

# Chemistry and Brewing Science

## Faculty

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## Program Overview

The Chemistry Department offers four distinct programs — Chemistry Honours, Chemistry Major, Chemistry Minor and Brewing Science Minor. Our three chemistry programs provide students with a balanced, rich, and practical education in all sub-disciplines of Chemistry (Analytical, Biochemical, 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. The Minor in Brewing Science gives the opportunity to our student community to learn about the brewing process and science behind beer brewing.

Class sizes in chemistry and brewing science 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 Benchtop NMR, a GC/MS, a MP-AES and a HPLC/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
CHM 191 and CHL 191	CHM 192 and CHL 192
BIO 196 and BIL 196	PHY 192 and PHL 192
PHY 191 and PHL 191	MAT 192
MAT 191	Humanities Option <sup>1</sup>
Humanities Option <sup>1</sup>	Arts and Science Option <sup>2</sup>

<sup>1</sup> *The Humanities optional courses can be selected from the writing-intensive courses (course codes ending by W) or they can be selected in the following disciplines: Classical Studies (CLA), English (ENG), History (HIS), Liberal Arts (LIB), Philosophy (PHI) and Religion, Society and Culture (RSC).*

<sup>2</sup> *The Arts and Science requirement consist in taking at least three credits in either the Division of Humanities or the Division of Social Sciences.*

## Chemistry Honours (81 credits)

HONCHEM

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 14 co-requisite lab courses. The Chemistry Honours degree program is shown in Table 2.

### 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 141, CHM 341 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 225 or CHM 245, CHM 231 or CHM 331 and all co-requisite labs).

**Table 2. Honours Chemistry Program<sup>1</sup>**

	Fall Semester	Winter Semester
<b>Year 2</b>	CHM 111 and CHL 111 CHM 121 CHM 141 and CHL 141 BIO 201 Option <sup>2</sup>	CHM 211 and CHL 211 CHM 131 CHM 341 and CHL 341 BCH 210 Option <sup>2</sup>
<b>Year 3</b>	CHM 311 CHM 231 and CHL 231 <sup>3</sup> Science option <sup>4</sup> Option <sup>2</sup> Option <sup>2</sup>	Chem. Option <sup>5</sup> CHM 225 and CHL 225 <sup>6</sup> BCH 313 and BCL 313 Option <sup>2</sup> Option <sup>2</sup>
<b>Year 4</b>	CHM 331 / CHL 331 <sup>3</sup> CHM 471 <sup>7</sup> CHM 499 <sup>8</sup> BIO 386 <sup>9</sup> Option <sup>2</sup>	CHM 245 and CHL 245 <sup>6</sup> CHM 471 <sup>7</sup> CHM 499 <sup>8</sup> Option <sup>2</sup> Option <sup>2</sup>

<sup>1</sup> All Chemistry students must take any two Humanities lecture courses in the first year. For details, please refer to the Divisional section of the Academic Calendar. Students with a D.E.C. may be credited with these options.

<sup>2</sup> Chemistry Honours students must also take one lecture course from the Humanities or the Social Sciences and one science option and two 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.

<sup>3</sup> CHM231 / CHM331 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.

<sup>4</sup> Students doing honours are encouraged to take a science option based on the field of their specialization:

**Physical chemistry:** MAT 108 or PHY 206 or MAT 206

**Analytical chemistry:** MAT 103 or MAT 310

**Organic chemistry:** BCH 311 or BIO 208

**Environment:** MAT 103

<sup>5</sup> Students registered in the honours program will have to complete a CHM 400 level course in the field of their honours research project as an independent study.

<sup>6</sup> CHM 225 and CHM 245, 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.

<sup>7</sup> CHM 471 is a full-year, 3-credit course.

<sup>8</sup> CHM 499 is a full-year, 6-credit research project.

<sup>9</sup> Honours students should register in BIO 386 – Scientific writing. Permission from the instructor is required. If denied, this course can be replaced by a free elective.

**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 14 co-requisite lab courses. The Chemistry Major degree program is shown in Table 3. 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<sup>1</sup>**

	Fall Semester	Winter Semester
<b>Year 2</b>	CHM 111 and CHL 111 CHM 121 CHM 141 and CHL 141 BIO 201 Option <sup>2</sup>	CHM 211 and CHL 211 CHM 341 and CHL 341 BCH 210 CHM 131 Option <sup>2</sup>
<b>Year 3</b>	CHM 231 and CHL 231 <sup>3</sup> CHM 311 Option <sup>2</sup> Option <sup>2</sup> Option <sup>2</sup>	CHM 225 and CHL 225 <sup>4</sup> BCH 313 and BCL 313 Option <sup>2</sup> Option <sup>2</sup> Option <sup>2</sup>
<b>Year 4</b>	CHM 331 and CHL 331 <sup>3</sup> CHM 371 <sup>5</sup> Option <sup>2</sup> Option <sup>2</sup> Option <sup>2</sup>	CHM 245 and CHL245 <sup>4</sup> CHM 371 <sup>5</sup> Option <sup>2</sup> Option <sup>2</sup> Option <sup>2</sup>

<sup>1</sup> All Chemistry students must take any two Humanities lecture courses in their first year of study. For details, please refer to the Divisional section of the Academic Calendar. Students with a D.E.C. may be credited with these options.

