufficient background, the student should obtain approval from the instructor or department concerned and an electronic permission issued.

The Credit Symbol, an Arabic numeral in parentheses, denotes the credits earned for the course. Credit is granted in semester hours. Except for small seminars where the reading and/or writing requirements are intensive, one credit represents no less than one hour of class meeting time each week of the term, and usually represents two hours of work outside of class for each class hour.

Area distribution designation is approved by the LS&A Curriculum Committee on a yearly basis. A course may be approved with the designation natural science (*NS*), social science (*SS*), humanities (*HU*), mathematical and symbolic analysis (*MSA*), creative expression (*CE*), interdisciplinary (*ID*), or excluded from distribution (*Excl*).

Courses meeting certain college requirements are so listed. Language other than English (*LR*) courses may be used toward meeting the Language Requirement. The First-Year Writing Requirement may be met by courses designated (Introductory Composition). Courses approved with the designation "Language Requirement" or "Introductory Composition" may not be used as part of an area distribution plan. If an introductory language course is designated "Excluded" (*Excl*), it may not be used to satisfy the LS&A language requirement. (*BS*) means that the course may be used toward the 60 approved credits required for the B.S. degree. Courses meeting or partially meeting the Quantitative Reasoning

requirement are designated (*QR/1*) or (*QR/2*). Courses with standard approval for meeting the Race & Ethnicity (*R&E*) requirement are so indicated. Other courses may meet the R&E or QR requirements on a term-by-term basis and are listed on the LS&A website (<http://www.lsa.umich.edu/>).

Experiential, Independent Study, and Tutorial courses are so designated. (See Experiential and Directed Reading/Independent Study Courses in *Chapter IV*.)

Repetition of a course that varies in content from term to term is permitted only under certain conditions. When a department or program has a policy about the repetition of a course for credit, that policy is included in the course listing. The general statement "May be repeated for credit with permission" usually means "With permission of a concentration advisor." In all other instances, a student must get permission from both the department or program and the Academic Standards Board to repeat a course for credit. Generally, a course may be elected for credit once only.

Excluded combinations of course elections are designated in the listing of affected courses.

Special Grading pattern for a course is indicated in the course listing. Some LS&A courses are offered *mandatory credit/no credit*. (See Non-Graded Courses in *Chapter IV*.)

The Term Symbol, a Roman numeral, denotes the term(s) some courses are offered. The University year is divided into three terms: Fall (I), Winter (II), and Spring-Summer (III). The Spring-Summer Term is further divided: Spring-Half (IIIa) and Summer-Half (IIIb).

Courses That Count Toward Graduate Programs

Courses Approved for Regular Rackham Graduate Credit. All courses taken in fulfillment of Rackham degree requirements must be approved for Rackham graduate credit. Be certain that any courses you plan to take--especially those numbered in the 400s--are approved for Rackham credit before you enroll in them. The Graduate School policy on courses is as follows: Courses at the 400 level and above are acceptable for graduate credit if they have been approved by the Graduate School.

If you are uncertain whether or not a course is approved for Rackham credit, check with the department offering the course or with the Rackham Course Approval Officer (764-8221).

If you elect a course that has not been approved for Rackham graduate credit, the course will appear on your university transcript with the notation "Not for Graduate Credit." The course grade will appear on the transcript, but it will not be averaged into your cumulative grade point average or your credit toward program (CTP) total.

Courses Not Approved for Graduate Credit. Courses at the 300 level and below are not acceptable for graduate credit, without exception. Undergraduate level foreign language courses may occasionally be used in fulfillment of some departmental foreign language requirements.

Under unusual circumstances you may petition to receive graduate credit for a course not normally approved for graduate credit (*e.g.*, such as an undergraduate course where you will be expected to perform more advanced work than the undergraduates). Because there is no guarantee of approval, you should submit your petition to the Graduate School's Office of Academic Records and Dissertations (OARD) before taking the course. Your petition must be endorsed by the course instructor and by the graduate chair of your department or program, and it must include an explanation for requesting the exception. You will be expected to perform graduate level work in the course, and the petition must show how this will be accomplished. You may obtain a petition form from your department, from OARD, or online.

Chemistry

Chemistry

Chemistry CHEM 334

LSA
Chemistry
Chemistry

<http://www.umich.edu/~michchem/>

Undergraduate Courses

105 **CHEM 105 / AOSS 105 / ENSCEN 105.**

Our Changing Atmosphere.

(3,3) : May not be repeated for credit.

(NS). (BS).

The greenhouse effect, stratospheric ozone depletion, the polar ozone holes, and urban smog are discussed from a scientific perspective using the latest information. Human-induced change in atmospheric composition is a primary vehicle for Global Change. These changes can affect atmospheric motions, including jet streams, fronts and violent storms. The atmosphere interacts with all other components of the environment: the oceans, the geosphere (solid earth), the biosphere (living plants and animals), and the cryosphere (glaciers and ice-caps). These interactions and "feedback mechanisms" are a central theme of this course, which is intended for non-science concentrators.

108 **CHEM 108 / GEOSCI 130 / PHYSICS 119.**

The Physical World.

(4,4) : May not be repeated for credit.

(NS). (BS). (QR/2).

High-school algebra.

A lecture course which introduces physics, chemistry and algebraic concepts of Earth and Planetary Science on a quantitative basis.

109 **CHEM 109 / PHYSICS 109.**

Natural Science: Bridging the Gaps.

(3) : May not be repeated for credit.

(NS). (BS).

An interdisciplinary, team-taught introduction to the scientific method, involving subject matter from physics, chemistry, astronomy, geology, biology, and ethics. Demonstrations provide nearly hands-on experience with relevant phenomena.

120 **CHEM 120.**

First-Year Seminar in Chemistry.

(3) : May not be repeated for credit.

(NS). (BS).

Only first-year students, including those with sophomore standing, may pre-register for First-Year Seminars. All others need permission of instructor.

