CHEMISTRY AND BIOCHEMISTRY *Section 31.050*

Faculty

Chair
CHRISTINE DEWOLF, PhD *Imperial College of Science, Technology and Medicine*; *Associate Professor*

Distinguished Professors Emeriti
MARK DOUGHTY, PhD *University of London*
OSWALD S. TEE, PhD *University of East Anglia*

Professors
JOHN A. CAPOBIANCO, PhD *University of Geneva*
YVES GÉLINAS, PhD *Université du Québec à Montréal*
PAUL JOYCE, PhD *Dalhousie University*
GILLES H. PESLHERBE, PhD *Wayne State University*

Associate Professors
LOUIS CUCCIA, PhD *McGill University*
GEORGE DÉNÈS, PhD *Université de Rennes I*
PAT FORGIONE, PhD *University of Ottawa*
GUILLAUME LAMOUREUX, PhD *Université de Montréal*
HEIDI M. MUCHALL, PhD *University of Essen*
JUNG KWON (JOHN) OH, PhD *University of Toronto*
XAVIER OTTENWAELDER, PhD *Université Paris-XI (Orsay)*
PETER PAWELEK, PhD *McGill University*
JUSTIN B. POWLOWSKI, PhD *University of Minnesota*
INGO SALZMANN, PhD *Humboldt University of Berlin*
CAMERON SKINNER, PhD *McGill University*
CHRISTOPHER WILDS, PhD *McGill University*

Assistant Professors
BRANDON FINDLAY, PhD *University of Manitoba*
ASHLEE HOWARTH, PhD *University of British Columbia*
MAREK MAJEWSKI, PhD *University of British Columbia*
RAFIK NACCACHE, PhD *Concordia University*
DAJANA VUCKOVIC, PhD *University of Waterloo*

Senior Lecturers
SÉBASTIEN ROBIDOUX, PhD *McGill University*
CERRIE ROGERS, PhD *University of British Columbia*

For the complete list of faculty members, please consult the Department website.

Location

Loyola Campus
Richard J. Renaud Science Complex, Room: SP 201.01
514-848-2424, ext. 3366

Department Objectives

Chemistry is the science that examines the structure of substances and the reactions to produce novel and useful products. Biochemistry is that part of chemistry which deals with chemical changes occurring in biologically relevant systems; i.e. changes taking place in living cells that are responsible for life processes.
The mission of the Department is fourfold: (i) excellence in teaching and research in the fields of chemistry and biochemistry; (ii) develop and maintain strong undergraduate and graduate teaching programs; (iii) develop and maintain state-of-the-art quality research; and (iv) meet the high standards of the scientific and industrial communities. Our programs have strength in both the applied and the theoretical fields.

Programs

Students are responsible for satisfying their particular degree requirements.
The Department helps students to ensure that they adhere to the academic code of conduct while taking the Department's courses. Attendance at a 45-minute seminar on academic integrity is required of all students registered in any department course. The seminar is offered several times near the beginning of each term.
The Ordre des chimistes du Québec (OCQ) has fully accredited the curricula of i) Honours in Chemistry; ii) Honours in Biochemistry; iii) Specialization in Biochemistry; iv) Specialization in Chemistry. Upon satisfactory completion of any of the above-mentioned programs, a graduate is eligible for membership in the OCQ. A working knowledge of French is required.
Students should note that CHEM 450 has a performance prerequisite and is essential for honours programs. CHEM 419 has a performance prerequisite for the specialization programs. Students who cannot meet these prerequisites will not be able to complete the programs but may complete a major. For more details, students should consult with the Department.
Courses that consist of both laboratories and lectures require that a satisfactory performance be obtained in each of the components for successful completion of the course.
The superscript indicates credit value.