<sup>2</sup> Students must also take one course from either the Humanities or the Social Sciences and six 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.

<sup>3</sup> CHM 231 and CHM 331, 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.

<sup>4</sup> CHM 225 and CHM 245, 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.

<sup>5</sup> CHM 371 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, and their co-requisite labs, together with 3 one-semester 3-credit courses (and their co-requisite labs) chosen from CHM 311, CHM 411, CHM 231, CHM 331, CHM 341, BCH 210 or BCH 313.

### Recommended Electives

MAT 108, MAT 206 and PHY 206 are recommended electives for students pursuing a career in Physical Chemistry.

MAT 103, MAT 310 and PHY 206 are recommended electives for students pursuing a career in Analytical Chemistry.

BCH 311 and BIO 208 are recommended electives for students pursuing a career in Organic Chemistry.

MAT 103 is a recommended elective for students pursuing a career in Environmental Chemistry.

## Minor In Brewing Science (24 credits) MINBRW

The Minor in Brewing Science gives the opportunity to our student community to learn about the brewing process and science behind beer brewing while completing a major/honors in another field.

### Required Courses (18 course credits):

BRS 401 Brewhouse Chemistry  
 BRS 402 Malt and Malting  
 BRS 403 Hops  
 BRS 404 Microorganisms in the Brewery  
 BRS 405 Chemical Analysis of Beer and its Ingredients  
 BRS 498 Brewing Practicum I

### Required optional courses\* (6 course credits from list):

BRS 406 Business of Brewing  
 BRS 499 Brewing Practicum II  
 CHM 111 Organic Chemistry  
 CHM 141 Analytical Chemistry  
 AGR 210 Food Science  
 BCH 311 Proteins  
 BCH 312 Lipids and Bio-membranes  
 BCH 313 Metabolism  
 BIO 352 Microbiology  
 PHY 101 Statistical Methods in Experimental Science

\* Note that students cannot select a course that is part of his/her major/honours from the list of required optional courses. They must select courses outside of their program in order to avoid double counting.

## 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 2 lab credits of physical chemistry.
2. 9 course credits and 3 lab credits of analytical chemistry.
3. 9 course credits and 2 lab credits of organic chemistry.
4. 6 course credits and 1 lab credit of inorganic chemistry.
5. 6 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 111 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 orbitals 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*

### CHL 311 Organic Chemistry Laboratory III 1-0-4

Laboratory and spectroscopic techniques used in the synthesis, separation, and purification of simple organic compounds.

### 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 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 225 Inorganic Chemistry II 3-3-0

This course provides students with a survey of inorganic chemistry. The course begins with the general chemistry of the inorganic elements (properties, oxidation states, introduction to their chemistry). This is followed up with two distinct sections. 1) Transition Metal Chemistry will look at crystal and ligand field theory, Werner complexes, and introduce organometallic complexes. 2) Main Group Chemistry will look at the structure and bonding of a selection of compounds from each group of the p-block.

*Pre-requisites: CHM 121, CHM 111 / CHL 111*

*Co-requisites: CHL 225*

### CHL 225 Inorganic Chemistry II Lab 1-0-4

This lab is comprised of experiments that provide an illustration of many of the topics covered in CHM 225. It combines experimental methods typical of inorganic chemistry (e.g. inert atmosphere) with the use of the instrumentation necessary to probe the properties of interest (e.g. FT-IR, UV-Vis, Magnetochemistry)

*Co-requisites: CHM 225*

### 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-requisite: CHM 225*

## 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.*

### CHL 131 Physical Chemistry Laboratory I 1-0-4

A series of experiments in Physical Chemistry to complement CHM 131.

*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*

*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 H<sub>2</sub><sup>+</sup> molecular ion, via [Ni(En)<sub>3</sub>]<sup>2+</sup> 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*

**CHM 245 Instrumental Analysis 3-3-0**

This course provides students within depth coverage of the theory of instrumental methods of analysis. The topics covered will be chromatography theory and chromatographic methods, atomic absorption and emission spectrometry, and electrochemical methods.