These seminars, which are restricted to first-year students, are small group classes (approximately 15-25 students) taught by regular and emeritus faculty.

125 **CHEM 125.**

General Chemistry Laboratory I.

(1,1) : May not be repeated for credit.

(NS). (BS).

To be elected by students who are eligible for (or enrolled in) CHEM 130, and concurrent enrollment in CHEM 126. Credit is not granted without concurrent enrollment in and completion of CHEM 126. Laboratory fee (\$80) required. I, II, IIIa.

One four-hour laboratory and one discussion. Basic laboratory techniques and applications to simple chemical systems.

- 126 **CHEM 126.**
General Chemistry Laboratory II.
 (1,1) : May not be repeated for credit.
 (NS). (BS).
To be elected by students who are eligible for (or enrolled in) CHEM 130, and concurrent enrollment in CHEM 125. Credit is not granted without concurrent enrollment in and completion of CHEM 125. I, II, IIIa.
 One four-hour laboratory and one discussion. Basic laboratory techniques and applications to simple chemical systems.
- 130 **CHEM 130.**
General Chemistry: Macroscopic Investigations and Reaction Principles.
 (3,3) : May not be repeated for credit.
 (NS). (BS). (QR/2).
Three years of high school math or MATH 105; one year of high school chemistry recommended. Placement by testing, or permission of Chemistry department. Intended for students without AP credit in chemistry. I, II, IIIa.
 Introduction to the major concepts of chemistry, including the microscopic picture of atomic and molecular structure, periodic trends in chemical reactivity, the energetics of chemical reactions and the nature of chemical equilibria. Students are introduced both to the fundamental principles of modern chemistry and to the underlying theories that account for observed macroscopic behavior. Students learn to think critically, examine experimental data, and form generalizations about data as chemists do. Three lectures and one discussion. A special section of CHEM 130 is reserved for students who would benefit from a smaller lecture section and more frequent contact with both senior faculty and teaching assistants. Four lectures and one discussion. Approval of a counselor is required for registration in this section.
- 210 **CHEM 210.**
Structure and Reactivity I.
 (4,4) : May not be repeated for credit.
 (NS). (BS).
High school chemistry. Placement by examination during Orientation. To be taken with CHEM 211. I, II, IIIa.
 The content of organic chemistry is used to introduce students to major concepts of chemistry including ideas about bonding, energy, equilibrium, kinetics, stereochemistry, and the relationship between the structure and the reactivity of a chemical species. Three lectures and one discussion.
- 211 **CHEM 211.**
Investigations in Chemistry.
 (1,1) : May not be repeated for credit.
 (NS). (BS).
To be taken with CHEM 210. Laboratory fee (\$87.50) required. I, II, IIIa.
 An introduction to laboratory techniques in chemistry using inorganic and organic compounds, with emphasis on thin layer chromatography, stoichiometry, acid-base chemistry, and microscale organic reactions. Four-hour laboratory.
- 215 **CHEM 215.**
Structure and Reactivity II.
 (3,3) : May not be repeated for credit.
 (NS). (BS).
CHEM 210/211. To be taken with CHEM 216. I, II, IIIa.
 Continuation of CHEM 210. Students get further practice in applying the major concepts of chemistry to predicting the physical and chemical properties of organic compounds, including macromolecules, both synthetic and biological. Three lectures and informal help/tutoring sessions for students who need them.
- 216 **CHEM 216.**
Synthesis and Characterization of Organic Compounds.
 (2,2) : May not be repeated for credit.
 (NS). (BS).
CHEM 210/211. Must be taken with CHEM 215. Laboratory fee (\$82.50) required. I, II, IIIa.
 Students participate in a number of projects in which they have to decide how to synthesize an organic compound on a microscale, then how to purify and how to characterize the compound using chromatographic and spectroscopic techniques. One lecture and a four-hour laboratory.

- 218 **CHEM 218.**
Independent Study in Biochemistry.
(1,1) : May be repeated for credit for a maximum of 4 credits.
(Excl). (INDEPENDENT).
Consent of instructor required (Prerequisites enforced at registration). For students with less than junior standing. I, II, III, IIIa, IIIb.
Undergraduate biochemistry research. This course provides an introduction to independent biochemistry research under the direction of a faculty member whose project is in the biochemistry area. CHEM 218 is for biochemistry concentrators, and research projects must be approved by a biochemistry advisor. Exact details such as nature of research, level of involvement of the student, and criteria for grading are individually determined in consultation with the faculty member. At the end of each term, three copies of a written report are submitted — one for the Advising Office, one for the student, and one for the faculty supervisor.
- 219 **CHEM 219.**
Independent Study in Chemistry.
(1,1) : May be repeated for credit for a maximum of 4 credits.
(Excl). (INDEPENDENT).
Consent of instructor required (Prerequisites enforced at registration). For students with less than junior standing. I, II, III, IIIa, IIIb.
Research in an area of interest to, and supervised by, a departmental faculty member. Exact details such as nature of the research, level of involvement of the student, credits awarded and criteria for grading are individually determined in consultation with the faculty member. At the end of each term, three copies of a written report are submitted — one for the Advising Office, one for the student, and one for the faculty supervisor. For a student to receive Chemistry credit for CHEM 219, the student must work on a research project supervised by a faculty member of the Chemistry Department, either alone, or in collaboration with a colleague within the department, from another department, or from another school. This collaboration must be an ongoing one, and the student must receive direct supervision by all of the faculty who have agreed to sponsor the project.
- 230 **CHEM 230.**
Physical Chemical Principles and Applications.
(3,3) : May not be repeated for credit.
(NS). (BS).
CHEM 215/216. Students who plan to continue beyond a fourth term in chemistry would typically enroll in CHEM 260/241/242 instead of CHEM 230; credit will not be given for both of these courses. No credit granted to those who have completed or are enrolled in CHEM 260. I, II, IIIa.
An introduction to the physical principles underlying some of the major topics of inorganic and analytical chemistry. The liquid and solid states of matter, phase transitions, solutions, electrochemistry, coordination complexes, spectroscopy, and the principles of thermodynamics that explain observed chemical reactions are studied from the viewpoint of the experimental scientist, with an emphasis on the application of chemical principles to a wide range of professions. Three lectures and one discussion.
- 241 **CHEM 241.**
Introduction to Chemical Analysis.
(2,2) : May not be repeated for credit.
(NS). (BS).
Prior or concurrent enrollment in CHEM 230 or 260, and concurrent enrollment in CHEM 242.
Introduction to the chemical basis of both classical wet analysis methods and modern instrumental analysis methods. Course emphasizes statistical methods and the analytical applications of equilibria, electrochemistry, spectroscopy, and radioactivity.
- 242 **CHEM 242.**
Introduction to Chemical Analysis Laboratory.
(2,2) : May not be repeated for credit.
(NS). (BS).
Prior or concurrent enrollment in CHEM 230 or 260, and concurrent enrollment in CHEM 241. Laboratory fee (\$75) required.
Introductory laboratory in wet chemical and modern instrumental analysis. Experiments emphasize equilibria, separations, electrochemistry, and spectroscopy.

