# Chemistry

This section presents the requirements for programs in:

- Chemistry B.Sc. Honours
- Chemistry B.Sc. General
- Chemistry with Concentration in Nanotechnology B.Sc. Honours
- Chemistry and Earth Sciences B.Sc. Combined Honours
- Chemistry and Physics B.Sc. Combined Honours
- Minor in Chemistry

## Graduation Requirements

In addition to the requirements listed below, students must satisfy:

1. the University regulations (see the Academic Regulations of the University section of this Calendar),
2. the common regulations applying to all B.Sc. programs including those relating to Science Continuation and Breadth requirements (see the Academic Regulations for the Bachelor of Science Degree).

Students should consult with the Department when planning their program and selecting courses.

## Program Requirements

### Chemistry B.Sc. Honours (20.0 credits)

**A. Credits Included in the Major CGPA (10.5 credits)**

1. **6.0 credits in:**
   - CHEM 1001 [0.5] General Chemistry I
   - CHEM 1002 [0.5] General Chemistry II
   - CHEM 2103 [0.5] Physical Chemistry I
   - CHEM 2203 [0.5] Organic Chemistry I
   - CHEM 2302 [0.5] Analytical Chemistry I
   - CHEM 2303 [0.5] Analytical Chemistry II
   - CHEM 2501 [0.5] Introduction to Inorganic and Bioinorganic Chemistry
   - CHEM 3100 [0.5] Physical Chemistry II
   - CHEM 3101 [0.5] Quantum Chemistry
   - CHEM 3201 [0.5] Advanced Organic Chemistry I
   - CHEM 3503 [0.5] Inorganic Chemistry I
   - CHEM 3504 [0.5] Inorganic Chemistry II

2. **1.0 credit from:**
   - CHEM 4907 [1.0] Honours Essay and Research Proposal
   - CHEM 4908 [1.0] Research Project and Seminar

3. **0.5 credit in:**
   - CHEM 2204 [0.5] Organic Chemistry II

4. **1.0 credit from:**
   - CHEM 3106 [0.5] Computational Chemistry Methods Laboratory
   - CHEM 3107 [0.5] Experimental Methods in Nanoscience
   - CHEM 3205 [0.5] Experimental Organic Chemistry
   - CHEM 3305 [0.5] Advanced Analytical Chemistry Laboratory

5. **0.5 credit in:**
   - CHEM 3401 [0.5] Physical Aspects of Biochemistry (or any BIOC course)

6. **1.0 credit in CHEM at the 4000 level, or 0.5 credit in BIOC at the 4000 level and:**
   - BIOC 3102 [0.5] General Biochemistry II

7. **0.5 credit in CHEM at the 3000 or 4000 level**

**B. Credits Not Included in the Major CGPA (9.5 credits)**

8. **2.0 credits in:**
   - MATH 1004 [0.5] Calculus for Engineering or Physics
   - MATH 1107 [0.5] Linear Algebra I
   - MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
   - MATH 2007 [0.5] Elementary Calculus II
   - MATH 2008 [0.5] Intermediate Calculus

9. **1.0 credit from:**
   - PHYS 1003 [0.5] & PHYS 1004 [0.5] Introductory Mechanics and Thermodynamics
   - PHYS 1007 [0.5] & PHYS 1008 [0.5] Elementary University Physics I

10. **0.5 credit in Science Continuation (not CHEM)**

11. **1.0 credit in Science Faculty Electives at the 1000 level, not BIOL 1902**

12. **2.0 credits in Science Faculty Electives or Science Continuation Courses, not BIOL 1902**

13. **0.5 credit in:**
   - NSCI 1000 [0.5] Seminar in Science (or approved courses outside the faculties of Science and Engineering and Design)

14. **1.5 credits in approved courses outside the faculties of Science and Engineering and Design (may include NSCI 1000 if not used above)**

15. **1.0 credit in free elective.**

Total Credits: 20.0

### Chemistry B.Sc. General (15.0 credits)

**A. Credits Included in the Major CGPA (6.0 credits)**

1. **4.5 credits in:**
   - CHEM 1001 [0.5] General Chemistry I
   - CHEM 1002 [0.5] General Chemistry II
   - CHEM 2103 [0.5] Physical Chemistry I
   - CHEM 2203 [0.5] Organic Chemistry I
   - CHEM 2302 [0.5] Analytical Chemistry I
   - CHEM 2303 [0.5] Analytical Chemistry II
   - CHEM 3100 [0.5] Physical Chemistry II
   - CHEM 3101 [0.5] Quantum Chemistry
   - CHEM 3201 [0.5] Advanced Organic Chemistry I
   - CHEM 3503 [0.5] Inorganic Chemistry I
   - CHEM 3504 [0.5] Inorganic Chemistry II

2. **1.0 credit from:**
   - CHEM 4907 [1.0] Honours Essay and Research Proposal
   - CHEM 4908 [1.0] Research Project and Seminar

3. **0.5 credit in:**
   - CHEM 2204 [0.5] Organic Chemistry II

4. **1.0 credit from:**
   - CHEM 3106 [0.5] Computational Chemistry Methods Laboratory
   - CHEM 3107 [0.5] Experimental Methods in Nanoscience
   - CHEM 3205 [0.5] Experimental Organic Chemistry
   - CHEM 3305 [0.5] Advanced Analytical Chemistry Laboratory

5. **0.5 credit in:**
   - CHEM 3401 [0.5] Physical Aspects of Biochemistry (or any BIOC course)

6. **1.0 credit in CHEM at the 4000 level, or 0.5 credit in BIOC at the 4000 level and:**
   - BIOC 3102 [0.5] General Biochemistry II

7. **0.5 credit in CHEM at the 3000 or 4000 level**

8. **2.0 credits in:**
   - MATH 1004 [0.5] Calculus for Engineering or Physics
   - MATH 1107 [0.5] Linear Algebra I
   - MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
   - MATH 2007 [0.5] Elementary Calculus II
   - MATH 2008 [0.5] Intermediate Calculus

9. **1.0 credit from:**
   - PHYS 1003 [0.5] & PHYS 1004 [0.5] Introductory Mechanics and Thermodynamics
   - PHYS 1007 [0.5] & PHYS 1008 [0.5] Elementary University Physics I

10. **0.5 credit in Science Continuation (not CHEM)**

11. **1.0 credit in Science Faculty Electives at the 1000 level, not BIOL 1902**

12. **2.0 credits in Science Faculty Electives or Science Continuation Courses, not BIOL 1902**

13. **0.5 credit in:**
   - NSCI 1000 [0.5] Seminar in Science (or approved courses outside the faculties of Science and Engineering and Design)

14. **1.5 credits in approved courses outside the faculties of Science and Engineering and Design (may include NSCI 1000 if not used above)**

15. **1.0 credit in free elective.**

Total Credits: 15.0
Chemistry

B.Sc. Honours (20.0 credits)

A. Credits Included in the Major CGPA (10.5 credits)

1. 8.5 credits in:
   - CHEM 1001 [0.5] General Chemistry I
   - CHEM 1002 [0.5] General Chemistry II
   - CHEM 2103 [0.5] Physical Chemistry I
   - CHEM 2203 [0.5] Organic Chemistry I
   - CHEM 2302 [0.5] Analytical Chemistry I
   - CHEM 2501 [0.5] Introduction to Inorganic and Bioinorganic Chemistry
   - CHEM 3100 [0.5] Physical Chemistry II
   - CHEM 2303 [0.5] Analytical Chemistry II
   - CHEM 3101 [0.5] Quantum Chemistry
   - CHEM 3107 [0.5] Experimental Methods in Nanoscience
   - CHEM 3201 [0.5] Advanced Organic Chemistry I
   - CHEM 3503 [0.5] Inorganic Chemistry I
   - CHEM 3600 [0.5] Introduction to Nanotechnology
   - CHEM 4103 [0.5] Surface Chemistry and Nanostructures
   - CHEM 4104 [0.5] Physical Methods of Nanotechnology
   - CHEM 4908 [1.0] Research Project and Seminar

2. 0.5 credit in:
   - CHEM 2204 [0.5] Organic Chemistry II

3. 1.0 credit from:
   - CHEM 3106 [0.5] Computational Chemistry Methods Laboratory
   - CHEM 3205 [0.5] Experimental Organic Chemistry
   - CHEM 3305 [0.5] Advanced Analytical Chemistry Laboratory
   - CHEM 3504 [0.5] Inorganic Chemistry II

4. 0.5 credit in:
   - CHEM 3401 [0.5] Physical Aspects of Biochemistry (or any BIOC course)

