# Chemistry

## Faculty

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## Program Overview

The Chemistry Department offers three distinct programs — Chemistry Honours, Chemistry Major, and Chemistry Minor. All of our programs provide students with a balanced, rich, and practical education in all sub-disciplines of Chemistry (Analytical, Biochemical, Environmental, Inorganic, Organic, and Physical) and students graduating with a Chemistry degree from Bishop's University have had an excellent record of being admitted to graduate schools and professional programs (Medicine, Dentistry, Pharmacy, Education, etc.) or in finding employment in their field.

Class sizes in chemistry courses are small, which promotes close personal interaction between members of the faculty and students. The faculty are also directly involved in all undergraduate laboratories, which enhances personal contact and results in a friendly and very productive learning in experimental chemistry.

The Chemistry Department has an excellent set of modern instruments, such as a 400 MHz NMR and a GC/MS, which are used by undergraduates in their laboratory courses and in research projects. This is in contrast to most universities where many instruments are reserved for graduate students. Hands-on, extensive training on this modern instrumentation and equipment greatly benefits our students and ensures that they are very well prepared for graduate studies or future employment.

## Undergraduate Programs

It is strongly recommended that students enrolled in Department of Chemistry programs follow the order of courses outlined in the tables below. Some Chemistry courses are offered on two-year rotations, so failure to follow the suggested course sequence may result in students not being able to fulfill their degree requirements in the normal time frame.

### Table 1. First year of study in the 4-year Chemistry Honours and Major programs

| Fall Semester | Winter Semester |
|---|---|
| CHM191 and CHL191 | CHM192 and CHL192 |
| BIO196 and BIL196 | PHY192 and PHL192 |
| PHY191 and PHL191 | MAT192 |
| MAT191 | Humanities Option |
| ELA116 | Humanities Option |

## Chemistry Honours (81 credits) HONCHE

The Chemistry Honours program fulfills the academic requirements for membership in the Chemical Institute of Canada and for accreditation by l'Ordre des chimistes du Québec. (For membership in the latter, it is necessary to possess a working knowledge of the French language.) The Chemistry Honours program is a four-year program that prepares a student for graduate studies in chemistry, as well as for direct professional employment. The program requires 37 three-credit one-semester courses, one 3-credit full year course, and a full year, 6-credit research project in the final year for a total of 120 course credits. In addition, students must also complete the 18 co-requisite lab courses. The Chemistry Honours degree program is shown in Table 1.

### Entrance Requirements for Honours

To be eligible to enter the third year of the Honours Chemistry program, a student must achieve a minimum average of 70% in the required second year Chemistry courses (CHM 111, CHM 211, CHM 121, CHM 131, CHM 231, CHM 141, and all co-requisite labs). To be eligible to enter the final year of the Honours Chemistry program, a student must achieve a minimum average of 70% in the third year required Chemistry courses (CHM 311, CHM 221 or CHM 222, CHM 331, CHM 242, CHM 341, and all co-requisite labs).

### Table 2. Honours Chemistry Program[1]

| | Fall Semester | Winter Semester |
|---|---|---|
| **Year 2** | CHM 111 and CHL 111 | CHM 211 and CHL 211 |
| | CHM 121 | CHM 131 and CHL 131 |
| | CHM 141 and CHL 141 | CHL 142 |
| | Option[2] | Option[2] |
| | Option[2] | Option[2] |
| | | Option[2] |
| **Year 3** | CHM 311 and CHL 311 | Chem. Option[3] |
| | CHM 221 and CHL 221[4] | CHM 242 and CHL 242[4] |
| | CHM 231 and CHL 231 | CHM 331 and CHL 331 |
| | CHM 341 and CHL 341 | BCH 313 and BCL 313 |
| | Option[2] | Option[2] |
| **Year 4** | CHM 222 / CHL 222[4] | CHM 471[5] |
| | CHM 471[5] | CHM 4996 |
| | CHM 499[6] | Chem. Option[3] |
| | Chem. Option[3] | Option[2] |
| | Option[2] | Option[2] |
| | Option[2] | |

*[1] All Chemistry students must take any two Humanities lecture courses in the first year. Students with a D.E.C. may be credited with these options.*