- 260 **CHEM 260.**
Chemical Principles.
 (3,3) : May not be repeated for credit.
 (NS). (BS).
CHEM 215/216, MATH 115, and prior or concurrent enrollment in PHYSICS 140 (or 160). I, II, IIIa.
 Introduction to the quantal nature of matter, basic chemical thermodynamics, and chemical kinetics. Description of the fundamental physical principles that underlie spectroscopic and electrochemical analysis
- 261 **CHEM 261.**
Introduction to Quantum Chemistry.
 (1,1) : May not be repeated for credit.
 (Excl). (BS).
CHEM 215/216, MATH 115, and prior or concurrent enrollment in PHYSICS 140 (or 160). CHEM 261 is intended primarily for Chemical Engineering students. No credit granted for students that have completed or are enrolled in CHEM 260. I, II, IIIa.
 Introduction to the quantal nature of matter and the basic principles of quantum chemistry. Course meets only for the first third of the term.
- 302 **CHEM 302.**
Inorganic Chemistry: Principles of Structure, Reactivity, and Function.
 (3,3) : May not be repeated for credit.
 (NS). (BS).
CHEM 260 (or CHEM 261 and CHE 330).
 This course provides an introduction to the structure and properties of those elements other than carbon. Topics include the electronic structure of atoms, molecules and extended solids, bonding, periodicity, main group and transition element chemistry, catalysis and bioinorganic chemistry. Three lectures and one discussion.
- 312 **CHEM 312.**
Synthesis and Characterization.
 (2) : May not be repeated for credit.
 (Excl). (BS).
CHEM 215/216. Prior or concurrent enrollment in CHEM 302. Laboratory fee (\$95) required.
 Introduces students to advanced techniques used in the synthesis, purification, and characterization of inorganic and organic compounds. Two four-hour laboratory periods.
- 398 **CHEM 398.**
Undergraduate Research in Biochemistry.
 (1-4,1-4) : May be repeated for credit for a maximum of 4 credits.
 (Excl). (BS). (INDEPENDENT).
Consent of instructor required (Prerequisites enforced at registration). Junior standing, and permission of a biochemistry concentration advisor and the professor who will supervise the research. I, II, III, IIIa, IIIb.
 Elected starting in the junior or senior year, this course is an optional requirement for Biochemistry students and a requirement for Honors Biochemistry students, who must elect it for a total of four credits spread out over two or more terms. At the end of each term, a written report evaluating the progress of the project is submitted — one copy to the faculty member, one copy for the Chemistry Advising Office (1500 Chemistry), and one copy for the student. Interim reports need not be lengthy, but the final report for CHEM 398 is expected to be more detailed and longer than the reports in CHEM 218.

- 399 **CHEM 399.**
Undergraduate Research.
 (1-4,1-4) : May be repeated for credit for a maximum of 4 credits.
 (Excl). (BS). (INDEPENDENT).
Consent of instructor required (Prerequisites enforced at registration). Junior standing, and permission of a chemistry concentration advisor and the professor who will supervise the research. I, II, III, IIIa, IIIb.
 Elected starting in the junior or senior year, this course is a requirement for B.S. Chemistry students, who must elect it for a total of four credits spread out over two or more terms. The student must work on a research project supervised by a faculty member of the Chemistry Department, either alone, or in collaboration with a colleague within the department, from another department, or from another school. This collaboration must be an ongoing one, and the student must receive direct supervision by all of the faculty who have agreed to sponsor the project. Final evaluation of the research effort and the report, as well as the grade for the course, rests with the faculty member from the Chemistry Department. The student is expected to put in at least three hours a week of actual work for each credit hour elected. At the end of each term, a written report evaluating the progress of the project is submitted; one copy to the faculty member, one copy for the chemistry academic advisor and one copy for the student. Interim reports need not be lengthy, but the final report for CHEM 399 is expected to be more detailed and longer than the reports in CHEM 219.
- 402 **CHEM 402.**
Intermediate Inorganic Chemistry.
 (3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 302, and 461/462.
 A second course in inorganic chemistry at the undergraduate level.
- 436 **CHEM 436.**
Polymer Synthesis and Characterization.
 (3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 260.
 A lecture and laboratory course that introduces students to the special techniques used to study macromolecules.
- 453 **CHEM 453.**
Biophysical Chemistry I: Thermodynamics and Kinetics.
 (3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 260 (or CHEM 261 and CHE 330), CHEM 451, PHYSICS 240, and MATH 215. No credit granted to those who have completed or are enrolled in CHEM 463.
 First in a two-term biophysical chemistry sequence for biochemistry students. Emphasis on topics and applications relevant to biochemistry and modern biophysical chemistry, building on CHEM 260. Rigorous mathematical theory of classical thermodynamics is developed, including application to entropy, heat engines, solution properties, and phase and chemical equilibrium. Modern statistical thermodynamics, modern theories of fundamental reaction rates and enzyme kinetics and molecular transport theories are described and developed.
- 454 **CHEM 454.**
Biophysical Chemistry II: Macromolecular Structure and Dynamics.
 (3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 453 or 463, and CHEM 451/452 or equivalent.
 This course builds on the CHEM 451-453 sequence and aims at providing an understanding of the structure and dynamics of biological macromolecules. After introducing the necessary nomenclature and reviewing thermodynamic principles, modern techniques to characterize the structure and dynamics of biopolymers is the focus. Sedimentation, electrophoresis, mass spectrometry, X-ray diffraction, scattering, and spectroscopic techniques such as absorption, circular dichroism, fluorescence, and NMR are covered. Both physical principles and practical applications in the Life Sciences are highlighted