B. Credits Not Included in the Major CGPA (9.0 credits)

5. 2.0 credits in:
   - MATH 1004 [0.5] Calculus for Engineering or Physics
   - MATH 1107 [0.5] Linear Algebra I
   - MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
   - MATH 2008 [0.5] Intermediate Calculus

6. 1.0 credit from:
   - PHYS 1003 [0.5] Introductory Mechanics and Thermodynamics
   - PHYS 1004 [0.5] Introductory Electromagnetism and Wave Motion
   - PHYS 1007 [0.5] Elementary University Physics I
   - PHYS 1008 [0.5] Elementary University Physics II

7. 0.5 credit in Science Continuation (not CHEM) 0.5

8. 1.0 credit in Science Faculty Electives at the 1000 level, not BIOL 1902 1.0

9. 1.5 credit in Science Faculty Electives or Science Continuation Courses, not BIOL 1902 1.5

10. 0.5 credit in NSCI 1000 or approved courses outside the faculties of Science and Engineering and Design 0.5

11. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design (may include NSCI 1000, if not used above) 1.5

12. 1.0 credit in free electives. 1.0

Total Credits 15.0

Chemistry with Concentration in Nanotechnology

B.Sc. Honours (20.0 credits)

Chemistry and Earth Sciences

B.Sc. Combined Honours (20.0 credits)

A. Credits Included in the Major CGPA (13.5 credits)

1. 4.0 credits in:
   - CHEM 1001 [0.5] General Chemistry I
   - CHEM 1002 [0.5] General Chemistry II
   - CHEM 2103 [0.5] Physical Chemistry I
   - CHEM 2302 [0.5] Analytical Chemistry I
   - CHEM 2501 [0.5] Introduction to Inorganic and Bioinorganic Chemistry
   - CHEM 3100 [0.5] Physical Chemistry II
   - CHEM 2303 [0.5] Analytical Chemistry II
   - CHEM 3107 [0.5] Experimental Methods in Nanoscience
   - CHEM 3201 [0.5] Advanced Organic Chemistry I
   - CHEM 3503 [0.5] Inorganic Chemistry I
   - CHEM 3600 [0.5] Introduction to Nanotechnology
   - CHEM 4103 [0.5] Surface Chemistry and Nanostructures
   - CHEM 4104 [0.5] Physical Methods of Nanotechnology
   - CHEM 4908 [1.0] Research Project and Seminar

2. 1.0 credit in CHEM at the 4000-level 1.0

3. 1.0 credit in:
   - ERTH 1006 [0.5] Exploring Planet Earth
   - ERTH 1009 [0.5] The Earth System Through Time

4. 3.0 credits in:
   - ERTH 2102 [0.5] Mineralogy to Petrology
   - ERTH 2104 [0.5] Igneous Systems, Geochemistry and Processes
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERTH 2105</td>
<td>Geodynamics</td>
</tr>
<tr>
<td>ERTH 2314</td>
<td>Sedimentation and Stratigraphy</td>
</tr>
<tr>
<td>ERTH 2406</td>
<td>Geology and Map Interpretation</td>
</tr>
<tr>
<td>ERTH 2802</td>
<td>Field Geology I</td>
</tr>
<tr>
<td>ERTH 3203</td>
<td>Sedimentology</td>
</tr>
<tr>
<td>ERTH 3206</td>
<td>Sedimentary Depositional Systems</td>
</tr>
<tr>
<td>ERTH 3003</td>
<td>Geochemistry and Geochronology</td>
</tr>
<tr>
<td>ERTH 3204</td>
<td>Mineral Deposits</td>
</tr>
<tr>
<td>ERTH 3207</td>
<td>Metamorphic Petrology and Processes</td>
</tr>
<tr>
<td>ERTH 3806</td>
<td>Structural Geology</td>
</tr>
<tr>
<td>ERTH 3203</td>
<td>Sedimentology</td>
</tr>
<tr>
<td>ERTH 3206</td>
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<tr>
<td>ERTH 3003</td>
<td>Geochemistry and Geochronology</td>
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<tr>
<td>ERTH 3204</td>
<td>Mineral Deposits</td>
</tr>
<tr>
<td>ERTH 3207</td>
<td>Metamorphic Petrology and Processes</td>
</tr>
<tr>
<td>ERTH 3806</td>
<td>Structural Geology</td>
</tr>
<tr>
<td>CHEM 4907</td>
<td>Honours Essay and Research Proposal</td>
</tr>
<tr>
<td>CHEM 4908</td>
<td>Research Project and Seminar</td>
</tr>
<tr>
<td>ERTH 4908</td>
<td>Honours Thesis</td>
</tr>
<tr>
<td>ERTH 4909</td>
<td>Research in Earth Sciences (and 0.5 credit in ERTH at the 4000-level)</td>
</tr>
<tr>
<td>MATH 1004</td>
<td>Calculus for Engineering or Physics</td>
</tr>
<tr>
<td>MATH 1107</td>
<td>Linear Algebra I</td>
</tr>
<tr>
<td>STAT 2507</td>
<td>Introduction to Statistical Modeling I</td>
</tr>
<tr>
<td>GEOM 2007</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>PHYS 1003</td>
<td>Introductory Mechanics and Thermodynamics</td>
</tr>
<tr>
<td>PHYS 1004</td>
<td>Introductory Electromagnetism and Wave Motion</td>
</tr>
<tr>
<td>PHYS 1007</td>
<td>Elementary University Physics I</td>
</tr>
<tr>
<td>PHYS 1008</td>
<td>Elementary University Physics II</td>
</tr>
<tr>
<td>MATH 2007</td>
<td>Elementary Calculus II</td>
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<td>MATH 1107</td>
<td>Linear Algebra I</td>
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<tr>
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<tr>
<td>PHYS 1007</td>
<td>Elementary University Physics I</td>
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<tr>
<td>PHYS 1008</td>
<td>Elementary University Physics II</td>
</tr>
<tr>
<td>BIOL 1104</td>
<td>Foundations of Biology II</td>
</tr>
<tr>
<td>PHYS 1002</td>
<td>Foundations of Physics II (recommended)</td>
</tr>
<tr>
<td>CHEM 2103</td>
<td>Physical Chemistry I</td>
</tr>
<tr>
<td>CHEM 2203</td>
<td>Organic Chemistry I</td>
</tr>
<tr>
<td>CHEM 2204</td>
<td>Organic Chemistry II</td>
</tr>
<tr>
<td>CHEM 2501</td>
<td>Introduction to Inorganic and Bioinorganic Chemistry</td>
</tr>
<tr>
<td>CHEM 3100</td>
<td>Physical Chemistry II</td>
</tr>
<tr>
<td>CHEM 3102</td>
<td>Methods of Computational Chemistry</td>
</tr>
<tr>
<td>CHEM 3503</td>
<td>Inorganic Chemistry I</td>
</tr>
<tr>
<td>CHEM 4102</td>
<td>Advanced Topics in Physical Chemistry II</td>
</tr>
<tr>
<td>CHEM 4908</td>
<td>Research Project and Seminar</td>
</tr>
<tr>
<td>PHYS 4909</td>
<td>Fourth-Year Project</td>
</tr>
<tr>
<td>PHYS 4907</td>
<td>Fourth-Year Project</td>
</tr>
<tr>
<td>PHYS 4908</td>
<td>Fourth-Year Project</td>
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<tr>
<td>CHEM 3106</td>
<td>Computational Chemistry Methods Laboratory</td>
</tr>
<tr>
<td>CHEM 3107</td>
<td>Experimental Methods in Nanoscience</td>
</tr>
<tr>
<td>CHEM 3108</td>
<td>Methods of Computational Chemistry</td>
</tr>
<tr>
<td>CHEM 3503</td>
<td>Inorganic Chemistry I</td>
</tr>
<tr>
<td>CHEM 4102</td>
<td>Advanced Topics in Physical Chemistry II</td>
</tr>
<tr>
<td>CHEM 3106</td>
<td>Computational Chemistry Methods Laboratory</td>
</tr>
<tr>
<td>CHEM 3107</td>
<td>Experimental Methods in Nanoscience</td>
</tr>
</tbody>
</table>

**Note:** for Item 5 above, ERTH 3203 is required if prerequisite conditions are met.
Graduation:

General programs must present the following credits at graduation:

- Students in Bachelor of Science Honours, Major, or Breadth Requirement for the B.Sc. Degree must be in Good Standing.

The regulations presented in this section apply to all Bachelor of Science programs. In addition to the requirements presented here, students must satisfy the University regulations common to all undergraduate students including the process of Academic Performance Evaluation (see the Academic Regulations of the University section of this Calendar).

Breadth Requirement for the B.Sc.