*[2] Chemistry Honours students must take one lecture course from either the Humanities or the Social Sciences and one course from MAT108, BIO201, or PHY206 and one lecture course from any of the Sciences. All other options are free electives. If a course has a co-requisite lab then the lab must be taken as well.*

*[3] Students must take three 400 level chemistry courses and any co-requisite labs in the third and fourth year.*

*[4] CHM221 / CHM222, CHM242, and their co-requisite labs are offered on a rotating basis, so the order in which they are taken may flip depending on the year the student entered the program.*

*[5] CHM471 is a full-year, 3-credit course.*

*[6] CHM499 is a full-year, 6-credit research project.*

## Chemistry Major (69 credits) MAJCHE

The Chemistry Major program prepares students for industrial or other employment that requires an extensive knowledge of chemistry. The program has sufficient flexibility to allow students to obtain a second major or a minor in another academic discipline. The program fulfills the academic requirements for membership in the Chemical Institute of Canada and for accreditation by l'Ordre des Chimistes du Québec. (For membership in the latter, it is necessary to possess a working knowledge of the French language.) The four-year Chemistry Major program requires 39 three-credit one-semester courses and one 3-credit full year course for a total of 120 course credits. In addition, students must complete the 18 co-requisite lab courses. The Chemistry Major degree program is shown in Table 2. Students in a minor program in another division may, with permission of the Department, reduce science options to a minimum of 9 credits.

**Table 3. Chemistry Major Program[1]**

| | Fall Semester | Winter Semester |
|---|---|---|
| **Year 2** | CHM 111 and CHL 111 | CHM 211 and CHL 211 |
| | CHM 121 | CHM 131 and CHL 131 |
| | CHM 141 and CHL141 | CHL 142 |
| | Option[2] | Option[2] |
| | Option[2] | Option[2] |
| | | Option[2] |
| **Year 3** | CHM 311 and CHL 311 | Chem. Option[3] |
| | CHM 221 and CHL 221[4] | CHM 242 and CHL 242[4] |
| | CHM 231 and CHL 231 | CHM 331 and CHL 331 |
| | CHM 341 and CHL 341 | BCH 313 and BCL 313 |
| | Option[2] | Option[2] |
| **Year 4** | CHM 222 and CHL 222[4] | CHM 371[4] |
| | CHM 371[5] | Option[2] |
| | Option[2] | Option[2] |
| | Option[2] | Option[2] |
| | Option[2] | Option[2] |
| | Option[2] | |

*[1] All Chemistry students must take any two Humanities lecture courses in their first year of study. Students with a D.E.C. may be credited with these options.*

*[2] Students must take one course from either the Humanities or the Social Sciences, one course from MAT108, BIO201, or PHY206 and four lecture courses from any of the Sciences. All other options are free electives. If a course has a co-requisite lab then the lab must be taken as well.*

*[3] Students must take one 400 level chemistry course and any co-requisite lab in the third or fourth year.*

*[4] CHM221 / CHM222, CHM242, and their co- requisite labs are offered on a rotating basis, so the order in which they are taken may flip depending on the year the student entered the program.*

*[5] CHM371 is a full-year, 3-credit course.*

## Chemistry Minor (24 credits) MINCHE

A Chemistry Minor will be awarded for the completion of CHM 111, CHM 211, CHM 121, CHM 131, CHM 141, CHM 241 and their co-requisite labs, together with 2 one-semester 3-credit courses (and their co-requisite labs) chosen from CHM 311, CHM 411, CHM 221, CHM 222, CHM 231, CHM 331, CHM 242, CHM 341, BCH 210 or BCH 313. Students taking a Chemistry Minor have a one-lecture course (3 credits) reduction towards the credits necessary for their degree.

# Recommended Electives

MAT 206, MAT 207, MAT 108, and PHY 101 are recommended science options for students who wish to pursue further mathematical and/or statistical studies.

PHY 206 is recommended for students who have not completed CEGEP physics.

BIO 201 and BCH 210 are recommended science elective for students interested in the field of organic chemistry..

# Concentrations in Chemistry

Chemistry concentrations are available to students pursuing degrees in Biochemistry. Further information on these programs can be found in the Biochemistry section of this calendar.