*Prerequisites: CHM 121, CHM 141 and CHL 141*

**CHL 245 Instrumental Analysis Laboratory 1-0-4**

This lab focuses mainly on learning to use the Department's extensive suite of chromatographic instrumentation (GC, GC-MS, HPLC, LC-MS) by performing numerous analyses on each instrument. The analyses will illustrate the importance of chromatography as an analytical method by using examples from forensic, environmental, and food and beverage science.

*Co-requisite: CHM 245*

**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 111 and CHM 141*

*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 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*

**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.

*Prerequisites: CHM 141, CHL 141, CHM 191, CHL 191, CHM 192, CHL 192, CHM 341, CHL 341*

## 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. *For science students, this course cannot be taken for science credit, but only for free elective credits. For non-science students, this course can count as a science elective course.*

**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. *For science students, this course cannot be taken for science credit, but only for free elective credits. For non-science students, this course can count as a science elective course.*

## 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 Brewhouse Chemistry 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.

**BRS 404 Microorganisms in the Brewery 3-3-0**  
The role of brewer's yeast in the brewing process, particularly its fermentation of sugars to produce alcohol, is fairly well known. However, yeast is also responsible for producing dozens, if not hundreds, of chemical compounds as it metabolizes the sugars, amino acids, and other components during fermentation. Many of these compounds contribute significantly to the flavour and aroma of beer. Other microorganisms, such as wild yeast and bacteria, are also potential contributors to the complex chemistry and biochemistry that occurs in the fermenter; sometimes to the benefit of the beer but more often to its detriment. This course will look at all of the microorganisms that are commonly found in the brewery and provide a detailed description of their chemistry and thus their impact on beer flavour and aroma.  
*Prerequisites: CHM 211 and BIO 201*

**BRS 405 Chemical Analysis of Beer and its Ingredients 3-3-0**  
As a food product, beer is rigorously controlled at both the federal and provincial levels of government. Part of this process is ensuring that a number of analytical parameters are accurately reported (e.g. alcohol by volume). Many other properties of beer are indicators of the efficacy of the brewing process and whether the brewer is producing a quality product. Analysis of the ingredients of beer (water, malt, hops, yeast) is essential to ensure that standards of quality necessary to produce good beer are met. This course will provide students with an in depth look at the chemical analyses commonly used to analyse beer and its precursors, using the methods database of the American Society of Brewing Chemists. Students will use what they learn to analyse the ingredients and the beer that they use / produce in the co-requisite practicum in brewing.  
*Prerequisites: CHM 141 and CHL 141*

**BRS 406 The Business of Brewing**

3-3-0

There is a great deal of time and hard work that goes into planning, building, equipping, and running even a small microbrewery. When a microbrewery fails, it is generally because the ownership doesn't have a particular skill set, whether it be on the brewing side or on the business side. This course will take students through all of the steps necessary to get a microbrewery from the planning to the operation stage, and also introduce them to the business knowledge necessary for running a successful microbrewery.

**BRS 498 Practicum in Brewing I**

3-3-0

Ultimately, brewing is a hands-on activity. The brewer must pay careful attention at every step of the brewing process in order to ensure that they have the best chance of producing the desired final product. Even then, the beer, although well crafted, may not exhibit the characteristics of flavour, aroma, colour, bitterness, etc. that the brewer was attempting to produce. Recipe development is a wonderful example of the scientific method and this approach to brewing will be the main focus of this course. Upon completion of BRS 498, students will receive more than 90 hours of brewing experience, constantly comparing what they observe in the brewery with what they are learning in their BRS lecture courses. The aim is to produce a brewer who is proficient in the brewery but also understands the complex chemistry and biochemistry that is involved in producing the highest quality beers.

*Prerequisites: BRS 401*

**BRS 499 Practicum in Brewing II**

3-3-0

Ultimately, brewing is a hands-on activity. The brewer must pay careful attention at every step of the brewing process in order to ensure that they have the best chance of producing the desired final product. Even then, the beer, although well crafted, may not exhibit the characteristics of flavour, aroma, colour, bitterness, etc. that the brewer was attempting to produce. Recipe development is a wonderful example of the scientific method and this approach to brewing will be the main focus of this course. Upon completion of BRS 498 and BRS499, students will receive more than 180 hours of brewing experience, constantly comparing what they observe in the brewery with what they are learning in their BRS lecture courses. The aim is to produce a brewer who is proficient in the brewery but also understands the complex chemistry and biochemistry that is involved in producing the highest quality beers.

*Prerequisites: BRS 401 and BRS 498*

# 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