Students in Bachelor of Science Honours, Major, or General programs must present the following credits at graduation:

1. 2.0 credits in Science Continuation courses not in the major discipline. Students completing a double major are considered to have completed this requirement providing they have 2.0 credits in science continuation courses in each of the two majors.

2. 2.0 credits in courses outside of the faculties of Science and Engineering and Design (but may include NSCI 1000).

In most cases, the requirements for individual B.Sc. programs, as stated in this Calendar, contain these requirements, explicitly or implicitly.

Students admitted to B.Sc. programs by transfer from another institution must present at graduation (whether taken at Carleton or elsewhere):

1. 2.0 credits in courses outside of the faculties of Science and Engineering and Design (but may include NSCI 1000) if, on transfer, the student received credit for fewer than 10.0 credits.

2. 1.0 credit in courses outside of the faculties of Science and Engineering and Design (but may include NSCI 1000) if, on transfer, the student received credit for 10.0 or more credits.

Declared and Undeclared Students

Students who are registered in a program within the degree are called Declared students. Most students designate a program of study when they first apply for admission and so begin their studies as Declared students. Students may also choose to begin their studies within the B.Sc. degree without being registered in a program. These students are referred to as Undeclared students.

The recommended course pattern for Undeclared students is provided in the Undeclared entry of the Programs section of this Calendar. Undeclared students normally must apply to enter a program before beginning their second year of study. The Science Student Success Centre (SSSC) provides Undeclared students guidance to the appropriate support services in making this decision.

Change of Program within the B.Sc. Degree

Students may transfer to a program within the B.Sc. degree if upon entry to the new program they would be in good academic standing.

Other applications for change of program will be considered on their merits; students may be accepted in the new program in Good Standing or on Academic Warning.

Applications to declare or change their program within the B.Sc. Degree must be made online through Carleton Central by completing a Change of Program Elements (COPE) application form within the published deadlines. Acceptance into a program or into a program element or option is subject to any enrolment, and/or specific program, program element or option requirements as published in the relevant Calendar entry.

Minors, Concentrations and Specializations

Students may add a minor, concentration or specialization by completing a Change of Program Elements (COPE) application form online through Carleton Central. Acceptance into a minor, concentration or specialization requires that the student be in Good Standing and is
subject to any specific requirements of the intended Minor, Concentration or Specialization as published in the relevant Calendar entry.

**Experimental Science Requirement**

Students in B.Sc. Honours, Major, or General degree programs must present at graduation at least two full credits of experimental science chosen from two different departments or institutes from the list below:

**Approved Experimental Science Courses**

<table>
<thead>
<tr>
<th>Biochemistry</th>
<th>CHEM 1001 [0.5]</th>
<th>General Chemistry I</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOC 2200 [0.5]</td>
<td></td>
<td>Cellular Biochemistry</td>
</tr>
<tr>
<td>BIOC 4001 [0.5]</td>
<td></td>
<td>Methods in Biochemistry</td>
</tr>
<tr>
<td>BIOC 4201 [0.5]</td>
<td></td>
<td>Advanced Cell Culture and Tissue Engineering</td>
</tr>
<tr>
<td>Biology</td>
<td>BIOL 1103 [0.5]</td>
<td>Foundations of Biology I</td>
</tr>
<tr>
<td>BIOL 1104 [0.5]</td>
<td></td>
<td>Foundations of Biology II</td>
</tr>
<tr>
<td>BIOL 2001 [0.5]</td>
<td></td>
<td>Animals: Form and Function</td>
</tr>
<tr>
<td>BIOL 2104 [0.5]</td>
<td></td>
<td>Plants: Form and Function</td>
</tr>
<tr>
<td>BIOL 2100 [0.5]</td>
<td></td>
<td>Cellular Biochemistry</td>
</tr>
<tr>
<td>BIOL 2600 [0.5]</td>
<td></td>
<td>Ecology</td>
</tr>
<tr>
<td>Chemistry</td>
<td>CHEM 1001 [0.5]</td>
<td>General Chemistry I</td>
</tr>
<tr>
<td>CHEM 1002 [0.5]</td>
<td></td>
<td>General Chemistry II</td>
</tr>
<tr>
<td>CHEM 1005 [0.5]</td>
<td></td>
<td>Elementary Chemistry I</td>
</tr>
<tr>
<td>CHEM 1006 [0.5]</td>
<td></td>
<td>Elementary Chemistry II</td>
</tr>
<tr>
<td>CHEM 2103 [0.5]</td>
<td></td>
<td>Physical Chemistry I</td>
</tr>
<tr>
<td>CHEM 2203 [0.5]</td>
<td></td>
<td>Organic Chemistry I</td>
</tr>
<tr>
<td>CHEM 2204 [0.5]</td>
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<td>Organic Chemistry II</td>
</tr>
<tr>
<td>CHEM 2302 [0.5]</td>
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<td>Analytical Chemistry I</td>
</tr>
<tr>
<td>CHEM 2303 [0.5]</td>
<td></td>
<td>Analytical Chemistry II</td>
</tr>
<tr>
<td>CHEM 2800 [0.5]</td>
<td></td>
<td>Foundations for Environmental Chemistry</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>ERTH 1006 [0.5]</td>
<td>Exploring Planet Earth</td>
</tr>
<tr>
<td>ERTH 1009 [0.5]</td>
<td></td>
<td>The Earth System Through Time</td>
</tr>
<tr>
<td>ERTH 2102 [0.5]</td>
<td></td>
<td>Mineralogy to Petrology</td>
</tr>
<tr>
<td>ERTH 2404 [0.5]</td>
<td></td>
<td>Engineering Geoscience</td>
</tr>
<tr>
<td>ERTH 2802 [0.5]</td>
<td></td>
<td>Field Geology I</td>
</tr>
<tr>
<td>ERTH 3111 [0.5]</td>
<td></td>
<td>Vertebrate Evolution: Mammals, Reptiles, and Birds</td>
</tr>
<tr>
<td>ERTH 3112 [0.5]</td>
<td></td>
<td>Vertebrate Evolution: Fish and Amphibians</td>
</tr>
<tr>
<td>ERTH 3204 [0.5]</td>
<td></td>
<td>Mineral Deposits</td>
</tr>
<tr>
<td>ERTH 3205 [0.5]</td>
<td></td>
<td>Physical Hydrogeology</td>
</tr>
<tr>
<td>ERTH 3806 [0.5]</td>
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<td>Structural Geology</td>
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<tr>
<td>Food Sciences</td>
<td>FOOD 3001 [0.5]</td>
<td>Food Chemistry</td>
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<tr>
<td>FOOD 3002 [0.5]</td>
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<td>Food Analysis</td>
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<tr>
<td>FOOD 3005 [0.5]</td>
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<td>Food Microbiology</td>
</tr>
<tr>
<td>Geography</td>
<td>GEOG 1010 [0.5]</td>
<td>Global Environmental Systems</td>
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<tr>
<td>GEOG 3108 [0.5]</td>
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<td>Soil Properties</td>
</tr>
<tr>
<td>Neuroscience</td>
<td>NEUR 3206 [0.5]</td>
<td>Sensory and Motor Neuroscience</td>
</tr>
<tr>
<td>NEUR 3207 [0.5]</td>
<td></td>
<td>Integrative Neuroscience</td>
</tr>
</tbody>
</table>

**Course Categories for B.Sc. Programs**

**Science Geography Courses**

- GEOG 1010 [0.5] Global Environmental Systems
- GEOG 2006 [0.5] Introduction to Quantitative Research
- GEOG 2013 [0.5] Weather and Water
- GEOG 2014 [0.5] The Earth's Surface
- GEOG 3003 [0.5] Quantitative Geography
- GEOG 3010 [0.5] Field Methods in Physical Geography
- GEOG 3102 [0.5] Geomorphology
- GEOG 3103 [0.5] Watershed Hydrology
- GEOG 3104 [0.5] Principles of Biogeography
- GEOG 3105 [0.5] Climate and Atmospheric Change
- GEOG 3106 [0.5] Aquatic Science and Management
- GEOG 3108 [0.5] Soil Properties
- GEOG 4000 [0.5] Field Studies
- GEOG 4005 [0.5] Directed Studies in Geography
- GEOG 4013 [0.5] Cold Region Hydrology
- GEOG 4017 [0.5] Global Biogeochecmical Cycles
- GEOG 4101 [0.5] Two Million Years of Environmental Change
- GEOG 4103 [0.5] Water Resources Engineering
- GEOG 4104 [0.5] Microclimatology
- GEOG 4108 [0.5] Permafrost