45 Core Component for Chemistry
CHEM 217^{3}, 218^{3}, 221^{3*}, 222^{3*}, 234^{3}, 235^{3}, 241^{3}, 242^{3}, 271^{3}, 293^{3}, 312^{3}, 324^{3}, 325^{3}, 333^{3}, 341^{3}
**For Cegep equivalents these courses must be replaced with an equivalent number of other Organic Chemistry credits.*

45 Core Component for Biochemistry
BIOL 261^{3}, 266^{3}, 364^{3}, 368^{3}; CHEM 217^{3}, 218^{3}, 221^{3*}, 222^{3*}, 234^{3}, 235^{3}, 241^{3}, 271^{3}, 293^{3}, 324^{3}, 375^{33}
**For students entering with the Cegep equivalents, these credits must be replaced with an equivalent number of other Organic Chemistry credits (for students in the specialization or honours) or with an equivalent number of credits in Chemistry or related disciplines, as approved by the departmental advisor (for students in the major).*

60 BSc Honours in Chemistry
45 Core component for Chemistry
3 CHEM 495^{3}
6 CHEM 450^{6}
6 Additional credits at the 400 level in Chemistry
NOTE: Students seeking admission to the honours program may apply either for direct entry on the University application form or, once in the program, to the departmental honours advisor normally following the completion of 30 credits. Students must meet the University regulations concerning the honours degree. Honours students in second year and beyond are encouraged to attend departmental seminars.

72 BSc Honours in Biochemistry
45 Core component for Biochemistry
3 CHEM 477^{3} or BIOL 466^{3}
18 CHEM 312^{3}, 325^{3}, 335^{3}, 450^{6}; BIOL 367^{3}
6 Credits of 400-level courses in the Biochemistry area (CHEM 470^{3}, 471^{3}, 472^{3}, 475^{3}, 476^{3}, 478^{3}, 481^{3}, and when appropriate, CHEM 498^{3}); three credits may be replaced by a 400-level course in Chemistry or a 400-level course in Cell and Molecular Biology (BIOL 443^{3}, 461^{3}, 462^{3}, 463^{3}, 467^{3}, 468^{3}, 472^{3}, and when appropriate, BIOL 498^{3}).
NOTE: Students seeking admission to the honours program may apply either for direct entry on the University application form or, once in the program, to the departmental honours advisor normally following the completion of 30 credits. Students must meet the University regulations concerning the honours degree. Honours students in second year and beyond are encouraged to attend departmental seminars.

60 BSc Specialization in Chemistry
45 Core component for Chemistry
3 CHEM 495^{3}
6 CHEM 419^{6} or, with departmental permission, CHEM 450^{6}
6 Additional credits at the 400 level in Chemistry
NOTE: Students in the specialization program must maintain a GPA of 2.00 or better in the core program, to be evaluated annually.

69 BSc Specialization in Biochemistry
45 Core component for Biochemistry
18 CHEM 312^{3}, 325^{3}, 335^{3}, 477^{3}; BIOL 367^{3}, 466^{3}
6 Credits of 400-level courses in the Biochemistry area (CHEM 470^{3}, 471^{3}, 472^{3}, 475^{3}, 476^{3}, 478^{3}, 481^{3}, and when appropriate, CHEM 498^{3}); three credits may be replaced by a 400-level course in Chemistry or by a 400-level course in Cell and Molecular Biology (443^{3}, 461^{3}, 462^{3}, 463^{3}, 467^{3}, 468^{3}, 472^{3}, and when appropriate, BIOL 498^{3}).
NOTE: CHEM 477^{3} or BIOL 466^{3} plus a non-biochemistry program elective can be replaced by CHEM 419^{6} or 450^{6}.
NOTE: Students in the specialization program must maintain a GPA of 2.00 or better in the core program, to be evaluated annually.

45 BSc Major in Chemistry
45 Core component for Chemistry. Substitution of courses from within the Core program by other courses in Chemistry or related disciplines (Mathematics, Physics, Biology, Geology) up to a maximum of nine credits, will be accepted, if previously approved by a departmental program advisor. It is expected that such substitutions will be in accord with the overall program of study being followed by the student.

45 BSc Major in Biochemistry
45 Core component for Biochemistry

24 Minor in Chemistry
24 Chosen from the Department's offerings, with due regard to prerequisites, such that the courses chosen form a coherent pattern which complements the student's other areas of study. The course pattern chosen must have been previously approved by a departmental program advisor.