- 480 **CHEM 480.**
Physical and Instrumental Chemistry.
 (3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 447 and 461/462; and concurrent enrollment in CHEM 463. Laboratory fee (\$75) required.
 A laboratory exploration of methods for the measurement of physical and spectroscopic properties of substances and the application of these methods in instrumental analysis.
- 485 **CHEM 485.**
Projects Laboratory.
 (2,2) : May not be repeated for credit.
 (Excl). (BS).
CHEM 480. Laboratory fee (\$75) required.
 A project-oriented laboratory in which students work on one or two projects in depth during the term.
- 495 **CHEM 495.**
Professional Development in the Chemical Sciences.
 (2,2) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461. Meets the Upper-Level Writing Requirement. II.
 A "studio" format course for students in the chemical sciences wishing to enhance their writing, speaking, and analysis skills. The course includes critical analysis and proficiency of written and oral communication and an introduction to the multi-faceted features of professional life.
- 498 **CHEM 498.**
Undergraduate Honors Thesis in Biochemistry.
 (1,1) : May not be repeated for credit.
 (Excl). (BS). (INDEPENDENT).
Consent of instructor required (Prerequisites enforced at registration). CHEM 398. To be elected in the term in which an Honors student presents a thesis on undergraduate research. I, II, III, IIIa, IIIb.
 A course for students who present an undergraduate thesis as a result of research. The Honors program requires satisfactory completion of an Honors thesis (CHEM 498) which describes and analyzes independent experimental work, based on the research done in CHEM 398.
- 499 **CHEM 499.**
Undergraduate Thesis.
 (1,1) : May not be repeated for credit.
 (Excl). (BS). (INDEPENDENT).
Consent of instructor required (Prerequisites enforced at registration). CHEM 399. To be elected in the term in which an Honors student presents a thesis on undergraduate research. I, II, III, IIIa, IIIb.
 A course for students who present an undergraduate thesis as a result of research. The Honors program requires satisfactory completion of an Honors thesis (CHEM 499) which describes and analyzes independent experimental work, based on the research done in CHEM 399.

Undergraduate and Graduate Courses

- 417 **CHEM 417 / PHYSICS 417.**
Dynamical Processes in Biophysics.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
MATH 216 or 256 or 286 or 316, and PHYSICS 340 or CHEM 463 (Prerequisites enforced at registration).
 The physical basis of diffusive processes in biology and biochemistry, and optical spectroscopic means for measuring its rates. Topics include: membrane electrical potentials, nerve impulses, synaptic transmission, the physics of chemoreception by cells, motion and reaction kinetics of membrane components, optical microscopy, visible and UV light absorption, fluorescence and phosphorescence, quasielastic light scattering, mathematics of random fluctuations, and chaotic processes in biology.

- 420 **CHEM 420.**
Intermediate Organic Chemistry.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 215/216.
 An exploration of selected topics in organic chemistry that builds on the basic concepts of structure and reactivity considered in the first courses in organic chemistry.
- 447 **CHEM 447.**
Physical Methods of Analysis.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 260 and 241/242.
 Theory and applicability of the principal physical and physiochemical approaches used in instrumental chemical analysis, including electrical, optical, and separation methods.
- 451 **CHEM 451 / BIOLCHEM 451.**
Introduction to Biochemistry I.
 (4,4;4,4) : May not be repeated for credit.
 (Excl). (BS).
CHEM 260; BIOLOGY 162; and MATH 115. No credit granted to those who have completed or are enrolled in BIOLOGY 310 or 311, or BIOLCHEM 415. I.
 CHEM 451 is the first of a two-term introduction to modern biochemistry. The course focuses on the chemical basis underlying a host of cellular events involving macromolecules such as proteins, nucleic acids, lipids, and glycoconjugates, in addition to small molecules such as vitamins, amino acids, and carbohydrates.
- 452 **CHEM 452 / BIOLCHEM 452.**
Introduction to Biochemistry II.
 (4,4;4,4) : May not be repeated for credit.
 (Excl). (BS).
CHEM 451. II.
 CHEM 452 is the second of a two-term introduction to modern biochemistry. The course focuses on the chemical basis underlying a host of cellular events involving macromolecules such as proteins, nucleic acids, lipids, and glycoconjugates, in addition to small molecules such as vitamins, amino acids and carbohydrates.
- 461 **CHEM 461.**
Physical Chemistry I.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 260, PHYSICS 240 (or 260), and MATH 215. I, II, IIIa.
 This is the second of a three term sequence in physical chemistry. This course builds on material introduced in CHEM 260. The Schrödinger Equation is solved in 1-, 2-, and 3-dimensions for important chemical problems. Group theory and quantum chemistry are used to understand chemical bonding and advanced spectroscopy. Should be elected in the same term as CHEM 462.
- 462 **CHEM 462.**
Computational Chemistry Laboratory.
 (1,1;1,1) : May not be repeated for credit.
 (Excl). (BS).
MATH 215, and prior or concurrent enrollment in CHEM 461. Laboratory fee (\$75) required.
 Introduction to the use of modern computational tools (Mathematica and Maple) for problem solving and graphical presentation in chemistry. Use of molecular modeling software (HyperChem and CAChe) for calculation of molecular structure. Should be elected in the same term as CHEM 461.