**Science Psychology Courses**

- PSYC 2001 [0.5] Introduction to Research Methods in Psychology
- PSYC 2002 [0.5] Introduction to Statistics in Psychology
- PSYC 2700 [0.5] Introduction to Cognitive Psychology
- PSYC 3000 [1.0] Design and Analysis in Psychological Research
- PSYC 3506 [0.5] Cognitive Development
- PSYC 3700 [1.0] Cognition (Honours Seminar)
- PSYC 3702 [0.5] Perception
- PSYC 2307 [0.5] Human Neuropsychology I
- PSYC 3307 [0.5] Human Neuropsychology II

**Science Continuation Courses**

- NEUR 4600 [0.5] Advanced Lab in Neuroanatomy
- PHYS 1001 [0.5] Foundations of Physics I
- PHYS 1002 [0.5] Foundations of Physics II
- PHYS 1003 [0.5] Introductory Mechanics and Thermodynamics
- PHYS 1004 [0.5] Introductory Electromagnetism and Wave Motion
- PHYS 1007 [0.5] Elementary University Physics I
- PHYS 1008 [0.5] Elementary University Physics II
- PHYS 2202 [0.5] Wave Motion and Optics
- PHYS 2604 [0.5] Modern Physics I
- PHYS 3007 [0.5] Third Year Physics Laboratory: Selected Experiments and Seminars
- PHYS 3606 [0.5] Modern Physics II
- PHYS 3608 [0.5] Modern Applied Physics
A course at the 2000 level or above may be used as a Science Continuation credit in a B.Sc. program if it is not in the student's major discipline, and is chosen from the following:

- BIOC (Biochemistry)
- BIOL (Biology)
- CHEM (Chemistry)

COMP (Computer Science) A maximum of two half-credits at the 1000-level in COMP, excluding COMP 1001 may be used as Science Continuation credits.

ERTH (Earth Sciences), except ERTH 2415 which may be used only as a free elective for any B.Sc. program. Students in Earth Sciences programs may use ERTH 2401, ERTH 2402, and ERTH 2403 only as free electives.

Engineering. Students wishing to register in Engineering courses must obtain the permission of the Faculty of Engineering and Design.

ENSC (Environmental Science)

FOOD (Food Science and Nutrition)

GEOM (Geomatics)

HLTH (Health Sciences)

MATH (Mathematics)

NEUR (Neuroscience)

PHYS (Physics), except PHYS 2903

Science Geography Courses (see list above)

Science Psychology Courses (see list above)

STAT (Statistics)

TSES (Technology, Society, Environment) Biology General, Major and Honours students may use these courses only as free electives.

Advanced Science Faculty Electives

Advanced Science Faculty Electives are courses at the 2000-4000 level chosen from the Science Faculty Electives list above.

Approved Courses Outside the Faculties of Science and Engineering and Design (may include NSCI 1000)

All courses offered by the Faculty of Arts and Social Sciences, the Faculty of Public Affairs, and the Sprott School of Business are approved as Arts or Social Sciences courses EXCEPT FOR: All Science Geography courses (see list above), all Geomatics (GEOM) courses, all Science Psychology courses (see list above). NSCI 1000 may be used as an Approved Course Outside the Faculties of Science and Engineering and Design.

Free Electives

Any course is allowable as a Free Elective providing it is not prohibited (see below). Students are expected to comply with prerequisite requirements and enrolment restrictions for all courses as published in this Calendar.

Courses Allowable Only as Free Electives in any B.Sc. Program

- CHEM 1003 [0.5] The Chemistry of Food, Health and Drugs
- CHEM 1004 [0.5] Drugs and the Human Body
- CHEM 1007 [0.5] Chemistry of Art and Artifacts
- ERTH 1010 [0.5] Our Dynamic Planet Earth
- ERTH 1011 [0.5] Evolution of the Earth
- ERTH 2415 [0.5] Natural Disasters
- ISCI 1001 [0.5] Introduction to the Environment
- ISCI 2000 [0.5] Natural Laws
- ISCI 2002 [0.5] Human Impacts on the Environment
- MATH 0107 [0.5] Algebra and Geometry
- PHYS 1901 [0.5] Planetary Astronomy
- PHYS 1902 [0.5] From our Star to the Cosmos
- PHYS 1905 [0.5] Physics Behind Everyday Life
- PHYS 2903 [0.5] Physics Towards the Future

Prohibited Courses

The following courses are not acceptable for credit in any B.Sc. program:

- COMP 1001 [0.5] Introduction to Computational Thinking for Arts and Social Science Students
- MATH 0005 [0.5] Precalculus: Functions and Graphs
- MATH 0006 [0.5] Precalculus: Trigonometric Functions and Complex Numbers
- MATH 1009 [0.5] Calculus: with Applications to Business
- MATH 1119 [0.5] Linear Algebra: with Applications to Business
- MATH 1401 [0.5] Elementary Mathematics for Economics I
- MATH 1402 [0.5] Elementary Mathematics for Economics II
Co-operative Education

For more information about how to apply for the Co-op program and how the Co-op program works please visit the Co-op website.

All students participating in the Co-op program are governed by the Undergraduate Co-operative Education Policy.

Undergraduate Co-operative Education Policy

Admission Requirements

Students can apply to co-op in one of two ways; directly from high school or after beginning a degree program at Carleton.

If a student is admitted to co-op from high school, their grades will be reviewed two terms to one year prior to their first work term to ensure they continue to meet the academic requirements after their 1st or 2nd year of study. The time at which evaluation takes place depends on the program of study. Students will automatically be notified via their Carleton email account if they are permitted to continue.

Students not admitted to Carleton University with the co-op option on their degree can apply for admission via the co-operative education program website. To view application deadlines, visit carleton.ca/co-op.

Admission to the co-op option is based on the completion of 5.0 or more credits at Carleton University, the CGPA requirement for the students' academic program as well as any course prerequisites. The articulated CGPA for each program is the normal standard for assessment. Please see the specific degree program sections for the unique admission and continuation requirements for each academic program.

English Language Proficiency

Students admitted to Carleton based on CAEL, IELTS or TOEFL assessments and who are required to take an ESL course must take and pass the Oral Proficiency in Communicative Settings (OPECS) Test. The test must be taken before being permitted to register in COOP 1000. Admission to the co-op program can be confirmed with a minimum score of 4+. 

Participation Requirements

COOP 1000

Once a student has been given admission or continuation confirmation to the co-op option s/he must complete and pass COOP 1000 (a mandatory online 0.0 credit course). Students will have access to this course a minimum of two terms prior to their first work term and will be notified when to register.

Communication with the Co-op Office

Students must maintain contact with the co-op office during their job search and while on a work term. All email communication will be conducted via the students' Carleton email account.

Employment

Although every effort is made to ensure a sufficient number of job postings for all students enrolled in the co-op option of their degree program, no guarantee of employment can be made. Carleton's co-op program operates a competitive job search process and is dependent upon current market conditions. Academic performance, skills, motivation, maturity, attitude and potential will determine whether a student is offered a job. It is the student's responsibility to actively conduct a job search in addition to participation in the job search process operated by the co-op office. Once a student accepts a co-op job offer (verbally or written), his/her job search will end and access to co-op jobs will be removed for that term. Students that do not successfully obtain a co-op work term are expected to continue with their academic studies. The summer term is the exception to this rule. Students should also note that hiring priority is given to Canadian citizens for co-op positions in the Federal Government of Canada.

Registering in Co-op Courses

Students will be registered in a Co-op Work Term course while at work. The number of Co-op Work Term courses that a student is registered in is dependent upon the number of four-month work terms that a student accepts.

While on a co-op work term students may take a maximum of 0.5 credit throughout each four-month co-op work term. Courses must be scheduled outside of regular working hours.

Students must be registered as full-time before they begin their co-op job search (2.0 credits). All co-op work terms must be completed before the beginning of the final academic term. Students may not finish their degree on a co-op work term.

Work Term Assessment and Evaluation

To obtain a Satisfactory grade for the co-op work term students must have:

1. A satisfactory work term evaluation by the co-op supervisor;
2. A satisfactory grade on the work term report.

Students must submit a work term report at the completion of each four-month work term. Reports are due on the 16th of April, August, and December and students are notified of due dates through their Carleton email account.

Workplace performance will be assessed by the workplace supervisor. Should a student receive an unsatisfactory rating from their co-op employer, an investigation by the co-op program manager will be undertaken. An unsatisfactory employer evaluation does not preclude a student from achieving an overall satisfactory rating for the work term.

Graduation with the Co-op Designation

In order to graduate with the co-op designation, students must satisfy all requirements for their degree program in addition to the requirements according to each co-op program (i.e. successful completion of three or four work terms).
Note: Participation in the co-op option will add up to one additional year for a student to complete their degree program.