# Accreditation by l'Ordre des Chimistes du Quebec and the Canadian Institute for Chemistry

The OCQ and CIC are professional orders that oversee and accredit Chemistry, Biochemistry, and related disciplines in Quebec and Canada respectively. In order to meet the accreditation standards of these orders, a student must meet the following criteria.

## L'Ordre des Chimistes du Québec

A student must earn a minimum of 55 credits in Chemistry, of which 18 credits must be for laboratory work and 30 credits must be for lecture courses. The OCQ considers 3 credits of course or lab work to be the equivalent of 45 hours of class time and personal work (3 course credits in Chemistry at Bishop's is 36 hours of class time) and 1 credit of laboratory work to be the equivalent of 45 hours of lab time (1 lab-credit in Chemistry at Bishop's is 40-50 hours and thus is equivalent to 3 credits for the OCQ). The chemistry credits offered at Bishop's are divided in the following manner.

1. 9 course credits and 3 lab credits of physical chemistry.
2. 9 course credits and 4 lab credits of analytical chemistry.
3. 9 course credits and 3 lab credits of organic chemistry.
4. 9 course credits and 2 lab credits of inorganic chemistry.
5. 3 course credits and 1 lab credit of biochemistry.
6. 3 course credits on scientific writing.
7. 3 course credits as advanced option in any field of chemistry.

# Canadian Institute for Chemistry

The CIC expects a program to involve a total of about 1000 hours of laboratory and classroom work in chemistry, with the minimum hours of each being about 400. The laboratory hours should be distributed in such a way that every student is exposed to meaningful laboratory experience in at least four (and preferably five) of the five sub-disciplines (analytical chemistry, biochemistry, inorganic, organic and physical chemistry).

The core program beyond the first-year level shall include the equivalent of 12 chemistry courses including at least one in each of the five sub-disciplines of chemistry. In addition, there should be a selection of advanced offerings in the core disciplines and in other subjects such as for instance theoretical chemistry, solid state chemistry, natural products, polymers, advanced instrumentation, research thesis, etc. to bring the total number of hours of instruction to that described above. The program must also include at least 15 course credits in two or more of mathematics (algebra, calculus, statistics), physics, computer science and biology. In the case of pure chemistry programs, at least 6 credits in each of calculus and physics will be required. The inclusion of other cognate subjects as well as some liberal arts requirements is to be encouraged.

# List of Chemistry Courses

## General Chemistry

**CHM 191 General Chemistry I 3-3-0**
A course for students lacking Collegial Chemistry NYA or its equivalent.
Atoms, molecules, and ions. Chemical formulae and equations. Thermochemistry. Electronic structure of atoms. Periodic Table and properties of elements. Chemical bonds. Physical properties and structure. Chemical kinetics
*Co-requisite: CHL 191*

**CHL 191 Introductory Chemistry Laboratory I 1-0-4**
A series of experiments in Introductory Chemistry to complement Chemistry 191 which must be taken concurrently.
*Co-requisite: CHM 191*

**CHM 192 General Chemistry II 3-3-0**
A course for students lacking Collegial Chemistry NYB or its equivalent.
Solutions. Chemical equilibrium. Acids and Bases. Gases, Solids, and Liquids. Ionic equilibria.
*Prerequisites: CHM 191 (or permission of instructor) or Collegial Chemistry*
*Co-requisite: CHL 192*

**CHL 192 Introductory Chemistry Laboratory II 1-0-4**
A series of experiments in Introductory Chemistry to complement CHM 192 which must be taken concurrently.
*Co-requisite: CHM 192*

## Organic Chemistry

**CHM 111 Organic Chemistry I: Introductory 3-3-0**
An introductory structural survey of the most commonly encountered organic functional groups that are present in carbon compounds, emphasizing their significance in biologically important molecules (lipids, carbohydrates, amino acids, proteins, steroids, and other types of natural products). Stereochemistry and the fundamental principles behind essential organic reaction mechanisms will be stressed throughout. Some basic definitions and nomenclature will be introduced.
*Prerequisites: CHM 191 and CHM 192 or Collegial Chemistry NYA and NYB*
*Co-requisite: CHL 111*