Chemistry and Biochemistry Co-operative Program

Director
XAVIER OTTENWAELDER, *Associate Professor*

The Chemistry and Biochemistry co-operative program is offered to students who are enrolled in the BSc Honours or Specialization in Chemistry and Biochemistry. Students interested in applying for the Chemistry and Biochemistry co-op should refer to §24 where a full description of the admission requirements is provided.
Academic content is identical to that of the regular program, but six or seven study terms are interspersed with three work terms. Students are supervised personally and must meet the requirements specified by the Faculty of Arts and Science and the Institute for Co-operative Education, in order to continue their studies in the co-op format.
Liaison between the student, the employers and the Institute for Co-operative Education is provided by the Chemistry and Biochemistry co-op committee, which includes the student's advisors.
Please refer to §24 for the schedule of study and work terms and the full description of admission requirements.

Courses

A student may be exempted from one or more of the introductory courses, on the basis of work done at the Cegep level. Where exemptions are given, replacement courses must be chosen with the approval of a department advisor. In the case of certain programs approved by the Ordre des chimistes du Québec, the courses must be replaced with an equivalent number of credits in the same subdiscipline as the exemptions.

Students who have successfully completed the Cegep equivalent for CHEM 205, 206, 221 and/or 222 should verify on their Concordia student record that they have received an exemption. Similarly, students who have successfully completed the equivalent course(s) at another university should verify on their Concordia student record that they have received credit or exemption as appropriate for this course. If not, they should see the departmental advisor.

CHEM 203 ***Forensic Analysis*** (3 credits)
This course introduces the non-science student to the fundamentals of chemical analysis as it is used in modern forensics. It introduces the basic concepts of the scientific method, molecules and chemical reactions, primarily focusing on chemical analysis. The key techniques used in modern forensics are presented with applications in drug, DNA, fingerprint, explosive and combustion/arson analysis.
NOTE: This course is not a prerequisite for any Chemistry course. Students in programs leading to the BSc degree may take this course as an elective, but may not take this course for credit to be applied to their program of concentration.

CHEM 204 ***From Alchemy to Modern Chemistry: A Historical Evolution of Chemistry*** (3 credits)
This course examines the development of chemistry before the 20th century from the Greek, Chinese and Islamic religions and philosophies to the development of measurement and instrumentation to analyze matter. The objective is to understand the roots of modern chemistry, and look at contributions and principles that are representative of the period in which they emerged.
NOTE: This course is not a prerequisite for any Chemistry course. Students in programs leading to the BSc degree may take this course as an elective, but may not take this course for credit to be applied to their program of concentration.

CHEM 205 ***General Chemistry I*** (3 credits)
Stoichiometry, states of matter, atomic structure, electron structure of atoms, the periodic table, periodic properties, bonding, solids. Lectures and laboratory.
NOTE: This course presumes a good grounding in secondary-school mathematics. Students lacking such grounding or non-science students seeking only an awareness of chemistry are advised to enrol in CHEM 208.
NOTE: Students in programs leading to the BSc degree may not take this course for credit to be applied to their program of concentration.

CHEM 206 ***General Chemistry II*** (3 credits)
Prerequisite: CHEM 205. Thermochemistry, solutions and their properties, equilibrium, ionic equilibrium, pH, buffers, kinetics, reaction mechanisms, other selected topics related to biochemistry, biology, and engineering. Lectures and laboratory.
NOTE: Students in programs leading to the BSc degree may not take this course for credit to be applied to their program of concentration.

CHEM 208 ***Chemistry in Our Lives*** (3 credits)
This course is designed as an introduction to chemistry for non-science students. It concentrates on establishing the chemical concepts and vocabulary necessary to understand the many roles chemistry plays in people's daily lives. Issues to be presented will range from design and testing of drugs to protection of the ozone layer. The chemical phenomena, methodology, and theory will be presented as needed to understand the various issues covered in the course. Lectures only.
NOTE: This course is not a prerequisite for any Chemistry course. This course may not be taken for credit by science students.

CHEM 209 ***Discovering Biotechnology*** (3 credits)
The course begins with an exploration of the roles of genes and proteins in life processes. It then proceeds to an examination of the basic scientific principles behind manipulation of biological molecules to produce desired changes. Students are introduced to the specific applications of the technology to medicine, agriculture, and the environment. Economic and ethical issues raised by biotechnology are also examined.
NOTE: This course is intended for non-scientists, and may not be taken for credit by Biochemistry or Biology students.