Voluntary Withdrawal from the Co-op Option
Students may withdraw from the co-op option of their degree program during a study term ONLY. Students at work may not withdraw from the work term or the co-op option until s/he has completed the requirements of the work term.

Students are eligible to continue in their regular academic program provided that they meet the academic standards required for continuation.

Involuntary or Required Withdrawal from the Co-op Option
Students may be required to withdraw from the co-op option of their degree program for one or any of the following reasons:
1. Failure to achieve a grade of SAT in COOP 1000
2. Failure to pay all co-op related fees
3. Failure to actively participate in the job search process
4. Failure to attend all interviews for positions to which the student has applied
5. Declining more than one job offer during the job search process
6. Continuing a job search after accepting a co-op position
7. Dismissal from a work term by the co-op employer
8. Leaving a work term without approval by the Co-op manager
9. Receipt of an unsatisfactory work term evaluation
10. Submission of an unsatisfactory work term report

Standing and Appeals
The Co-op and Career Services office administers the regulations and procedures that are applicable to all co-op program options. All instances of a student’s failure during a work term or other issues directly related to their participation in the co-op option will be reported to the academic department.

Any decision made by the Co-op and Career Services office can be appealed via the normal appeal process within the University.

International Students
All International Students are required to possess a Co-op Work Permit issued by Immigration, Refugees and Citizenship Canada before they can begin working. It is illegal to work in Canada without the proper authorization. Students will be provided with a letter of support to accompany their application. Students must submit their application for their permit before being permitted to view and apply for jobs on the Co-op Services database. Confirmation of a position will not be approved until a student can confirm they have received their permit. Students are advised to discuss the application process and requirements with the International Student Services Office.

B.Sc. Honours Chemistry: Co-op Admission and Continuation Requirements
- Maintain full-time status in each study term (2.0 credits);
- Be eligible to work in Canada (for off-campus work);
- Have successfully completed COOP 1000 [0.0]

In addition to the following:
1. Completion of 5.0 or more credits at Carleton University;
2. Registered as a full-time student in the Bachelor of Science Honours degree program;
3. Obtained and maintained a major CGPA of 8.0 or higher and an overall CGPA of 6.50 or higher

B.Sc. Honours Chemistry students must successfully complete three (3) work terms to obtain the co-op designation.

Work Term Course: CHEM 3999

Work/Study Pattern:

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<tr>
<th>Year 1</th>
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<th>Year 3</th>
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- Maintain full-time status in each study term (2.0 credits);
- Be eligible to work in Canada (for off-campus work);
- Have successfully completed COOP 1000 [0.0]

Admissions Information
Admission Requirements are for the 2019-20 year only, and are based on the Ontario High School System. Holding the minimum admission requirements only establishes eligibility for consideration. The cut-off averages for admission may be considerably higher than the minimum. See also the General Admission and Procedures section of this Calendar. An overall average of at least 70% is normally required to be considered for admission. Some programs may also require specific course prerequisites and prerequisite averages and/or supplementary admission portfolios. Higher averages are required for admission to programs for which the demand for places by qualified applicants exceeds the number of places available. The overall average required for admission is determined each year on a program by program basis. Consult admissions.carleton.ca for further details.

Note: Courses listed as recommended are not mandatory for admission. Students who do not follow the recommendations will not be disadvantaged in the admission process.

Degrees
- B.Sc. (Honours)
- B.Sc. (General)
- B.Sc. (Major)
Admission Requirements
Honours Program
First Year
The Ontario Secondary School Diploma (OSSD) or equivalent including a minimum of six 4U or M courses. For most programs including Biochemistry, Bioinformatics, Biotechnology, Chemistry, Combined Honours in Biology and Physics, Chemistry and Physics, Computational Biochemistry, Food Science, Nanoscience, Neuroscience, Neuroscience and Mental Health, and Psychology, the six 4U or M courses must include Advanced Functions and two of Biology, Chemistry, Earth and Space Sciences or Physics. (Calculus and Vectors is strongly recommended).

Specific Honours Admission Requirements
For the Honours programs in Earth Sciences, Environmental Science, Geomatics, Interdisciplinary Science and Practice, and Physical Geography, Calculus and Vectors may be substituted for Advanced Functions.

For the Honours programs in Physics and Applied Physics and for double Honours in Mathematics and Physics, Calculus and Vectors is required in addition to Advanced Functions and one of 4U Physics Chemistry, Biology, or Earth and Space Sciences. For all programs in Physics, 4U Physics is strongly recommended.

For the Combined Honours program in Chemistry and Computer Science, 4U Chemistry and Calculus and Vectors are strongly recommended.

For Honours in Psychology, a 4U course in English is recommended.

For Honours in Environmental Science, a 4U course in Biology and Chemistry is recommended.

Advanced Standing
For entry to an Honours program after the completion of 5.0 included credits, a student must have a major CGPA of 5.50 or higher, an overall CGPA of 4.50 or higher and the recommendation of the Honours department or committee. A student beginning the final 10.0 credits towards an Honours degree must present a major CGPA of 6.00 or higher, an overall CGPA of 5.00 or higher and the recommendation of the Honours department or committee. A student beginning the final 5.0 credits towards an Honours degree must present a major CGPA of 6.50 or higher and an overall CGPA of 5.00 or higher, as calculated for graduation. Advanced standing will be granted for studies undertaken elsewhere when these are recognized as the equivalent of subjects offered at Carleton University.

Co-op Option
Direct Admission to the First Year of the Co-op Option
Applicants must:
1. meet the required overall admission cut-off average and prerequisite course average. These averages may be higher than the stated minimum requirements;
2. be registered as a full-time student in the Bachelor of Science Honours program;
3. be eligible to work in Canada (for off-campus work placements).

Note that meeting the above requirements only establishes eligibility for admission to the program. The prevailing job market may limit enrolment in the co-op option.

Note: continuation requirements for students previously admitted to the co-op option and admission requirements for the co-op option after beginning the program are described in the Co-operative Education Regulations section of this Calendar.

Chemistry (CHEM) Courses
CHEM 0999 [0.0 credit]
Chemistry Matters

CHEM 1001 [0.5 credit]
General Chemistry I
This maths-intensive course covers introduction to periodicity, gas laws, equilibrium, bonding, electrochemistry, and organic chemistry. This is a specialist course for students intending to take second year chemistry.

Includes: Experiential Learning Activity
Precludes additional credit for CHEM 1000 (no longer offered), CHEM 1005, CHEM 1101.
Prerequisite(s): Ontario 4U/M in Chemistry or equivalent.
Lectures and tutorial four hours a week, laboratory three hours every other week.
CHEM 1002 [0.5 credit]
General Chemistry II
This maths-intensive course covers an introduction to solution chemistry, acids and bases, thermodynamics, and kinetics. Specialist course for students intending to take second year chemistry.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 1000 (no longer offered), CHEM 1006.
Prerequisite(s): CHEM 1005 with a minimum grade of B-, or CHEM 1001.
Lectures and tutorial four hours a week, laboratory three hours every other week.

CHEM 1003 [0.5 credit]
The Chemistry of Food, Health and Drugs
Aspects of chemistry relating to food, food additives, drugs (illicit and beneficial) and their relation to metabolism and health. Topics may include: proteins, carbohydrates, fats, vitamins, cofactors, enzymes, steroids, electrolyte and pH balance, trace elements. Available only as a free option for Science students.
Prerequisite(s): a course in Chemistry (e.g. Ontario Grade 11).
Lectures three hours a week.

CHEM 1004 [0.5 credit]
Drugs and the Human Body
No science background required. Topics include drug origins, laws, metabolism and dependence, pharmaceutical industry, over the counter medications, placebo effect, antibiotics, pain killers, stimulants, alcohol, marijuana, hallucinogens, birth control and steroids.
Students in Science programs may use this course only as a free elective.
Lectures three hours a week.

CHEM 1005 [0.5 credit]
Elementary Chemistry I
Introduction to stoichiometry, periodicity, gas laws, equilibrium, bonding, and organic chemistry with emphasis on examples of relevance to the life sciences. For students who lack the prerequisite for CHEM 1001 or who are not intending to take upper year chemistry.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 1000 (no longer offered), CHEM 1001, CHEM 1101.
Lectures and tutorial four hours a week, laboratory three hours every other week.

CHEM 1006 [0.5 credit]
Elementary Chemistry II
Introduction to solution chemistry, acids and bases, thermodynamics, and kinetics, with emphasis on examples of relevance to the life sciences. For students who lack the prerequisite for CHEM 1002 or who are not intending to take upper year chemistry.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 1000 (no longer offered), CHEM 1002.
Prerequisite(s): CHEM 1001 or CHEM 1005.
Lectures and tutorial four hours a week, laboratory three hours every other week.