**CHL 111 Organic Chemistry Laboratory I 1-0-4**
Experiments in the separation and purification of organic compounds including the use of chromatography. Introduction to functional group analysis and organic synthesis.
*Co-requisite: CHM 111*

**CHM 211 Organic Chemistry II: Introductory 3-3-0**
This course is a continuation of Chemistry 105 and will elaborate upon the chemistry of the organic functional groups and their involvement in organic synthesis, emphasizing the importance of electronic factors (resonance, induction, acidity, electrophiles, nucleophiles, leaving groups, and carbenium ions) in influencing organic reaction mechanisms. Spectroscopic analysis (NMR,IR) and the importance of molecular obritals are introduced briefly.
*Prerequisite: CHM 111 or Collegial Chemistry BFB*
*Co-requisite: CHL 211*

**CHL 211 Organic Chemistry Laboratory II 1-0-4**
Further experiments in organic synthesis and in chromatographic separations. An introduction to multi-step synthesis.
*Co-requisite: CHM 211.*

**CHM 311 Organic Chemistry III 3-3-0**
A more advanced discussion of organic reaction mechanisms; stereochemistry and conformational analysis; molecular rearrangements; pericyclic reactions; oxidations; tautomerism.
*Pre-requisite: CHM 111 and CHM 211*
*Co-requisite: CHL 311*

**CHL 311 Organic Chemistry Laboratory III 1-0-4**
Laboratory and spectroscopic techniques used in the synthesis, separation, and purification of simple organic compounds.
*Co-requisite: CHM 311 is a corequisite for Chemistry and Biochemistry Honours and Majors*

**CHM 411 Organic Chemistry IV 3-3-0**
The importance of electrophiles, nucleophiles, leaving groups, eliminations and dehydrations in the chemistry and reaction mechanisms of organosilicon, carbonyl, and biologically-important compounds.
*Pre-requisite: CHM 311.*

**CHL 300 Advanced Methods in Organic Chemistry 1-0-4**
Advanced laboratory techniques as applied to multistep syntheses and natural product isolation.
*Pre-requisite: CHL 311, CHL 211, and CHL 111*

## Inorganic Chemistry

**CHM 121 Inorganic Chemistry I 3-3-0**
The principles of nuclear, atomic, metallic, ionic, molecular structure. Valence bond and molecular orbital theory. Molecular and orbital symmetry.
*Prerequisites: CHM 191 and CHM 192 or Collegial Chemistry NYA and NYB*

**CHM 221 Transition Metals and Bioinorganic Chemistry 3-3-0**
This course introduces students to the chemistry of the transition metals and their role in biochemical systems. The first half of the course focuses on the chemistry of the transition metals and their complexes, covering topics including oxidation states, coordination, crystal and ligand field theory, and inorganic reaction mechanisms. The second half of the course focuses on bioinorganic chemistry, covering topics including oxygen transport and storage, metalloenzymes, cytochromes and bioinorganic redox chemistry, cobalamins, photosynthesis, and nitrogen fixation.
*This course is currently only offered in odd-numbered years.*
*Pre-requisites: CHM 121, CHM 131*
*Co-requisite: CHL 221*

**CHL 221 Transition Metals Laboratory 1-0-4**
This laboratory course focuses on the synthesis of transition metal complexes and bioinorganic model compounds as practical examples of the material covered in CHM 221.
*This course is currently only offered in odd-numbered years*
*Co-requisite: CHM 221*

**CHM 222 Elements and Minerals 3-3-0**
This course is an extensive survey of the chemistry of the s- and p-blocks of the periodic table with particular focus on the environmental (e.g. nitrates and phosphates) and geochemical (e.g. minerals, allotropes) properties of the elements.
*This course is currently only offered in even-numbered years.*
*Pre-requisite: CHM 121, CHM 131*
*Co-requisite: CHL 222*

**CHL 222 Elements and Minerals Laboratory 1-0-4**
This laboratory course focuses on the synthesis of compounds of the s- and p-blocks.
*This course is currently only offered in even-numbered years.*
*Co-requisites: CHM 222*

**CHM 421 Advanced Inorganic Chemistry 3-3-0**
Selected topics in inorganic chemistry covering all aspects of inorganic chemistry from the alkali metals to the noble gases.
*Pre-requisites: CHM 221 and CHM 222*