- 463 **CHEM 463.**
Physical Chemistry II.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461/462.
 This is the third of a three term sequence in physical chemistry and focuses on thermodynamics and kinetics. Both classical thermodynamics (entropy, phase and chemical equilibria) and statistical thermodynamics are discussed. Fundamental theories underlying chemical kinetics are discussed and solid state structures are introduced.
- 467 **CHEM 467 / AOSS 467 / ENVIRON 467 / GEOSCI 465 / ENSCEN 467.**
Biogeochemical Cycles.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
MATH 116, CHEM 210, and PHYSICS 240 (or 260).
 The biogeochemical cycles of water, carbon, nitrogen, and sulfur; the atmosphere and oceans as reservoirs and reaction media; the fate of natural and human-made sources of carbon, nitrogen, and sulfur compounds; the interactions among major biogeochemical cycles and resultant global change: greenhouse gases, acid rain, and ozone depletion.
- 507 **CHEM 507.**
Inorganic Chemistry.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461. I.
 Structural concepts relating to inorganic and organometallic compounds, inorganic stereochemistry, crystal chemistry, coordination theory, ligand field theory, catalysis and generalizations about the periodic table.
- 511 **CHEM 511 / MATSCIE 510.**
Materials Chemistry.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461, BIOLCHEM 415, CHEM 430; and permission of course director.
 This course presents concepts in materials chemistry. The main topics covered include structure and characterization, macroscopic properties and synthesis and processing.
- 520 **CHEM 520 / BIOPHYS 520.**
Biophysical Chemistry I.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 463, BIOLCHEM 415, or CHEM 420; permission of course director.
 This course is the first of a two term biophysical chemistry series CHEM 520/521. The course offers an overview of protein, nucleic acid, lipid and carbohydrate structures.
- 521 **CHEM 521 / BIOPHYS 521.**
Biophysical Chemistry II.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461, BIOLCHEM 415, and CHEM 430; and permission of course director.
 This course gives background applications of several physical techniques used in biophysical research. General principles of spectroscopy are explained. Macromolecular structure determination by X-ray diffraction and two-dimensional NMR are treated in detail. IR, Raman, CD, EXAFS, EPR, and ESEEM are introduced.
- 525 **CHEM 525 / BIOLOGY 525.**
Chemical Biology I.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 451, 452, 461, and 463.
 Exploration of the application of chemical principles to biology. Together with CHEM 526, this constitutes a comprehensive one year introduction to the field of chemical biology.

- 526 **CHEM 526 / BIOLOGY 526.**
Chemical Biology II.
(3,3;3,3) : May not be repeated for credit.
(Excl). (BS).
CHEM 525. Prior or concurrent enrollment in CHEM 402 or equivalent. II.
Exploration of the application of chemical principles to biology. Together with CHEM 525, this constitutes a comprehensive one year introduction to the field of chemical biology.
- 536 **CHEM 536 / MACROMOL 536.**
Laboratory in Macromolecular Chemistry.
(2;2) : May not be repeated for credit.
(Excl). (BS).
CHEM 535 or PHYSICS 418. Laboratory fee (\$50) required.
Experimental methods for the study of macromolecular materials in solution and in the bulk state.
- 538 **CHEM 538 / MACROMOL 538.**
Organic Chemistry of Macromolecules.
(3;3) : May not be repeated for credit.
(Excl). (BS).
CHEM 215/216, and 230 or 260. I.
The preparation, reactions, and properties of high molecular weight polymeric materials of both natural and synthetic origin.
- 540 **CHEM 540.**
Organic Principles.
(3,3;3,3) : May not be repeated for credit.
(Excl). (BS).
CHEM 312 and 461.
Fundamental principles of chemical binding, reaction mechanisms, and stereochemistry of organic compounds.
- 541 **CHEM 541.**
Advanced Organic Chemistry.
(3,3;3,3) : May not be repeated for credit.
(Excl). (BS).
CHEM 540. II.
Synthetic organic chemistry. The scope and limitations of the more important synthetic reactions are discussed within the framework of multistep organic synthesis.
- 542 **CHEM 542.**
Applications of Physical Methods to Organic Chemistry.
(3,3;3,3) : May not be repeated for credit.
(Excl). (BS).
CHEM 260, 241/242, and 312.
Applications of infrared, ultraviolet and nuclear magnetic resonance spectroscopy, optical rotary dispersion, mass spectrometry and other physical methods to the study of the structure and reactions of organic compounds.
- 545 **CHEM 545.**
Analytical Chemistry.
(3,3;3,3) : May not be repeated for credit.
(Excl). (BS).
CHEM 447, 461.
The course emphasizes the fundamental scientific and technological principles underlying modern analytical chemistry, with an emphasis on bioanalytical chemistry. Major topics of the current offering include chemometrics, biopolymer solution chemistry and physics, diffusive and convective transport processes in separation systems and principles of microfabricated instrumentation and sensors. General principles will be illustrated with applications from current analytical chemistry practice.