CHEM 1007 [0.5 credit]
Chemistry of Art and Artifacts
The chemistry of arts and artifacts created throughout the ages (Paleolithic, Neolithic, Bronze, Iron, Middle and Modern) will be examined. Basic chemical principles will be explored and reviewed when required. Students in Science programs may use this course only as a free elective.
Lectures three hours a week.

CHEM 1101 [0.5 credit]
Chemistry for Engineering Students
Topics include stoichiometry, atomic and molecular structure, thermodynamics and chemical equilibrium, acid-base chemistry, carbon dioxide in water, alkalinity, precipitation, electrochemistry, kinetics and basic organic chemistry. Laboratory component emphasizes techniques and methods of basic experimental chemistry.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 1000 (no longer offered), CHEM 1001, and CHEM 1005.
Prerequisite(s): Ontario 4U/M in Chemistry or equivalent.
Lectures three hours a week, laboratory three hours every other week.

CHEM 2103 [0.5 credit]
Physical Chemistry I
Basic principles of thermodynamics. Development of the laws of thermodynamics, enthalpy, entropy and free energy, and their applications to phase equilibria, electrochemistry, and kinetics. Brief introduction to quantum mechanics.
Includes: Experiential Learning Activity
Precludes additional credit for BIOC 2300, CHEM 2101 (no longer offered) and CHEM 2102 (no longer offered).
Prerequisite(s): CHEM 1006 with a minimum grade of B-, or CHEM 1002, MATH 1004, MATH 1107, PHYS 1007 and PHYS 1008 or PHYS 1003 and PHYS 1004.
Lectures three hours a week, problems one hour a week, laboratory three hours a week.
CHEM 2203 [0.5 credit]
**Organic Chemistry I**
Structure, organization, and scope of organic chemistry including molecular structures of well-known and important organic chemicals, types of chemical reactions, and spectroscopic methods used in identification. Training in the handling and purification of organic compounds, organic chemical reactions, and the use of infrared spectroscopy.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 2207.
Prerequisite(s): CHEM 1006 with a minimum grade of B-, or CHEM 1002.
Lectures three hours a week and laboratory three hours a week.

CHEM 2204 [0.5 credit]
**Organic Chemistry II**
Further discussion of chemical bonding in organic compounds, nomenclature, stereochemistry, and a systematic coverage of the chemical reactions of organic functional groups. Laboratory experience in organic chemical reactions, use of infrared spectroscopy and other techniques to determine the structure of unknown organic compounds.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 2208 and CHEM 2206.
Prerequisite(s): CHEM 2203.
Lectures three hours a week and laboratory three hours a week.

CHEM 2207 [0.5 credit]
**Introduction to Organic Chemistry I**
Structure, organization, and scope of organic chemistry, including molecular structures of well-known and important organic chemicals, types of chemical reactions, and spectroscopic methods used in identification.
Precludes additional credit for CHEM 2203.
Prerequisite(s): CHEM 1006 with a minimum grade of B-, or CHEM 1002.
Lectures three hours a week.

CHEM 2208 [0.5 credit]
**Introduction to Organic Chemistry II**
Further discussion of the chemical bonding in organic compounds, nomenclature, stereochemistry, and a systematic coverage of chemical reactions of the organic functional groups.
Precludes additional credit for CHEM 2204 and CHEM 2206.
Prerequisite(s): CHEM 2207 or CHEM 2203.
Lectures three hours a week.

CHEM 2209 [0.5 credit]
**Analytical Chemistry I**
Introduction to quality assurance measures, calibration strategies and the fundamentals of solution-based analytical measurement processes. Qualitative and quantitative analysis using potentiometric and electrolysis techniques including ion selective electrodes, coulometry, amperometry and voltammetry. Redox, acid/base and EDTA titrations in the context of various buffer systems.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 2300.
Prerequisite(s): CHEM 1006 with a minimum grade of B-, or CHEM 1002 or CHEM 1101 and (MATH 1007 or MATH 1004).
Lectures three hours a week, laboratory three hours a week.

CHEM 2210 [0.5 credit]
**Analytical Chemistry II**
Spectrophotometric analysis using Uv-Vis, fluorescence and FTIR instrumentation. Modern separation methods including CE, GC and LC. Recent techniques and applications using mass spectrometry. Applications of all of the above to real-world analysis including the advancement of environmental, biochemistry and health-related research.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 2300 and CHEM 2301.
Prerequisite(s): CHEM 1006 with a minimum grade of B-, or CHEM 1002, or CHEM 1101, and (MATH 1007 or MATH 1004).
Lectures three hours a week, laboratory three hours a week.

CHEM 2400 [0.5 credit]
**Independent Research I**
Students carry out a laboratory research project under the supervision of a faculty member from the Department of Chemistry. A research report must be submitted by the last day of classes for evaluation by the Chair and Faculty supervisor.
Includes: Experiential Learning Activity
Prerequisite(s): restricted to Honours students having second-year standing in a Chemistry program with an overall CGPA of 10.0 or higher, and approval of the Chair and a Faculty supervisor.
Laboratory research for at least three hours a week over two terms.
CHEM 2501 [0.5 credit]
Introduction to Inorganic and Bioinorganic Chemistry
The basic concepts of inorganic chemistry, including the origins of elemental properties, simple theories of bonding, intermolecular forces, main group and transition metal chemistry, coordination chemistry. Inorganic ions in biochemistry, including ion transport and storage, oxygen carriers and hydrolases, redox proteins. Precludes additional credit for CHEM 3506. Prerequisite(s): CHEM 1006 with a minimum grade of B-, or CHEM 1002. Lectures three hours a week, tutorial one hour a week.

CHEM 2800 [0.5 credit]
Foundations for Environmental Chemistry
A basis of chemistry needed to understand the environment: composition of the atmosphere and natural waters; equilibrium; surface properties; kinetics and spectroscopy; physical and chemical properties of chemicals in the environment. Limited enrolment course. Priority is given to students in Environmental Science/Engineering. Includes: Experiential Learning Activity
Prerequisite(s): CHEM 1006 with a minimum grade of B- or CHEM 1002, or CHEM 1101, (MATH 1007 or MATH 1004). Lectures three hours a week, laboratory three hours a week.

CHEM 3100 [0.5 credit]
Physical Chemistry II
Further development of thermodynamic equations and their applications to mass changes, chemical potential, chemical equilibria, transport properties and advanced phase equilibria. Use of partial differentials and development of Maxwell's relations will also be covered. Includes: Experiential Learning Activity
Precludes additional credit for CHEM 2102. Prerequisite(s): CHEM 2103 or BIOC 2300, and MATH 1005 or MATH 2007. Lectures three hours a week, problems one hour a week, laboratory three hours a week.

CHEM 3101 [0.5 credit]
Quantum Chemistry
Classical equations of motion, harmonic oscillator, diatomic and polyatomic molecules, molecular mechanics, quantum mechanics, Schrödinger equation and wave functions, vibrational spectra, hydrogen atom, quantum numbers, electronic spectra, bonding in small molecules. Includes: Experiential Learning Activity
Prerequisite(s): CHEM 2103, MATH 2007 and MATH 2008. Lectures and problems three hours a week.

CHEM 3102 [0.5 credit]
Methods of Computational Chemistry
Molecular orbital theory of organic and inorganic chemistry. Applications of computational chemistry to chemical bonding, aromaticity, molecular spectra. Semi-empirical and ab initio electronic structure theory. Comparison of theoretical methods used to obtain molecular properties. Introduction to statistical thermodynamics. Includes: Experiential Learning Activity
Prerequisite(s): CHEM 3101. Lectures and problems three hours a week.

CHEM 3106 [0.5 credit]
Computational Chemistry Methods Laboratory
Industry-standard quantum chemistry software is used for Hartree-Fock, density functional, and post Hartree-Fock correlation calculations. Results are applied to problems in molecular structure, thermodynamics, vibrational spectroscopy, and kinetics. The UNIX operating system, Bourne-shell programming, and Python scripting are also introduced. Includes: Experiential Learning Activity
Prerequisite(s): CHEM 3102 (may be taken concurrently). Laboratory three hours a week.

CHEM 3107 [0.5 credit]
Experimental Methods in Nanoscience
Thin film production and characterization, scanning electron microscopy, synthesis of metal nanoparticles and particle size determination, computational modeling of nanostructures. Includes: Experiential Learning Activity
Prerequisite(s): CHEM 3100. Laboratory four hours a week.

