

# Chemistry

This section presents the requirements for programs in:

- **Chemistry B.Sc. Honours**
- **Chemistry with Concentration in Chemical Toxicology B.Sc. Honours**
- **Chemistry with Concentration in Nanotechnology B.Sc. Honours**
- **Chemistry B.Sc.**
- **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 (11.0 credits)

<b>1. 9.0 credits in:</b>	<b>9.0</b>
CHEM 1011 [0.5]	Enriched General Chemistry 1
CHEM 1012 [0.5]	Enriched General Chemistry 2
CHEM 2103 [0.5]	Physical Chemistry I
CHEM 2104 [0.5]	Physical Chemistry II
CHEM 2203 [0.5]	Organic Chemistry I
CHEM 2204 [0.5]	Organic Chemistry II
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 3101 [0.5]	Quantum Chemistry
CHEM 3102 [0.5]	Methods in Computational Chemistry
CHEM 3201 [0.5]	Advanced Organic Chemistry I
CHEM 3503 [0.5]	Inorganic Chemistry I
CHEM 3504 [0.5]	Inorganic Chemistry II
CHEM 3701 [0.5]	Chemistry in Practice for the 21st Century
CHEM 4401 [0.5]	Physical Aspects of Biochemistry
CHEM 4908 [1.0]	Research Project and Seminar
or CHEM 4907 [1.0]	Honours Essay and Research Proposal
<b>2. 1.0 credit from:</b>	<b>1.0</b>
CHEM 3107 [0.5]	Experimental Methods in Nanoscience
CHEM 3205 [0.5]	Experimental Organic Chemistry

CHEM 3305 [0.5]	Advanced Analytical Chemistry Laboratory	
CHEM 3400 [0.5]	Independent Research II	
FOOD 4002 [0.5]	Analysis of Food Contaminants	
<b>3. 1.0 credit in CHEM at the 4000-level</b>		<b>1.0</b>
<b>B. Credits Not Included in the Major CGPA (9.0 credits)</b>		
<b>4. 2.0 credits in:</b>		<b>2.0</b>
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	
or MATH 2007 [0.5]	Elementary Calculus II	
MATH 2008 [0.5]	Intermediate Calculus	
<b>5. 1.0 credit from:</b>		<b>1.0</b>
PHYS 1003 [0.5]	Introductory Mechanics and	
& PHYS 1004 [0.5]	Thermodynamics	
	Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5]	Elementary University Physics I	
& PHYS 1008 [0.5]	Elementary University Physics II	
<b>6. 1.0 credit in science (not CHEM)</b>		<b>1.0</b>
<b>7. 2.0 credits in science at the 2000-level or higher</b>		<b>2.0</b>
<b>8. 0.5 credit in:</b>		<b>0.5</b>
ISAP 1000 [0.5]	Seminar in Science	
<b>9. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design</b>		<b>1.5</b>
<b>10. 1.0 credit in free electives</b>		<b>1.0</b>
<b>Total Credits</b>		<b>20.0</b>

### Chemistry

#### with Concentration in Chemical Toxicology B.Sc. Honours (20.0 credits)

##### A. Credits Included in the Major CGPA (11.5 credits)

<b>1. 10.0 credits in:</b>		<b>10.0</b>
CHEM 1011 [0.5]	Enriched General Chemistry 1	
CHEM 1012 [0.5]	Enriched General Chemistry 2	
BIOL 2200 [0.5]	Cellular Biochemistry	
CHEM 2103 [0.5]	Physical Chemistry I	
CHEM 2203 [0.5]	Organic Chemistry I	
CHEM 2204 [0.5]	Organic Chemistry II	
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 2800 [0.5]	Foundations for Environmental Chemistry	
BIOC 3101 [0.5]	Unlocking Metabolism: Pathways, Enzymes, and Control	
CHEM 3201 [0.5]	Advanced Organic Chemistry I	
CHEM 3503 [0.5]	Inorganic Chemistry I	
CHEM 3701 [0.5]	Chemistry in Practice for the 21st Century	
CHEM 3800 [0.5]	The Chemistry of Environmental Pollutants	
BIOC 4708 [0.5]	Principles of Toxicology	
CHEM 4305 [0.5]	Environmental Chemistry and Toxicology	
CHEM 4908 [1.0]	Research Project and Seminar	
or CHEM 4907 [1.0]	Honours Essay and Research Proposal	