CHEM 212 ***Analytical Chemistry for Biologists*** (3 credits)
Prerequisite: CHEM 205, 206; PHYS 204, 206, 224, 226; MATH 205; or equivalents for **all** prerequisite courses. This course introduces the basic concepts of analytical chemistry to students in the biological sciences. Topics include treatment of analytical data; chemical equilibria and titrations; introduction to spectroscopy; separation science; electrochemistry. Lectures and laboratory.
NOTE: This course may not be taken for credit by students registered in a Chemistry or Biochemistry program.

CHEM 217 ***Introductory Analytical Chemistry I*** (3 credits)
Prerequisite: CHEM 205, 206; PHYS 204, 206, 224, 226; MATH 203, 205; or equivalents for **all** prerequisite courses. Precipitation methods and solubility products; activity, chemical equilibria and titration curves of neutralization and complexation systems; treatment of analytical data. Lectures and laboratory.

CHEM 218 ***Introductory Analytical Chemistry II*** (3 credits)
Prerequisite: CHEM 217. Chemical equilibria and titration curves of oxidation-reduction, precipitation, and non-aqueous systems; potentiometry and potentiometric titrations; introduction to spectroscopy with emphasis on molecular and atomic absorption spectroscopy, fluorescence spectroscopy. Lectures and laboratory.

CHEM 221 ***Introductory Organic Chemistry I*** (3 credits)
Prerequisite: CHEM 205, 206. Basic aspects of orbitals and their role in covalent bonding; delocalization of electrons. Alkanes: structure, nomenclature, isomerism, reactions. Introductory stereochemistry: enantiomers, diastereomers, conformers, Fischer and Newman projections, specification of chirality, E/Z isomerism. Conformations of cyclic compounds. Alkylhalides: S_N1; S_N2; E1; E2 reaction mechanisms. Free-radical reactions, organometallic compounds. Chemistry of alkenes, alkynes, and dienes. Lectures and laboratory.

CHEM 222 ***Introductory Organic Chemistry II*** (3 credits)
Prerequisite: CHEM 221. Introduction to the use of IR and NMR spectroscopy for the identification of simple organic compounds. Benzene and aromatic compounds: aromaticity, electrophilic aromatic substitution, nucleophilic aromatic substitution, substituent effects. Chemistry of aldehydes and ketones: nucleophilic addition, oxidation, reduction, and condensation reactions, tautomerism. Chemistry of carboxylic acids and their derivatives. Chemistry of alcohols, ethers, and related compounds. Amines: basicity, reactions. Lectures and laboratory.

CHEM 234 ***Physical Chemistry I: Thermodynamics*** (3 credits)
Prerequisite: CHEM 205, 206; PHYS 204, 206, 224, 226; MATH 203, 205; or equivalents for **all** prerequisite courses. The properties of real gases; fugacities; first, second and third laws of thermodynamics; the Phase Rule; one- and two-component systems; real solutions, and partial molal properties. Lectures and tutorials.

CHEM 235 ***Physical Chemistry II: Kinetics of Chemical Reactions*** (3 credits)
Prerequisite: CHEM 234. Mathematical treatment of experimental results; theories of reaction rates; unimolecular reactions; the steady-state approximation; factors influencing rates of reactions in solution; acid-base catalysis; catalysis by enzymes and the Michaelis-Menten mechanism; free-radical reactions; photochemical reactions; experimental methods and techniques. Lectures and laboratory.

CHEM 241 ***Inorganic Chemistry I: Introduction to Periodicity and Valence Theory*** (3 credits)
Prerequisite: CHEM 205, 206; PHYS 204, 206, 224, 226; MATH 203, 205; or equivalents for **all** prerequisite courses. The structure of the atom; the periodic table; properties of atoms, covalent bonding treatments including Lewis theory, valence shell electron pair repulsion theory of structure, valence bond and molecular orbital theory. Crystal field theory applied to the structure and properties of transition metal complexes. Bonding theories of metallic materials and semi-conductors. Lectures and laboratory.

CHEM 242 ***Inorganic Chemistry II: The Chemistry of the Main Group Elements*** (3 credits)
Prerequisite: CHEM 241. A survey of the properties and reactions of: hydrogen; Group 1, lithium to cesium; and Group 2, beryllium to radium; including the theory of ionic bonding and structure. The descriptive chemistry of Group 13, boron to thallium; Group 14, carbon to lead; Group 15, nitrogen to bismuth; Group 16, sulphur to polonium; Group 17, the halogens; and Group 18, the chemistry of the noble gases. Lectures and laboratory.