# Physical Chemistry

**CHM 131 Physical Chemistry I 3-3-0**
Ideal and real gases; chemical kinetics and mechanism; an introduction to thermodynamics and chemical equilibrium; ionic equilibria and electrochemistry. This course may be taken online by students who are not registered in a Bishop's Chemistry Program, subject to approval by the instructor.
*Prerequisites: CHM 191, CHM 192, MAT 191, MAT 192, PHY 191, and PHY 192 or Collegial Chemistry NYA and NYB, Math NYA and NYB, and Physics NYA and NYB.*
*Co-requisite: CHL 131*

**CHL 131 Physical Chemistry Laboratory I 1-0-4**
A series of experiments in Physical Chemistry to complement CHM 103 which must be taken concurrently by full-time Bishop's students.
*Co-requisite: CHM 131*

**CHM 231 Physical Chemistry II 3-3-0**
Chemical thermodynamics; Zeroth Law and equations of state; First Law and thermochemistry; the Second Law and chemical equilibrium; the Third Law and introduction to statistical thermodynamics; thermodynamic databases; phase equilibrium; calculation of chemical equilibrium in complex systems. Maple-assisted calculus and computations in physical chemistry. This course may be taken online, subject to instructor approval.
*This course is currently only offered in odd-numbered years.*
*Pre-requisite: CHM 131*
*Co-requisite: CHL 231*

**CHL 231 Physical Chemistry Laboratory II 1-0-4**
Experiments related to the topics of Chemistry 223 which must be taken concurrently by full-time Bishop's students.
*This course is currently only offered in odd-numbered years.*
*Co-requisites: CHM 231*

**CHM 331 Physical Chemistry III 3-3-0**
Maple-assisted computational statistical mechanics and kinetic theory of gases; gas reactions, chemical dynamics. Quantum chemistry, and spectroscopy; atomic structure, atomic orbitals, and atomic spectra (AAS, XPS, ESCA, EDX,...); introduction to molecular orbitals: LCAO, hybridization. Molecular electronic structure and molecular spectroscopy (physical principles of IR/Raman, rotovibrational spectra, ESCA, EPR and NMR spectroscopies).
*This course is currently only offered in even-numbered years.*
*Pre-requisites: CHM 131, CHM 211, CHM 231*
*Co-requisite: CHL 331 for all Chemistry students and for all biochemistry students planning to do honours research projects in the area of physical chemistry*

**CHL 331 Physical Chemistry Laboratory III 1-0-4**
Experiments related to topics of CHM 331, which must be taken concurrently by chemistry students and by biochemistry students who are planning to do honours research projects in the area of physical chemistry.
*This course is currently only offered in even-numbered years.*
*Co-requisite: CHM 331*

**CHM 431 Computational Chemistry and Molecular Modelling 3-3-0**
Maple-assisted calculations of molecular orbitals and molecular modelling subroutines; from H2+ molecular ion, via [Ni(En)3]2+ and cis-platin (cancer chemotherapy), to cholesterol and cyclosporin; symmetry and point group analysis of molecular vibration; hybridization and Simple-Huckel Molecular Orbital calculations. Semi-empirical and ab initio methods; calculation of reaction and activation energies via modern alternatives to the Hartree-Fock self-consistent field method; density functional. Combinatorial processing parent-compound libraries and Spartan-assisted CSDB.
*This course may be taken online (conditions apply, including instructor's permission and level of enrolment)*
*Pre-requisites: CHM 231 and CHM 331*

# Analytical Chemistry

**CHM 141 Analytical Chemistry 3-3-0**
Data handling, stoichiometric calculations, gravimetric analysis, acid-base equilibria and titrations, redox equilibria and titrations, complexometric titrations, precipitation reactions and titrations, electrochemical cells and electrode potentials.
*Prerequisites: CHM 191 and CHM 192 or Collegial Chemistry NYA and NYB*
*Co-requisite: CHL 141*

**CHL 141 Analytical Chemistry Laboratory 1-0-4**
Quantitative analysis of unknown samples by volumetric, gravimetric, and spectrometric methods will be carried out.
*Co-requisite: CHM 141*