CHEM 3201 [0.5 credit]
Advanced Organic Chemistry I
Instrumental methods for determining organic structures. Selected organic reactions with emphasis on mechanisms and reactive intermediates. Prerequisite(s): CHEM 2204 or CHEM 2206 or CHEM 2208. Lectures three hours a week, tutorial one and a half hours per week.

CHEM 3202 [0.5 credit]
Advanced Organic Chemistry II
Continued mechanistic survey of additional organic reactions with emphasis on synthetic usefulness and stereochemistry. Interspersed with selected topics such as instrumental methods, photochemistry, literature of organic chemistry, natural and synthetic polymers, heterocycles, terpenes and alkaloids. Prerequisite(s): CHEM 3201 or equivalent. Lectures three hours a week, tutorial one and a half hours per week.
CHEM 3205 [0.5 credit]
Experimental Organic Chemistry
A laboratory-based course including advanced concepts and techniques in organic synthesis, structure determination, and the rates and mechanisms of reactions. Students are responsible for literature surveys, acquisition of theoretical background, and design of experimental procedures.
Includes: Experiential Learning Activity
Prerequisite(s): CHEM 2204 or CHEM 2206 and CHEM 3201.
Laboratory four hours a week.

CHEM 3305 [0.5 credit]
Advanced Analytical Chemistry Laboratory
Advanced instrumentally based techniques of analysis. Emphasis on identification and quantitation of low-level contaminants in environmental matrices using chromatographic and spectroscopic methods, including sampling, cleanup, measurement and reporting of results.
Includes: Experiential Learning Activity
Prerequisite(s): CHEM 2302 or CHEM 2303.
Laboratory four hours a week.

CHEM 3400 [0.5 credit]
Independent Research II
Students carry out a laboratory research project supervised by a Chemistry faculty member. A research report must be submitted by the last day of classes for evaluation by the Chair and Faculty supervisor; expectations of student performance and evaluation exceed that of CHEM 2400.
Includes: Experiential Learning Activity
Prerequisite(s): restricted to Honours students having third-year standing in a Chemistry program with an overall CGPA of 10.0 or higher, and approval of the Chair and a Faculty supervisor.
Laboratory research for at least three hours a week over two terms.

CHEM 3401 [0.5 credit]
Physical Aspects of Biochemistry
Chemistry, structure and function of nucleic acids, proteins, carbohydrates, and lipids. Thermodynamics of biological systems, chemical mechanisms and organic transformations. Intended for Chemistry Majors.
Precludes additional credit for BIOC 2200, BIOL 2200, and BIOC 3101.
Prerequisite(s): CHEM 2103 and CHEM 2204.
Lectures three hours a week.

CHEM 3503 [0.5 credit]
Inorganic Chemistry I
Symmetry, identification of Raman and infrared active vibrations, symmetry-adapted molecular orbital theory of polyatomic molecules, electron deficient bonding, bonding in coordination complexes, solid state bonding, ionic lattices. Laboratory will introduce the student to a range of synthetic techniques and physical methods of characterization.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 3507.
Prerequisite(s): CHEM 2501.
Lectures three hours a week, tutorial one hour a week and laboratory four hours a week.

CHEM 3504 [0.5 credit]
Inorganic Chemistry II
Physical properties of coordination complexes, ligand substitutions and electron transfer reaction mechanisms, organometallic chemistry: bonding, nomenclature and catalysis. Laboratory will introduce the student to a range of synthetic techniques and physical methods of characterization.
Includes: Experiential Learning Activity
Precludes additional credit for CHEM 3508.
Prerequisite(s): CHEM 3503.
Lectures three hours a week, tutorial one hour a week and laboratory four hours a week.

CHEM 3507 [0.5 credit]
General Inorganic Chemistry I
Symmetry, identification of Raman and infrared active vibrations, symmetry-adapted molecular orbital theory of polyatomic molecules, electron deficient bonding, bonding in coordination complexes, solid state bonding, ionic lattices.
Precludes additional credit for CHEM 3503.
Prerequisite(s): CHEM 2501.
Lectures three hours a week, tutorial one hour a week.

CHEM 3508 [0.5 credit]
General Inorganic Chemistry II
Physical properties of coordination complexes, ligand substitutions and electron transfer reaction mechanisms, organometallic chemistry: bonding, nomenclature and catalysis.
Precludes additional credit for CHEM 3504.
Prerequisite(s): CHEM 3503 or CHEM 3507.
Lectures three hours a week, tutorial one hour a week.

CHEM 3600 [0.5 credit]
Introduction to Nanotechnology
Nanoscale units, bulk vs. nanoproperties, electrons, atoms and ions, metals, band structure, electrical conduction, biosystems, molecular devices, quantum mechanics and optics, tools for measuring nanostructures. Production of nanostructures: self assembly, nanoscale crystal growth, polymerization. Applications to sensors, magnets, electronics, drug delivery. Toxicology of nanostructures.
Prerequisite(s): CHEM 3100.
Lectures three hours a week.
CHEM 3700 [0.5 credit]
Industrial Applications of Chemistry
Uses of chemistry in a number of industries: fertilizers, electrochemical, metallurgical, petrochemical, pulp and paper, plastics, pharmaceutical. Interaction of chemistry with economic, political, engineering, environmental, health, legal considerations. Guest lecturers. Prerequisite(s): (BIOC 2300 or CHEM 2103) and one of CHEM 2207 or CHEM 2203. Lecture three hours a week.

CHEM 3800 [0.5 credit]
The Chemistry of Environmental Pollutants
Inorganic and organic environmental pollutants: their toxicology, production, use pattern and known effects on the environment. Aspects of risk and regulation. Chemistry involved in water and sewage treatment. Prerequisite(s): CHEM 2207 or CHEM 2203 or CHEM 2800. Lectures three hours a week.

CHEM 3999 [0.0 credit]
Co-operative Work Term
Includes: Experiential Learning Activity

CHEM 4100 [0.5 credit]
Advanced Topics in Physical Chemistry I
Principles of Group Theory as applied to Chemistry. Point groups, character tables, symmetry orbitals, molecular orbitals, aromaticity, allowed and forbidden reactions, sandwich complexes. Selection rules in spectroscopy, molecular vibrations. Prerequisite(s): CHEM 3102.

CHEM 4102 [0.5 credit]
Advanced Topics in Physical Chemistry II
Statistical thermodynamics, energy states, equilibrium, partition functions for diatomic molecules. Chemical kinetics: rate laws, solution of differential equations, transition state theory, bimolecular reactions in gases and in solution, chain reactions, catalysis, atmospheric chemical reactions and photochemistry. Prerequisite(s): CHEM 3102. Lectures and seminars three hours a week.

CHEM 4103 [0.5 credit]
Surface Chemistry and Nanostructures
Surface structure, thermodynamics and kinetics, specifically regarding adsorption/desorption and high vacuum models. Nanoscale structures and their formation, reactivity and characterization. Thin films, carbon nanotubes, self-assembled monolayers and supramolecular aggregates. Prerequisite(s): CHEM 3600 and CHEM 3107. Also offered at the graduate level, with different requirements, as CHEM 5108, for which additional credit is precluded. Lectures three hours a week.

CHEM 4104 [0.5 credit]
Physical Methods of Nanotechnology
An overview of methods used in nanotechnology. Principles of scanning probe techniques ranging from surface physics to biology. State of the art methods to create nanostructures for future applications in areas such as nanolithography, nanoelectronics, nano-optics, data storage and bio-analytical nanosystems. Prerequisite(s): CHEM 3600 and CHEM 3107. Lectures three hours a week.

CHEM 4201 [0.5 credit]
Macromolecular Nanotechnology
Biological and synthetic macromolecules related to nanoscale phenomena. Challenges and opportunities associated with natural and synthetic polymers on the nanoscale. Molecular recognition, self-assembled nanostructures, scaffolds and templates, functional nanomaterials, amphiphilic architectures, nanocomposites, and nanomachines. Applications to sensing, biomaterials, drug delivery, and polymer based devices. Prerequisite(s): CHEM 3600 or permission of the department. Also offered at the graduate level, with different requirements, as CHEM 5207, CHEM 5208, for which additional credit is precluded. Lectures three hours a week.

CHEM 4202 [0.5 credit]
Advanced Topics in Organic Chemistry I
Topics include 2-dimensional 1H and 13CNMR spectroscopy and structure determination of complex organic molecules. Prerequisite(s): CHEM 3201. Also offered at the graduate level, with different requirements, as CHEM 5407, for which additional credit is precluded.