CHEM 271 ***Biochemistry I*** (3 credits)
Prerequisite: CHEM 221. An introduction to the essentials of biochemistry: protein structure, enzymology, carbohydrate metabolism, electron transport, integration and regulation of metabolism. Lectures, tutorials and laboratory.

CHEM 293 ***Spectroscopy and Structure of Organic Compounds*** (3 credits)
Prerequisite: CHEM 222. This course examines the identification of organic compounds using methods based on electronic, vibrational, nuclear magnetic resonance and mass spectroscopies. In each case, there is an introduction to the principles of the spectroscopy and a discussion of how its spectra vary with structure. Particular emphasis is placed upon the UV-visible spectra of conjugated molecules; the identification of functional groups by IR spectroscopy; the use of NMR spectroscopy, including 2D methods, for the determination of stereochemistry; and the use of mass spectrometry for ascertaining molecular constitution. The use of computer simulation and information retrieval for structure determination is introduced. Lectures and laboratory.
NOTE: Students who have received credit for CHEM 393 may not take this course for credit.

CHEM 298 ***Selected Topics in Chemistry*** (3 credits)
Specific topics for this course, and prerequisites relevant in each case, are stated in the Undergraduate Class Schedule.

CHEM 312 ***Intermediate Analytical Chemistry*** (3 credits)
Prerequisite: CHEM 218. A continuation of CHEM 217 and 218, with emphasis on instrumental methods of analysis. Emission spectroscopy; X-ray spectroscopy; voltammetry and polarography; amperometric titrations; coulometry and coulometric titrations, conductometry; chromatography with particular emphasis on gas chromatography, and high performance liquid chromatography. Laboratory is taken concurrently and provides experience in analytical techniques described in lectures. Lectures and laboratory.

CHEM 324 ***Organic Chemistry III: Organic Reactions*** (3 credits)
Prerequisite: Students must have completed a minimum of 15 credits in chemistry including CHEM 222. A mechanistic survey of reactions of major synthetic utility. Determination of reaction mechanisms. Importance of reactive intermediates: carbocations, carbanions, radicals, and carbenes. Lectures and laboratory.

CHEM 325 ***Organic Chemistry IV: Organic Structure and Stereochemistry*** (3 credits)
Prerequisite: Students must have completed a minimum of 15 credits in chemistry including CHEM 222. Organic structure and stereochemistry including the relationship of stereochemistry to physical properties and chemical reactivity. Determination of organic structure and stereochemistry by chemical and spectroscopic means. Introduction to molecular symmetry. Lectures and laboratory.

CHEM 326 ***Natural Products*** (3 credits)
Prerequisite: CHEM 324. The structures, mechanisms of action, and biosynthetic origins of biologically important compounds such as fatty acids, polyketides, terpenes, steroids, alkaloids, and beta-lactam antibiotics are discussed. The role of traditional organic chemistry in the development of modern biochemistry and biotechnology is illustrated with examples from medicine and agriculture. Lectures only.

CHEM 327 ***Organic Chemistry of Polymers*** (3 credits)
Prerequisite: CHEM 222. Introduction to the fundamental aspects of polymers and polymerization. Methods of preparation, reaction mechanisms and kinetics of polymer synthesis including condensation polymerization; addition polymerization: free radical, anionic, cationic; heterogeneous (Ziegler-Natta) and homogeneous (metallocenes) coordination polymerization. Polymer characterization and uses. Lectures and problem sessions.

CHEM 333 ***Introduction to Quantum Theory*** (3 credits)
Prerequisite: CHEM 234, 241. The course introduces students to the concept of quantum mechanics and the electronic structure of atoms and molecules. Topics include the origins and postulates of quantum theory, the Schrödinger equation and applications to simple systems such as the harmonic oscillator, rigid rotor and the hydrogen atom. The course looks at the quantum mechanical treatment of the chemical bond and provides an introduction to spectroscopy. Lectures only.

