Chemistry and Brewing Science

Faculty
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Assistant Professor
Chair of the Department
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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, 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 Benchtop NMR, a GC/MS 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

<table>
<thead>
<tr>
<th>Fall Semester</th>
<th>Winter Semester</th>
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</thead>
<tbody>
<tr>
<td>CHM 191 and CHL 191</td>
<td>CHM 192 and CHL 192</td>
</tr>
<tr>
<td>BIO 196 and BIL 196</td>
<td>PHY 192 and PHL 192</td>
</tr>
<tr>
<td>PHY 191 and PHL 191</td>
<td>MAT 192</td>
</tr>
<tr>
<td>MAT 191</td>
<td>Humanities Option</td>
</tr>
<tr>
<td>ENG 116</td>
<td>Humanities Option</td>
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</tbody>
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Chemistry Honours (81 credits)

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall Semester</th>
<th>Winter Semester</th>
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<tbody>
<tr>
<td>2</td>
<td>CHM 111 and CHL 111</td>
<td>CHM 211 and CHL 211</td>
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<tr>
<td></td>
<td>CHM 121</td>
<td>CHM 131</td>
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<tr>
<td></td>
<td>CHM 141 and CHL 141</td>
<td>CHM 341 and CHL 341</td>
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<tr>
<td></td>
<td>BIO 201</td>
<td>BCH 210</td>
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<tr>
<td></td>
<td>Option²</td>
<td>Option²</td>
</tr>
<tr>
<td>Year 3</td>
<td>CHM 311</td>
<td>Chem. Option⁵</td>
</tr>
<tr>
<td></td>
<td>CHM 231 and CHL 231</td>
<td>CHM 225 and CHL 225⁶</td>
</tr>
<tr>
<td></td>
<td>Science option⁴</td>
<td>BCH 313 and BCL 313⁵</td>
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<tr>
<td></td>
<td>Option²</td>
<td>Option²</td>
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<tr>
<td></td>
<td>Option²</td>
<td>Option²</td>
</tr>
<tr>
<td>Year 4</td>
<td>CHM 331 / CHL 331³</td>
<td>CHM 245 and CHL 245⁶</td>
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<tr>
<td></td>
<td>CHM 4717</td>
<td>CHM 4717</td>
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<tr>
<td></td>
<td>CHM 499⁸</td>
<td>CHM 499⁸</td>
</tr>
<tr>
<td></td>
<td>BIO 386⁹</td>
<td>Option²</td>
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<td></td>
<td>Option²</td>
<td>Option²</td>
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</tbody>
</table>

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 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.

³ CHM 331 / CHL 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.
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

<table>
<thead>
<tr>
<th>Fall Semester</th>
<th>Winter Semester</th>
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<tbody>
<tr>
<td><strong>Year 2</strong></td>
<td></td>
</tr>
<tr>
<td>CHM 111 and CHL 111</td>
<td>CHM 211 and CHL 211</td>
</tr>
<tr>
<td>CHM 121</td>
<td>CHM 341 and CHL 341</td>
</tr>
<tr>
<td>CHM 141 and CHL 141</td>
<td>BCH 210</td>
</tr>
<tr>
<td>BIO 201</td>
<td>CHM 131</td>
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<tr>
<td>Option²</td>
<td>Option²</td>
</tr>
<tr>
<td><strong>Year 3</strong></td>
<td></td>
</tr>
<tr>
<td>CHM 231 and CHL 231³</td>
<td>CHM 225 and CHL 225⁴</td>
</tr>
<tr>
<td>CHM 311</td>
<td>BCH 313 and BCL 313</td>
</tr>
<tr>
<td>Option²</td>
<td>Option²</td>
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<tr>
<td>Option²</td>
<td>Option²</td>
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<tr>
<td>Option²</td>
<td>Option²</td>
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<tr>
<td><strong>Year 4</strong></td>
<td></td>
</tr>
<tr>
<td>CHM 331 and CHL 3313</td>
<td>CHM 245 and CHL 2454</td>
</tr>
<tr>
<td>CHM 371⁵</td>
<td>CHM 371³</td>
</tr>
<tr>
<td>Option²</td>
<td>Option²</td>
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<td>Option²</td>
<td>Option²</td>
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<tr>
<td>Option²</td>
<td>Option²</td>
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</tbody>
</table>

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. Students taking a Chemistry Minor have a one-lecture course (3 credits) reduction towards the credits necessary for their degree.