- 565 **CHEM 565.**
Nuclear Chemistry.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
Permission of instructor. Intended for graduate students and seniors.
 A survey of the properties of the nucleus, of the techniques for studying these properties, and of applications to allied fields which depend on nuclear properties and decay modes. Topics include radioactive decay processes, nuclear model, nuclear reactions, interactions or radiations with matter, applications of nuclear techniques to non-nuclear problems.
- 570 **CHEM 570.**
Molecular Physical Chemistry.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461 and 463.
 Basic concepts in modern chemical physics including molecular symmetry, group theory, operators, and introduction to the electronic structure of atoms and molecules.
- 575 **CHEM 575.**
Chemical Thermodynamics.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461.
 A discussion of chemical phase equilibria, the treatment of solutions, and chemical reactions by classical thermodynamics. The applications of electrochemical cells in studying chemical reactivities, utilization of molecular and atomic spectra in statistico-mechanical calculations as well as a brief treatment of non-equilibrium thermodynamics are usually included.
- 580 **CHEM 580.**
Molecular Spectra and Structure.
 (3,3;3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 570. II.
 Review of atomic spectra; rotational, vibration-rotation and electronic spectra of diatomic and simple polyatomic molecules; and deduction of molecular parameters from spectra.
- 673 **CHEM 673 / BIOLCHEM 673.**
Kinetics and Mechanism.
 (3;3) : May not be repeated for credit.
 (Excl).
BIOLCHEM 550 and calculus; Physical chemistry is recommended.
 Comprehensive treatment of thermodynamic and kinetic aspects of the binding of ligands to macromolecules, the use of rapid reaction techniques in the elucidation of enzyme reaction mechanisms, steady-state catalysis, and isotope effects.

Graduate Courses

- 501 **CHEM 501 / CHEMBIO 501 / BIOLCHEM 501 / BIOPHYS 501 / MEDCHEM 501.**
Chemical Biology I.
 (3) : May not be repeated for credit.
 (Excl). (BS).
 This course provides a high-level overview on the structure, function, and chemistry of biological macromolecules including proteins, nucleic acids, and carbohydrates. Topics include protein and nucleic acid folding, energetic of macromolecular interactions (kinetics and thermodynamics), and mechanistic enzymology. Using specific examples from the current literature, each topic stresses how chemists have used molecular level tools and probes to help understand the specific systems under study. The overarching theme in this course is the structure and function and intimately linked.

- 502 **CHEM 502 / CHEMBIO 502 / BIOLCHEM 502 / MEDCHEM 502.**
Chemical Biology II.
 (3) : May not be repeated for credit.
 (Excl). (BS).
 This course is a continuation of CHEM 501. The basic concepts obtained in CHEM 501 will be applied to and demonstrated in three broad areas of interest to both chemists and biologists. The first topic will discuss combinatorial methods including SELEX and gene shuffling, combinatorial organic synthesis, high throughput screening and chemical genetics. The second topic will focus on signal transduction, emphasizing general concepts (at the molecular level) and how small molecules have been used to probe and modulate signal transduction pathways. The final topic will cover protein translation, stressing mechanistic aspects of protein synthesis and folding in vivo.
- 528 **CHEM 528 / BIOLCHEM 528 / MEDCHEM 528.**
Biology and Chemistry of Protein Cofactors.
 (2) : May not be repeated for credit.
 (Excl). (BS).
CHEM 452.
 This course will explore the roles of organic and organometallic cofactors in biology. Topics covered are cofactor assembly, cofactors as sensors, and cofactors in enzyme chemistry, with an emphasis on modulation of cofactor reactivity by complexation with the protein. The lectures will be complemented by assigned reading material from the primary literature and will assume basic familiarity with bioorganic chemistry.
- 543 **CHEM 543.**
Organic Mechanisms.
 (2,2) : May not be repeated for credit.
 (Excl). (BS).
CHEM 215/216.
 Students will learn to propose and write reasonable mechanisms for organic reactions, including complex multi-step processes. Knowledge of the details of the fundamental organic reaction processes will also be gained.
- 548 **CHEM 548.**
New Frontiers at the Chemistry/Biology Interface.
 (1) : May be repeated for credit for a maximum of 2 credits.
 (Excl). (BS).
Permission of instructor.
 Students attend seminars that describe topics at the frontiers of Chemistry and Biology.
- 551 **CHEM 551 / BIOINF 551 / BIOLCHEM 551 / BIOMEDE 551.**
Proteome Informatics.
 (3) : May not be repeated for credit.
 (Excl). (BS).
Biochemistry and calculus.
 Introduction to proteomics, from experimental procedures to data organization and analysis. Basic syllabus: sample preparation and separations, mass spectrometry, database search analysis, *de novo* sequence analysis, characterizing post translational modifications, medical applications. Further topics may include, e.g.: 2-D gels, protein-protein interactions, protein microarrays. Research literature seminars required.
- 567 **CHEM 567 / AOSS 567.**
Chemical Kinetics.
 (3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 461 or AOSS 479.
 Chemical Kinetics is the study of the rates and mechanisms of systems undergoing chemical change. The extraction of rate data from reacting systems and the utilization of such data in other reacting systems is central to chemistry in the laboratory and in the practical worlds of combustion science, atmospheric science, and chemical synthesis. This course introduces the treatment of complex chemical systems and fundamental ideas about chemical reaction rates in gases and in solutions. Computer software is utilized to treat complex reaction systems.