CHEM 335 ***Biophysical Chemistry*** (3 credits)
Prerequisite: CHEM 234, 235, 271. This course examines the physical basis for the structures of biomolecules (energetics of protein folding), the organization and structures of bio-membranes and biologically relevant systems, and intermolecular interactions (e.g. ligand binding). Both fundamental theory and techniques used to characterize these physical properties are covered. Lectures and laboratory.

CHEM 341 ***Inorganic Chemistry III: The Transition Metals*** (3 credits)
Prerequisite: CHEM 217, 218, 241, 242. Theories of bonding in transition metal complexes, including ligand field theory, applied to structure, physical properties, and reactivity of transition metal complexes: organometallic chemistry and catalysis. Metals in biological systems. Lectures and laboratory.

CHEM 375 ***Biochemistry II*** (3 credits)
Prerequisite: CHEM 221, 222, 271. A survey of selected pathways in intermediary metabolism, including their regulation and physiological significance, lipid, amino acid and nucleoside metabolism, cholesterol biosynthesis, urea cycle and the biochemistry of protein synthesis. Lectures and laboratory.

CHEM 398 ***Selected Topics in Chemistry*** (3 credits)
Specific topics for this course, and prerequisites relevant in each case, are stated in the Undergraduate Class Schedule.

CHEM 415 ***Analytical Separations*** (3 credits)
Prerequisite: CHEM 218, 312. High performance liquid separations on an analytical (non-preparative) scale are surveyed. Fundamental separation mechanisms and application of the techniques are discussed. Emphasis is placed on separations of biologically relevant analytes which include peptides, proteins and nucleic acids. Lectures only.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 419 ***Independent Study and Practicum*** (6 credits)
Prerequisite: Must have completed 60 credits including the 45-credit Core program, or equivalent, with a GPA of 2.00 (C) or better in Core program courses. In collaboration with and under the direction of a member of Faculty, the student carries out independent study and practical work on a problem chosen from the student's area of concentration. The student presents his or her work to the Department in the form of a scientific poster and submits a written report to the supervisor.
NOTE: During the academic session before the one in which this project is to be undertaken, the student must have obtained the consent of the Department, by consultation with the CHEM 419 coordinator, and must have also been accepted by a faculty supervisor. Independent study and practical work.

CHEM 421 ***Physical Organic Chemistry*** (3 credits)
Prerequisite: CHEM 222, 235; CHEM 324 or 325. Determination of organic reaction mechanisms using kinetics, activation parameters, acid-base catalysis, Bronsted catalysis law, solvent effects, medium effects, isotope effects, substitutent effects, and linear free energy relationships. Lectures only.

CHEM 424 ***Organic Synthesis*** (3 credits)
Prerequisite: CHEM 324; 30 credits in chemistry or permission of the Department. This course is designed to introduce students to advanced methods in organic molecule synthesis. It includes an introduction to retrosynthetic analysis, a survey of some important classes of reactions, with particular emphasis on mechanistic understanding and rationale for observed selectivity when appropriate. The strategic use of specific reactions in complex molecule synthesis is highlighted.

CHEM 425 ***Nucleic Acid Chemistry*** (3 credits)
Prerequisite: CHEM 222, 271. This course introduces students to various topics in nucleic acid chemistry. The topics include nomenclature, structure and function of RNA and DNA; techniques and methods to investigate nucleic acid structure; DNA damage and repair; interaction of small molecules and proteins with nucleic acid; oligonucleotide-based therapeutics (antisense, antigene, RNAi); synthesis of purines, pyrimidines and nucleosides; and solid-phase oligonucleotide synthesis. Lectures only.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 426 ***Reactive Intermediates*** (3 credits)
Prerequisite: CHEM 293 previously or concurrently. This course offers an introduction to reactive intermediates with an emphasis on structure and stability as found in modern (physical) organic chemistry. While the focus is on radicals and carbenes, carbocations are discussed near the end of the term. The material covered is relevant to chemistry and biochemistry. Lectures only.
NOTE: Students who have received credit for CHEM 393 or for this topic under a CHEM 498 number may not take this course for credit.