**CHL 142 Chromatography Laboratory 1-0-4**
Study of chromatography and quantitative analysis by chromatographic methods (TLC, GLC, HPLC, and GCMS).
*Prerequisites: CHM 141*

**CHM 241 Environmental Chemistry I: Atmosphere and Energy 3-3-0**
This course explores the chemistry of the Earth's atmosphere and energy sources, both natural and anthropogenic. Topics covered in the section on the atmosphere include the chemical composition of the atmosphere and solar influence, stratospheric chemistry and ozone, tropospheric chemistry focusing on smog formation and acid precipitation, atmospheric aerosols, urban and indoor atmospheres, and global warming and climate change. Topics covered in the section on energy include solar energy, fossil fuels and the oil industry, nuclear energy, and the hydrogen economy.
*This course is currently only offered in odd-numbered years.*
*Pre-requisites: CHM 111, CHM 141*

**CHM 242 Environmental Chemistry II: Water and Soil 3-3-0**
This course explores the chemistry of the hydrosphere and the terrestrial environment. Topics covered in the section on the hydrosphere include distribution of species in aquatic systems, gases in water, organic matter in water, metals and semi-metals in the hydrosphere, chemistry of colloids and surfaces, microbiological processes focusing on the carbon, nitrogen, and sulfur cycles, and waster water treatment. Topics covered in the section on the terrestrial environment include physical and chemical properties of soil, and the chemistry of solid wastes.
*This course is currently only offered in even-numbered years.*
*Pre-requisites: CHM 111, CHM 141*
*Co-requisite : CHL 242*

**CHL 242 Environmental Chemistry Laboratory 1-0-4**
This laboratory is a survey of the analytical techniques and sample preparation methods related to environmental chemistry. The labs will cover the determination of chloride ion in natural waters, determination of hardness in natural waters, determination of iron and manganese in natural waters by spectrophotometry and colorimetry, determination of trace metals by atomic absorption spectrometry, spectrophotometric determination of the chemical oxygen demand of natural and wastewaters, pattern recognition of petroleum products using gas chromatography, properties of detergents, determination of carbon dioxide in the atmosphere, and the collection and chemistry of acid rain. Wherever possible, students will be performing their analyses on real environmental samples.
*This course is currently only offered in even-numbered years.*
*Co-requisite: CHM 242*

**CHM 341 Principles and Practices of Chemical Spectroscopy and Mass Spectrometry 3-3-0**
Theory and applications of multinuclear magnetic resonance, UV/VIS, EPR, and electron spectroscopies for chemical analysis. Mass spectrometry and hyphenated methods. Use of chemical spectroscopy and mass spectrometry for the identification of organic compounds. 2D- and imaging techniques, including MRI. This course may be taken online.
*Pre-requisites: CHM 131, CHM 141, and CHM 211*
*Co-requisite: CHL 341*

**CHL341 Principles and Practices of Chemical Spectroscopy and Mass Spectrometry Laboratory 1-0-4**
Experiments related to topics of CHM 341, which must be taken concurrently by chemistry and biochemistry students.
*Co-requisite: CHM 341*

**CHM 442 Surface and Interface Analysis 3-0-9**
This course will provide students with an overview of routine and state-of-the-art analytical methods for the characterisation of surfaces and interfaces. Students will understand how radiation is used to determine properties of surfaces and interfaces. Current applications using peer-reviewed scientific literature will be discussed. Students will understand the underlying principles of the methods discussed and will know how they are applied to real-world problems. Students will be able to critically analyse measurement challenges and propose analytical methodology for the characterisation of surface properties.
*Prerequistes: CHM 141, CHL 141, CHL 142, CHM 191, CHL 191, CHM 192, CHL 192, CHM 341, CHL 341 or Collegial Chemistry NYA, NYB*

# Chemical Literature and Research Projects

**CHM 371F Scientific Writing and Chemical Literature for Major Students 3-0-0**
This course introduces the Chemistry Major student to chemical information retrieval and requires two major term papers – one in the Fall semester, one in the Winter semester – each presented also in two short oral presentations. Students will use SciFinder/Chemical Abstracts to perform searching in structure/substructure, reaction, and bibliographic databases. The literature searching will be used in preparing the two term papers, chosen from a list of topics approved by the Chemistry Department, under the direction of a different member of faculty for each.
*Chemistry Major students must enrol in CHM 371 as part of their degree program and may only take this course in their final year. Students receiving credit for CHM 371 cannot also receive credit for CHM 471*