CHEM 4203 [0.5 credit]
Synthetic Organic Chemistry
The application of reactions to the synthesis or organic molecules. Emphasis on design of synthetic sequences, new reagents, and stereoselectivity. Topics include advanced methods for synthesis and reactions of alkenes, carbonyls, and enolates, functional group interconversion, oxidation and reduction, protecting groups, rearrangements, and metal-catalyzed cross-coupling. Prerequisite(s): CHEM 3201 and CHEM 3202. Lectures and seminars three hours a week.
CHEM 4204 [0.5 credit]  
Organic Polymer Chemistry  
Introduction to basic principles of polymer chemistry, industrial and synthetic polymers, different types of polymerization and polymer characterization. Study of commodity plastics, engineering thermoplastics, and specialty polymers, with emphasis on their synthesis. Prerequisite(s): CHEM 3201 or equivalent. Also offered at the graduate level, with different requirements, as CHEM 5406, for which additional credit is precluded. Lectures three hours a week.

CHEM 4205 [0.5 credit]  
Reactivity and Mechanism in Organic Chemistry  
The application of frontier molecular orbital theory (HOMO-LUMO interactions) to organic reactions, including thermal and photochemical cycloadditions of pi-systems (including 1,3-dipoles) and rearrangements. Reactions of radicals and carbenes; conformational analysis, stereochemical effects, and methods for the determination of reaction mechanisms. Prerequisite(s): CHEM 3202 and CHEM 3503 (may be taken concurrently). Lectures and seminars three hours a week.

CHEM 4206 [0.5 credit]  
Natural Products Chemistry  
A survey of the major classes of natural products with respect to their structural elucidation, synthesis, biosynthesis and bioactivity, with emphasis on compounds that have medicinal importance. Prerequisite(s): CHEM 3201 and CHEM 3202. Lectures and seminars three hours a week.

CHEM 4301 [0.5 credit]  
Advanced Topics in Analytical Chemistry I  
Trace and ultratrace analytical chemistry. Sampling and sample preservation. The problems of the blank. Trace and ultratrace analysis. Sampling and sample preparation. Atomic absorption, fluorescence and emission spectroscopy. Prerequisite(s): CHEM 2103 and one of CHEM 2302 or CHEM 2303. Lectures and seminars three hours a week.

CHEM 4302 [0.5 credit]  
Advanced Topics in Analytical Chemistry II  
Solutions and separations in analytical chemistry. Stability of aqueous solutions of standards and samples. Complex formation, multi-step and competing equilibria and their application to the design of selective methods of separation and determination. Electroanalytical techniques. Electroanalytical chemistry of aqueous solutions. Phase equilibria and solvent extraction. Prerequisite(s): CHEM 2103 and one of CHEM 2302 or CHEM 2303. Lectures and seminars three hours a week.

CHEM 4304 [0.5 credit]  
Advanced Applications In Mass Spectrometry  
Detailed breakdown of the physical, electrical and chemical operation of mass spectrometers. Applications in MS ranging from the analysis of small molecules to large biological macromolecules. Descriptions of the use of mass spectrometry in industry as well as commercial opportunities in the field. Prerequisite(s): CHEM 2103 or BIOC 2300, and one of CHEM 2302 or CHEM 2303. Also offered at the graduate level, with different requirements, as CHEM 5109, for which additional credit is precluded. Lectures and seminars three hours a week.

CHEM 4305 [0.5 credit]  
Environmental Chemistry and Toxicology  
Overview of environmental chemistry and toxicology principles including chemical sources, fate, and effects in the environment. Examining organic reactions occurring in abiotic environments and biological systems, and studying aspects of toxicant disposition and biotransformation. Emphasis on contemporary problems in human health and the environment. Prerequisite(s): CHEM 2203 or CHEM 2207, and CHEM 2800 or CHEM 2103, or BIOC 3101 or permission of the department. Also offered at the graduate level, with different requirements, as CHEM 5606, for which additional credit is precluded. Lectures three hours a week.

CHEM 4406 [0.5 credit]  
Pharmaceutical Drug Design  
Important elements of rational drug design. Ligand-receptor interactions, structure-activity relationships, molecular modeling of pharmacophores, structure and mechanism-based approaches to drug design. Enzyme inhibition in chemotherapy and design of anti-viral drugs. Includes: Experiential Learning Activity Prerequisite(s): CHEM 2103 and (CHEM 2203 or CHEM 2207), BIOC 3101 and (BIOC 3102 or BIOC 3008). Lectures and laboratory five hours a week.

CHEM 4407 [0.5 credit]  
Polymer Modeling  
Polymer architectures; Flexible and rigid rod polymers; Rotational isomeric states (RIS); Molecular mechanics, Ramachandran Map, Helix parameters; internal and external parameters; regular and random coil structures; molecular dynamics; calculation of end-to-end distance, NMR chemical shifts; conformational entropy and properties. Prerequisite(s): MATH 1107 and CHEM 2204 or permission of the department. Lectures three hours per week.
CHEM 4502 [0.5 credit]
Radiochemistry
A study of nuclear stability and decay; chemical studies of nuclear phenomena. Applications of radioactivity. Prerequisite(s): CHEM 2302, CHEM 2303, and CHEM 3100, or permission of the Department. Also offered at the graduate level, with different requirements, as CHEM 5905, for which additional credit is precluded. Lectures and seminars three hours a week.

CHEM 4503 [0.5 credit]
Advanced Topics in Inorganic Chemistry I
A quantitative basis for ligand field theory; unreal and real wavefunctions of d-orbitals; derivation of the energies of d-orbitals using variational principle, secular determinants, and ligand field operators; the effect of ligand field on free ion term symbols, wavefunction descriptions of terms symbols; applications. Prerequisite(s): CHEM 3504 and CHEM 3101. Lectures three hours a week.

CHEM 4504 [0.5 credit]
Advanced Topics in Inorganic Chemistry II
Reactivity of inorganic coordination compounds. Thermodynamic and kinetic factors affecting reactivity. Industrial and biochemical processes catalyzed by metal coordination compounds. Experimental methodologies, data analysis and rate law evaluation used to obtain reaction mechanisms leading to improved methods of catalysis. Prerequisite(s): CHEM 3504 or equivalent. Lectures three hours a week.

CHEM 4505 [0.5 credit]
Application of Physical Methods to Electron Transfer Chemistry
Spectroscopic techniques (e.g., UV-visible NIR, IR, EPR) and electrochemistry methods that are used to study photochemical and thermal intermolecular and intramolecular electron transfer in transition metal complexes are presented. Electron transfer theory and redox-active (non-innocent) ligands are discussed. Prerequisite(s): CHEM 3504. Lectures three hours a week.

CHEM 4700 [0.5 credit]
Special Topics in Chemistry
A topic of current interest in any branch of chemistry. Only one special topics course may be presented for credit. Prerequisite(s): permission of the Department.

CHEM 4800 [0.5 credit]
Atmospheric Chemistry
Properties of natural atmospheric constituents; biogeochemical cycles involving gases; chemical reactions in the atmosphere; anthropogenic atmospheric pollutants (e.g., chlorofluorocarbons, sulphur and nitrogen oxides, photochemical smog sources and effects on the biosphere. Relation between the structure of molecules and their spectral and reactive properties. Prerequisite(s): CHEM 2103 or CHEM 2800. Lectures three hours a week.

CHEM 4907 [1.0 credit]
Honours Essay and Research Proposal
Students conduct an independent research study using library resources, and prepare a critical review and study proposal on a topic approved by a faculty supervisor. A written report and oral poster presentation of the work are required before a grade can be assigned. Includes: Experiential Learning Activity Precludes additional credit for CHEM 4908, FOOD 4907 and FOOD 4908. Prerequisite(s): fourth year standing in an Honours Chemistry program and permission of the department.

CHEM 4908 [1.0 credit]
Research Project and Seminar
Senior students in Honours Chemistry carry out a research project under the direction of one of the members of the Department. A written report and an oral presentation of the work are required before a grade can be assigned. Includes: Experiential Learning Activity Precludes additional credit for CHEM 4907, FOOD 4907 and FOOD 4908. Prerequisite(s): any two of CHEM 3106, CHEM 3107, CHEM 3205, CHEM 3305 and CHEM 3504 and permission of the department. Laboratory and associated work equivalent to at least eight hours a week for two terms.

Summer session: some of the courses listed in this Calendar are offered during the summer. Hours and scheduling for summer session courses will differ significantly from those reported in the fall/winter Calendar. To determine the scheduling and hours for summer session classes, consult the class schedule at central.carleton.ca

Not all courses listed are offered in a given year. For an up-to-date statement of course offerings for the current session and to determine the term of offering, consult the class schedule at central.carleton.ca