CHEM 431 ***Computational Chemistry for Chemists and Biochemists*** (3 credits)
Prerequisite: CHEM 234, 241, 333 or 335, or permission of the Department. This course presents the concepts, tools, and techniques of modern computational chemistry, and provides a very broad overview of the various fields of application across chemistry and biochemistry. The course is divided into two parts: 1) *Molecular structure*, which covers molecular mechanics and elementary electronic structure theory of atoms and molecules; and 2) *Chemical reactivity*, which covers applications of quantum chemistry and molecular dynamics techniques to studies of chemical reactions. The applications discussed include organic molecules and their reactions, peptides and proteins, drug design, DNA, polymers, inorganics, and materials. The course includes a practical component where students acquire hands-on experience with commonly used computational chemistry computer software. Lectures and laboratory.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 435 ***Interfacial Phenomena*** (3 credits)
Prerequisite: CHEM 234, 235. This course examines the physical chemistry of interfaces including surface and interfacial tensions, the absorption of surface active substances/surface excess properties, and surfactant self-assembly. Topics covered may include Gibbs and Langmuir monolayers, micelle formation, emulsions, foams, surfactant liquid crystals, layer-by-layer polymer self-assembly, and biological membranes. Techniques for characterization and applications (biological and industrial) of these systems are addressed. Lectures only.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 436 ***Molecular Modelling of Proteins*** (3 credits)
Prerequisite: CHEM 234, 271. This course offers a hands-on introduction to the computer tools used to predict the structure of a protein from its amino acid sequence, and to gain insight into its function. Students learn modelling techniques such as sequence alignment, homology modelling, computer visualization, molecular dynamics, and molecular docking. Computer laboratory with pre-lab lectures.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 443 ***Organometallic Chemistry*** (3 credits)
Prerequisite: CHEM 324, 341, or equivalent. This course covers the structure and properties of organometallic compounds, their main reactions and their application in catalysis and organic chemistry. Lectures only.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 450 ***Research Project and Thesis*** (6 credits)
Prerequisite: 60 credits including the 45-credit Core program, or equivalent and enrolment in Honours in Chemistry; or Biochemistry, with a program GPA of 3.3 or better; or written permission of the Department. The student works on a research project in the student's area of concentration, selected in consultation with and conducted under the supervision of a faculty member of the Department. The student writes a thesis on the results and defends it before a departmental committee.
NOTE: During the academic session before the one in which this project is to be undertaken, the student must have obtained the consent of the Department, by consultation with the CHEM 450 coordinator, and must have also been accepted by a faculty supervisor.

CHEM 451 ***Nanochemistry*** (3 credits)
Prerequisite: CHEM 217, 218, 221, 222, 234, 235, 241. This modular course covers the areas of production, characterization and applications of nanoscale structures and materials. Each module is taught by a different professor as well as guest lecturers. Topics may include (but are not limited to) size dependent properties, synthesis of organic and inorganic nanostructures, self-assembled structures, chemical patterning and functional nanopatterns, biomaterials. Nanometer scale fabrication techniques such as lithographic methods, nano-stamping and patterned self-assembly are discussed. Modern analysis techniques such as atomic force microscopy and electron microscopy, which are used to map and measure at the single molecule level, are introduced. Applications such as photonics, optical properties, biodetection and biosensors, micro- and nano-fluidics, nanoelectronics and nanomachines are presented. The course includes a term project carried out using the nanoscience facilities held in the Department research labs.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 458 ***Aquatic Biogeochemistry*** (3 credits)
Prerequisite: CHEM 217, 218, 312. The major aim of this course is to present a quantitative treatment of the variables that determine the composition of natural waters. Chemical equilibrium is the central theme of the course, but consideration is also given to kinetics, steady-state and dynamic models. Related themes include global chemical cycles, air and water pollution, as well as current research topics in water chemistry and chemical oceanography. Lectures only.
NOTE: Students who have received credit for CHEM 418 or for this topic under a CHEM 498 number may not take this course for credit.

CHEM 470 ***Environmental Biochemistry*** (3 credits)
Prerequisite: CHEM 271, 375; BIOL 367; or permission of the Department. This course examines the biochemical effects of environmental stresses on organisms, and adaptations that allow organisms to face these stresses. Emphasis is placed on biochemical responses to toxic compounds such as aromatics, halogenated aliphatics, drugs, and heavy metals. Other topics may include adaptations to stresses such as temperature extremes, pathogens, and ionizing radiation. Applications to related biotechnological processes are also considered.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 471 ***Enzyme Kinetics and Mechanism*** (3 credits)
Prerequisite: CHEM 271, 375. Steady-state kinetics, including the use of initial velocity studies and product inhibition to establish a kinetic mechanism; nonsteady-state kinetics, isotope effects, energy of activation, detailed mechanisms of selected enzymes. Lectures only.