**CHM 471F Scientific Writing and Chemical Literature for Honours Students 3-0-0**
This course introduces the Chemistry Honours student to chemical information retrieval and requires two major term papers – one in the Fall semester, one in the Winter semester – each presented also in two short oral presentations. Students will use SciFinder/Chemical Abstracts to perform searching in structure/substructure, reaction, and bibliographic databases. The literature searching will be used in preparing the two term papers, chosen from a list of topics approved by the Chemistry Department, under the direction of a different member of faculty for each.
*Honours Chemistry students must enrol in CHM 471 as part of their degree program and may only take this course in their final year. Students receiving credit for CHM 471 cannot also receive credit for CHM 371.*

**CHM 491 Independent Study 3-0-0**

**CHM 492 Independent Study 3-0-0**

**CHM 499 Honours Chemistry Research Project 6-0-12**
Under the guidance of a faculty member, the student does an experimental research project requiring approximately 12 hours per week in both the Fall and Winter semesters, and presents the results of the project in a seminar and a written dissertation. The project chosen must be approved in advance by the Department, and may be in any field of chemistry plus material science.
*Prerequisites: Third Year Honours Chemistry registration or permission of the Department.*

# General Interest Courses

**CHM 181 The Chemistry of Everyday Life 3-3-0**
This course will discuss the chemistry underlying some everyday, or easily recognizable, products, processes, and policies. These may include: the chemistry of pollution, warfare, polymers and plastics, household products, and food.
*This course cannot be taken for credit by students who have received credit for CHM 191 or the collegial equivalent course, Chemistry NYA, or equivalent credit elsewhere.*
*Course registration requires the instructor's permission.*

**CHM 182 The History and Science of Beer and Brewing 3-3-0**
Beer is among the world's most popular beverages and the industry continues to grow at both the megabrewery and microbrewery levels. This course is a general interest course on the nature of beer from a historical, sociological, and scientific perspective. The diverse nature of beer will be explored, as well as how the beverage has developed from its origins many thousands of years ago to what it has become today. Of particular emphasis will be the development of a general understanding of the brewing process, and the science and engineering involved. Various examples of beer's impact on society and culture will also be discussed.
*This course cannot be taken for science credit.*

**CHM 183 Experiential Learning Project in Brewing 3-0-9**
This course is designed specifically for non-science students interested in gaining experience in brewing beer from scratch. Specifically, students will engage in recipe development by starting with a known formula and make changes, subtle or otherwise, to create a beer that is distinctly their own. The goal is to gain an understanding and appreciation of brewing process as well as the roles that the ingredients of beer (water, malt, hops, yeast, adjuncts) play in the taste, aroma, and mouth-feel of the final product. Due to limited space and the anticipated popularity of this course, interested students must submit a brief proposal outlining the beer they would like to produce and their reason for wanting to take the course. Two students per semester will be selected by the course instructor (Dr. Dale Wood) to participate.
*Pre or Corequisites: CHM 182 – The History and Science of Brewing*

**CHM 185 The Science of Cooking 3-3-0**
Food processing is one of the most common activities worldwide, but do we really know what is happening at the molecular level? This course is a general interest course on the chemistry of cooking and is designed to answer questions such as: Why does plunging food in ice water not stop the cooking process? What is happening when baking? And why does deep-fried food taste best and brown better when the oil is older? A particular emphasis will be placed on understanding what chemical transformations are involved during food processing. This course is normally offered during the spring session.
*This course cannot be taken for science credit.*