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.

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**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 191</td>
<td>General Chemistry I</td>
<td>3-3-0</td>
</tr>
<tr>
<td>CHL 191</td>
<td>Introductory Chemistry Laboratory I</td>
<td>1-0-4</td>
</tr>
<tr>
<td>CHM 192</td>
<td>General Chemistry II</td>
<td>3-3-0</td>
</tr>
<tr>
<td>CHL 192</td>
<td>Introductory Chemistry Laboratory II</td>
<td>1-0-4</td>
</tr>
</tbody>
</table>

**Organic Chemistry**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 111</td>
<td>Organic Chemistry I: Introductory</td>
<td>3-3-0</td>
</tr>
<tr>
<td>CHM 211</td>
<td>Organic Chemistry II: Introductory</td>
<td>3-3-0</td>
</tr>
<tr>
<td>CHM 311</td>
<td>Organic Chemistry III</td>
<td>3-3-0</td>
</tr>
<tr>
<td>CHM 411</td>
<td>Organic Chemistry IV</td>
<td>3-3-0</td>
</tr>
<tr>
<td>CHL 300</td>
<td>Advanced Methods in Organic Chemistry</td>
<td>1-0-4</td>
</tr>
</tbody>
</table>

**Inorganic Chemistry**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHM 121</td>
<td>Inorganic Chemistry I</td>
<td>3-3-0</td>
</tr>
<tr>
<td>CHM 225</td>
<td>Inorganic Chemistry II</td>
<td>3-3-0</td>
</tr>
</tbody>
</table>

Further details on each course can be found in the full program description.
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 probed the properties of interest (e.g. FT-IR, UV-Vis, Magnetochrometry
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 electrode chemistry. This course may be taken online by students who are not registered in a Bishop’s Chemistry Program, subject to approval by the instructor.
Pre-requisites:  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.

CHM 231  Physical Chemistry II  3-3-0
Chemical thermodynamics; Zeroth Law and equations of state; First Law and thermochrometry; 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 131  Physical Chemistry Laboratory I  1-0-4
A series of experiments in Physical Chemistry to complement CHM 131.
Co-requisite:  CHM 131

CHM 301  Chemical Thermodynamics  3-3-0
This course will provide students with an overview of routine and state-of-the-art instrumental methods of analysis. The topics covered will be chromatography theory and chromatographic methods, atomic absorption and emission spectrometry, and electrochemical methods.
Pre-requisites:  CHM 121, CHM 141 and CHL 141

CHM 311  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-requisite:  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
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

CHM 332  Analytical Chemistry  3-3-0
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 341  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.
Pre-requisites:  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 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

CHL 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

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.
Pre-requisites:  CHM 141, CHL 141, CHM 191, CHM 192, CHL 192, CHM 341, CHL 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.
Pre-requisites:  CHM 141, CHL 141, CHM 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
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

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 cannot be taken for science credit.

**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.
Computer Science

Faculty
Madjid Allili, B.Sc.(Algiers), M.Sc., Ph.D.(Sherbrooke); Professor
Chair of the Department
Layachi Bentabet, B.Sc.(Eng.National Polytechnic, Algeria), M.Sc.(Elec.Eng. Institut national des sciences appliquées, Lyon), Ph.D.(Sherbrooke); Professor
Stefan D. Bruda, B.Sc.Eng., M.Sc., Ph.D. (Queen’s); Professor
Russell Butler
Lin C. Jensen, B.Sc. (Stanford), M. Sc. (Concordia); Lecturer

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