CHEM 472 ***Chemical Toxicology*** (3 credits)
Prerequisite: CHEM 222, 271. Introduction to the general principles of toxicology with emphasis on the toxic effects of chemicals in humans. Dose-response relationship, types and routes of exposure, absorption and disposition of toxic substances, toxicokinetics, types of toxic response, and factors affecting toxic response. Toxicity testing, risk assessment, and interpretation of toxicological data. Lectures only.

CHEM 475 ***Protein Engineering and Design*** (3 credits)
Prerequisite: CHEM 271, 375 or permission of the Department. This course examines the principles behind protein design, how techniques of protein engineering are used, and the methods used to assess protein properties. Examples include studies of protein stability, structure-function relationships, and applications to drug design. Lectures only.

CHEM 476 ***Structure and Function of Biomembranes*** (3 credits)
Prerequisite: BIOL 266; CHEM 375 or permission of the Department. This course discusses what is known about how the membranes of biological organisms are assembled and the roles that these membranes play in a number of important processes. Emphasis is placed on the transport of proteins to and through biomembranes and the roles that membranes play in metabolite and ion transport. Where applicable, the significance of these processes is illustrated by examining the roles of membranes in health and disease. Lectures only.
NOTE: Students who have received credit for this topic under a CHEM 498 number may not take this course for credit.

CHEM 477 ***Advanced Laboratory in Biochemistry*** (3 credits)
Prerequisite: CHEM 271, 375. Theory and practice of techniques in enzymology and protein chemistry, including steady-state and stopped-flow enzyme kinetics, ligand binding, immunological techniques, proteomics, computer modelling, and chemical modification of proteins. Tutorials and laboratory.

CHEM 478 ***Hormone Biochemistry*** (3 credits)
Prerequisite: CHEM 271, 375. This course deals with an in-depth study of the vertebrate hormones and involves a study of the precise chemical structure and properties of each hormone, its biosynthesis and mode of secretion from the cell. The circulating form of the hormone is examined, as well as the nature of the hormone receptor. The cellular mechanism of action and the relationship of the hormone's action to the intact animal are investigated. Lectures only.

CHEM 481 ***Bioinorganic Chemistry*** (3 credits)
Prerequisite: CHEM 271, 241. Role of metals in biochemical systems. Essential trace elements, zinc enzymes, oxygen transport and storage, metalloproteins and biological electron transfer, structure-function relationships in heme enzymes, nitrogen fixation; model compounds for metallo-proteins and metalloenzymes. Lectures only.

CHEM 493 ***Magnetic Resonance Spectroscopy*** (3 credits)
Prerequisite: CHEM 222, 293. This course is designed to provide the background in magnetic resonance theory necessary to understand modern high-resolution NMR experiments and instrumentation. The basic theory in the introductory section also applies to electron spin resonance (ESR). Relaxation and through-bond and through-space interactions, and experiments to investigate them are considered. Spin manipulations and behaviour in multiple-pulse, Fourier transform NMR techniques used for common spectral editing and two-dimensional experiments are discussed. Lectures only.

CHEM 494 ***Mass Spectrometry*** (3 credits)
Prerequisite: CHEM 218, 222, 271. Production and interpretation of mass spectra. Topics include ionization methods (electron impact, chemical ionization and fast-atom bombardment); interpretation of mass spectra; introduction to quantitative analysis by mass spectrometry. Lectures only.

CHEM 495 ***Modern Spectroscopy*** (3 credits)
Prerequisite: CHEM 234, 241, 333. This course demonstrates how quantum theory applies to the measurement of absorption and emission spectra of atoms and molecules. The course examines rotational, vibrational, and electronic spectroscopy. Photoelectron and related spectroscopies. Lasers and laser spectroscopy. Lectures only.

CHEM 498 ***Advanced Topics in Chemistry*** (3 credits)

CHEM 499 ***Advanced Topics in Chemistry*** (6 credits)

Specific topics for these courses, and prerequisites relevant in each case, are stated in the Undergraduate Class Schedule.