**CHM 441 Quality Control and Product Analysis as Exemplified by Beer and Brewing 3-0-9**
This course will familiarize interested students with the concepts of Quality Control and Product Analysis using beer and the brewing process as an industrial model. Students will gain hands-on experience brewing their own beer with the goal of producing a consistent, high-quality product by tracking the parameters that affect the critical steps in the brewing process. In particular, students will study the effects of temperature, pH, nutrient concentration, and yeast type and how they affect the mash-in, boil (hopping), and fermentation processes, using GC-MS, NMR, HPLC, and other applicable instrumentation. Due to space considerations, this course will be limited to two students per semester, with preference given to students in their final year of study.
*Pre or Corequisites: BCH 210,CHM 131, CHM 141, CHM 111, CHM 211, CHM 341 and corequisite labs*

## Advanced Courses

**CHM 435 Advanced Topics in Organic Chemistry 3-3-0**
Advances topics in organic chemistry like stereoselective chemistry, radical chemistry and organometallic chemistry will be introduced through discussions and analysis of representative chemical transformations.

**CHM 436 Total Synthesis in Organic Chemistry 3-3-0**
In this course we will look at important total synthesis of natural products, analyze the chemical steps and propose alternative routes.

## Brewing Science Courses

**BRS 401 Brewing Water 3-3-0**
Water, referred to as Hot Liquor in brewing jargon, provides the medium in which all of the chemical and biochemical reactions that are involved in producing beer take place. Additionally, the mineral content of the Hot Liquor is a critical factor in determining many of the final characteristics of the beer, provides many of the essential elements for healthy yeast growth, and contributes enormously to mash pH. This course provides an in depth, comprehensive look at water, its properties, and how its mineral contents affect all aspects of beer and the brewing process. Students cannot receive credit for both BRS 401 and BRS 501. If the student intends to enroll in the Graduate Certificate in Brewing Science, they should not take any of the BRS 40x courses because they cannot be counted for credit toward both a B.Sc. and a Graduate Certificate.

**BRS 402 Malt and Malting 3-3-0**
Malt is produced by the germination of grain (barley, wheat, rye, etc.) followed by application of heat (kilning). It is the heat regimen, together with the type of grain that determines the characteristics of the malt. The malt is the source of the starch that is converted to sugars which the yeast ferments to produce alcohol and it is also primarily responsible for the colour of the beer. Malt is also an important contributor to flavour, aroma, characteristics of the foam (head), mouth feel, and other characteristics of the beer. This course will cover malt from farming and harvesting of the grain, through the transformations of the malting process, to its chemical and biochemical transformations in the brew house. Students cannot receive credit for both BRS 402 and BRS 502. If the student intends to enroll in the Graduate Certificate in Brewing Science, they should not take any of the BRS 40x courses because they cannot be counted for credit toward both a B.Sc. and a Graduate Certificate.

**BRS 403 Hops 3-3-0**
Hops is the ingredient that contributes the characteristic bitterness of beer. It is also responsible for much of the flavours and aromas of beer, particularly those observed in heavily hopped beers such as India Pale Ale, American Pale Ale, and even hoppier double IPAs. The first section of this course will cover the farming, harvesting and processing of hops. The second section will cover hop chemistry, focusing on the resins (bittering agents) and essential oils (flavour and aroma contributors) of the hop cone and their transformations during the brewing process. Students cannot receive credit for both BRS 403 and BRS 503. If the student intends to enroll in the Graduate Certificate in Brewing Science, they should not take any of the BRS 40x courses because they cannot be counted for credit toward both a B.Sc. and a Graduate Certificate.

# Computer Science

## Faculty

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# Program Overview

Computer science is a subject related to almost every contemporary intellectual discipline, the arts (computer-generated art, verification of historical documents, syntax study of languages including translation, etc.), social sciences (correlating experimental data, simulation, artificial intelligence studies), natural sciences (has always had application in this area), business and government (the largest single groups of users), education (computer-aided instruction, artificial intelligence), medicine, etc.

The department offers a wide selection of programs, ranging from broad to specialized:

**1) Undergraduate B.Sc. Degree Programs**
I. B.Sc, Honours in Computer Science
II. B.Sc, Major in Computer Science

**2) A multidisciplinary B.A. with a Major in Information Technology (BAIT)**

**3) Minor in Computer Science**

**4) Certificate Program in Computer Science**

***Note:*** *A Co-op program is offered for all students in programs 2) and 3) above. Please refer to the Co-op section.*

**5) Master's Degree Program (see *Graduate Programs* section)**
I. Thesis Option
II. Project Option