- 571 **CHEM 571.**
Quantum Chemistry.
 (3,3) : May not be repeated for credit.
 (Excl). (BS).
CHEM 570; Graduate standing and permission of instructor.
 Constitutes with CHEM 576 a full course for students specializing in physical chemistry. Review of quantum mechanics from a postulational viewpoint; variational and matrix methods, time-independent and time-dependent perturbation theory; applications to molecular systems including potential energy surfaces and reaction pathways.
- 576 **CHEM 576.**
Statistical Mechanics.
 (3,3) : May not be repeated for credit.
 (Excl). (BS).
Graduate standing and permission of instructor.
 Constitutes with CHEM 571 a full course for students specializing in physical chemistry. The foundation of equilibrium statistical mechanics and applications to problems of chemical interest. Included are discussions of imperfect gases and liquids, mixtures, solids, quantum statistics, surface chemistry and polymers.
- 597 **CHEM 597.**
Introduction to Graduate Research.
 (3) : May be elected twice for credit.
 (Excl).
Graduate standing. This course has a grading basis of "S" or "U."
 All Chemistry Ph.D. students are required to take a first-year graduate research course both Fall and Winter Academic Terms. This course consists of practical hands-on experience in a faculty's lab. Students receive training in research methods and techniques necessary for the successful conduct of dissertation research as the new curriculum changes require.
- 598 **CHEM 598.**
Integrated Graduate Education and Research Training Program (IGERT) Research Rotation.
 (3,3) : May be elected up to four times for credit.
 (Excl). (INDEPENDENT).
Graduate standing. This course has a grading basis of "S" or "U."
 In this program, we are seeking to bring together disciplines that are concerned with materials on a scale from the nanoscopic to the microscopic. These length scales for materials bridge the gap between the molecular (chemical) and the micron scale of devices. Chemists are increasingly concerned with complex "supramolecular" arrays, whereas the electronics engineers strive to decrease the sizes of their devices to molecular dimensions. The length scales associated with these disciplines are converging. Unfortunately, the language and laboratory skills that have evolved at the two extremes are quite different, making communication difficult. We envision a program that brings together these disciplines, creates a common language, and will produce a new generation of students skilled in molecularly designed materials. The course helps students establish "critical literacy" in areas outside their core expertise is our proposed research group rotation (RGR). In the RGR, a student will select 3 research mentors with whom three, short-term research projects will be carried out. Each project will include a definition of the problem, a literature search, some laboratory work, and a final written report. The student must interview a minimum of 5 prospective research mentors before choosing the three RGR mentors. The RGR student will take part in the full life of the host research laboratory, including participating in all group meetings, seminar activities, etc. of the host laboratory/department. At least one of the three research rotations must be outside the students home department and may include a summer term at a participating industrial or government laboratory.

- 599 **CHEM 599.**
Chemistry Biology Interface (CBI) Training Program Research Rotation.
 (3,3) : May not be repeated for credit.
 (Excl). (INDEPENDENT).
Graduate standing.
 The Chemistry Biology Interface (CBI) Training Program, a unique multidisciplinary Ph.D. training program, focuses on the fundamental underlying chemical principles that govern all biological processes. This dynamic new program emphasizes mechanistic and synthetic aspects of research at the chemistry biology interface and leads to a Ph.D. degree in either Chemistry, Biological Chemistry, or Medicinal Chemistry. Students enrolled in the program will gain a broad appreciation of the chemical foundations of biology including synthesis, analysis, and theory and will be prepared to pursue research on a vast array of critical biological problems in academic or industrial settings. Three different University of Michigan departments Chemistry, Biological Chemistry, and Medicinal Chemistry have combined strengths to create this challenging new program. Each student's course of study is tailored to suit his or her individual goals and includes laboratory rotations in at least two of the participating University departments. To learn more about research in an industrial setting, students will also be encouraged to perform a rotation at the Parke-Davis Research Laboratories adjacent to the University's North Campus. The CBI Training Program offers students the unique opportunity to participate in laboratory rotations at the Parke-Davis Research Laboratories in the following areas: 1.Medicinal chemistry 2.Peptides 3.Structure-based design chemistry 4.Exploratory chemistry 5.Computational chemistry 6.Molecular modeling 7.Bioorganic chemistry 8.Structural biology 9.Analytical research 10.Combinatorial chemistry 11.Automated chemical synthesis
- 602 **CHEM 602 / BIOPHYS 602.**
Protein Crystallography: Principles of Macromolecular Crystallography.
 (2,2) : May not be repeated for credit.
 (Excl).
Physical Chemistry. Graduate standing.
 Fundamental of the methods for determining 3-dimensional structures of large molecules by x-ray crystallography. Aimed at students who expect to use crystallography as a major tool for their research, and at those who want in-depth knowledge of the methods in order to analyze structure data.
- 603 **CHEM 603 / BIOPHYS 503.**
Biomolecular NMR: Structure & Dynamics in Solution & Solids.
 (3,3) : May not be repeated for credit.
 (Excl). (BS).
Graduate standing.
 After a classical introduction into 2D NMR, principles of multidimensional NMR will be treated, including quantum mechanical methods such as Density Matrices, Product Operators, Propagators and perturbation theory. Biomolecular applications of two-dimensional proton NMR and three- and four-dimensional heteronuclear NMR will be extensively covered. Methods applicable for solution as well as for solid samples will be introduced. Applications center on protein structure determination but nucleic acids NMR and relaxation experiments for the detection of molecular dynamics will be treated as well. An introduction into solid-state NMR will focus around the methods such as cross polarization, MAS, line-narrowing multiple-pulse techniques. Applications will be covered in the last lecture.
- 616 **CHEM 616.**
Advanced Inorganic Chemistry.
 (3,3) : May not be repeated for credit.
 (Excl).
CHEM 507 and 570. Graduate standing.
 The application of theoretical principles to the experimental observations of modern inorganic chemistry: ligand field and molecular orbital theory of complex ions, structural chemistry, magnetic properties, ESR, Mossbauer spectra, NQR.
- 646 **CHEM 646.**
Separation Processes.
 (3,3) : May not be repeated for credit.
 (Excl).
CHEM 545 and Graduate standing.
 Requirements for analytical and preparational separations. Pertinent phase rule considerations; theoretical plate concepts; efficiency calculations for multistage processes; nature of adsorption. Theory and practice of (a) precipitation and crystallization, (b) volatilization and distillation, and (c) extraction, partition and distribution processes, especially ion-exchange, liquid-liquid extraction, and various types of adsorption and partition chromatography (gas, paper, thin-layer, etc.).

- 648 **CHEM 648.**
Analytical Spectroscopy and Imaging.
(3,3) : May not be repeated for credit.
(Excl).
CHEM 447 and Graduate standing.
Theory, practice, and application of spectrochemical techniques for analysis and research with emphasis on emission and absorption spectroscopy in the principal regions of electromagnetic spectrum.
- 649 **CHEM 649.**
Electrical Methods in Analytical Chemistry.
(2-3,2-3) : May not be repeated for credit.
(Excl).
CHEM 447 and Graduate standing.
Fundamentals of modern electroanalytical methods including potentiometry, ion-selective electrodes, gas sensors, voltammetry, amperometry, conductimetry, chemically modified electrodes, pulsed voltammetric techniques, and biosensors. Instrumentation associated with these methods is also examined.
- 711 **CHEM 711.**
Special Topics in Inorganic Chemistry.
(3,3) : May not be repeated for credit.
(Excl).
CHEM 507. Graduate standing.
- 720 **CHEM 720.**
Chemical Sciences at the Interface of Education (CSIE) Seminar.
(1,1) : May not be repeated for credit.
(Excl).
Permission of instructor. Graduate standing.
Special seminar designed to discuss effective teaching strategies and methods to assess teaching effectiveness. Supervised teaching experiences in conjunction with an accelerated entrance into the research laboratory enable CSIE students to gain experience in curriculum revision for undergraduate lecture and laboratory courses.
- 744 **CHEM 744.**
Special Topics in Organic Chemistry.
(2,2) : May not be repeated for credit.
(Excl).
CHEM 541. Graduate standing.
One or two courses from the following groups will be offered:
Group A. 730-734. Physical organic chemistry: reaction mechanism, stereochemistry, physical methods, *etc.*
Group B. 735-739. Natural products: alkaloids, terpenes, proteins, *etc.*
Group C. 740-744.
- 755 **CHEM 755.**
Advanced Analytical Chemistry.
(2,2) : May not be repeated for credit.
(Excl).
CHEM 545 and Graduate standing.
- 799 **CHEM 799.**
Selected Topics in Chemistry.
(1-3,1-3) : May not be repeated for credit.
(Excl).
Graduate standing and permission of instructor.
Special topics selected from modern advances in Chemistry.

- 800 **CHEM 800.**
Seminar in Chemical Biology.
(2,2) : May be repeated for credit for a maximum of 12 credits.
(Excl).
Graduate standing. This course has a grading basis of "S" or "U."
Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 801 **CHEM 801.**
Seminar in Analytical Chemistry.
(2,2) : May not be repeated for credit.
(Excl).
Graduate standing.
Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 802 **CHEM 802.**
Seminar in Inorganic Chemistry.
(2,2) : May not be repeated for credit.
(Excl).
Graduate standing.
Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 803 **CHEM 803.**
Seminar in Organic Chemistry.
(2,2) : May not be repeated for credit.
(Excl).
Graduate standing.
Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 804 **CHEM 804.**
Seminar in Physical Chemistry.
(2,2) : May not be repeated for credit.
(Excl).
Graduate standing.
Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 805 **CHEM 805.**
Materials Seminar.
(2,2) : May not be repeated for credit.
(Excl).
Graduate standing.
Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)

- 806 **CHEM 806.**
Departmental Tuesday Seminar.
 (1,1) : May not be repeated for credit.
 (Excl).
Graduate standing.
 Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 807 **CHEM 807.**
Departmental Thursday Seminar.
 (1,1) : May not be repeated for credit.
 (Excl).
Graduate standing.
 Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 808 **CHEM 808.**
Departmental Friday Seminar.
 (1,1) : May not be repeated for credit.
 (Excl).
Graduate standing.
 Participation in the departmental seminars is required. Each student is expected to attend regularly one section of the weekly seminars and is required to present one seminar during his/her career. It is necessary to register for 2 credit hours in CHEM 80X in the term in which a seminar is given and a grade is given on the presentation. This must be done before admission to candidacy. (A later talk, the thesis colloquium, presenting the subject matter of the dissertation is given after the dissertation has been completed.)
- 895 **CHEM 895.**
Research in Chemistry.
 (1-8,1-4) : May not be repeated for credit.
 (Excl). (INDEPENDENT).
Consent of instructor required (Prerequisites enforced at registration). Approval of Graduate Committee. Graduate standing. Permission of instructor required.
 Research, the core of Michigan's Ph.D. program, involves applying state-of-the-art experimental techniques and theoretical frameworks toward developing a complete understanding of the nature of chemical and biological systems. Although you will be immersed in your chosen area of concentration, you will be encouraged to pursue an interdisciplinary approach to research. Research groups in the department are organized into several areas: ANALYTICAL CHEMISTRY; CHEMICAL BIOLOGY; INORGANIC CHEMISTRY; MATERIALS CHEMISTRY; ORGANIC CHEMISTRY; PHYSICAL CHEMISTRY.
- 990 **CHEM 990.**
Dissertation/Precandidate.
 (1-8,1-4) : May be repeated for credit.
 (Excl). (INDEPENDENT).
Election for dissertation work by doctoral student not yet admitted as a Candidate. Graduate standing. This course has a grading basis of "S" or "U."
 Election for dissertation work by doctoral student not yet admitted as a Candidate.
- 993 **CHEM 993.**
Graduate Student Instructor Training Program.
 (1,1) : May not be repeated for credit.
 (Excl).
Must have GSI award. Graduate standing. This course has a grading basis of "S" or "U."
 A seminar for all beginning graduate student instructors, consisting of a two day orientation before the term starts and periodic workshops/meetings during the Fall Term. Beginning graduate student instructors are required to register for this class.

995 **CHEM 995.****Dissertation/Candidate.**

(8,4) : May be repeated for credit.

(Excl). (INDEPENDENT).

Graduate School authorization for admission as a doctoral Candidate (Prerequisites enforced at registration). This course has a grading basis of "S" or "U."

Graduate School authorization for admission as a doctoral Candidate. N.B. The defense of the dissertation (the final oral examination) must be held under a full term Candidacy enrollment period.