FOOD 4103 [0.5]	Food Safety Risk Assessment	
<b>2. 0.5 credit from:</b>		<b>0.5</b>
BIOC 3103 [0.5]	Experimental Biochemistry I: Principles and Practices	
CHEM 3205 [0.5]	Experimental Organic Chemistry	
CHEM 3305 [0.5]	Advanced Analytical Chemistry Laboratory	
CHEM 3400 [0.5]	Independent Research II	
FOOD 4002 [0.5]	Analysis of Food Contaminants	
<b>3. 1.0 credit in CHEM or BIOC at the 3000- or 4000-level</b>		<b>1.0</b>
<b>B. Credits Not Included in the Major CGPA (8.5 credits)</b>		
<b>4. 1.5 credits in:</b>		<b>1.5</b>
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	
or MATH 2007 [0.5]	Elementary Calculus II	
<b>5. 1.0 credit from:</b>		<b>1.0</b>
PHYS 1003 [0.5]	Introductory Mechanics and	
& PHYS 1004 [0.5]	Thermodynamics	
	Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5]	Elementary University Physics I	
& PHYS 1008 [0.5]	Elementary University Physics II	
<b>6. 1.0 credit in:</b>		<b>1.0</b>
BIOL 1103 [0.5]	Foundations of Biology I	
BIOL 1104 [0.5]	Foundations of Biology II	
<b>7. 0.5 credit in:</b>		<b>0.5</b>
FOOD 2004 [0.5]	Scientific Communication in Food Science	
<b>8. 1.5 credits in science at the 2000-level or higher (not CHEM)</b>		<b>1.5</b>
<b>9. 0.5 credit in:</b>		<b>0.5</b>
ISAP 1000 [0.5]	Seminar in Science	
<b>10. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design</b>		<b>1.5</b>
<b>11. 1.0 credit in free electives</b>		<b>1.0</b>
<b>Total Credits</b>		<b>20.0</b>

## Chemistry with Concentration in Nanotechnology B.Sc. Honours (20.0 credits)

<b>A. Credits Included in the Major CGPA (11.0 credits)</b>		
<b>1. 10.0 credits in:</b>		<b>10.0</b>
CHEM 1011 [0.5]	Enriched General Chemistry 1	
CHEM 1012 [0.5]	Enriched General Chemistry 2	
CHEM 2103 [0.5]	Physical Chemistry I	
CHEM 2104 [0.5]	Physical Chemistry II	
CHEM 2203 [0.5]	Organic Chemistry I	
CHEM 2204 [0.5]	Organic Chemistry II	
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 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 3701 [0.5]	Chemistry in Practice for the 21st Century	
CHEM 4103 [0.5]	Surface Chemistry and Nanostructures	
CHEM 4104 [0.5]	Physical Methods of Nanotechnology	
CHEM 4401 [0.5]	Physical Aspects of Biochemistry	
CHEM 4908 [1.0]	Research Project and Seminar	
or CHEM 4907 [1.0]	Honours Essay and Research Proposal	
<b>2. 1.0 credit from:</b>		<b>1.0</b>
CHEM 3205 [0.5]	Experimental Organic Chemistry	
CHEM 3305 [0.5]	Advanced Analytical Chemistry Laboratory	
CHEM 3400 [0.5]	Independent Research II	
CHEM 3504 [0.5]	Inorganic Chemistry II	
<b>B. Credits Not Included in the Major CGPA (9.0 credits)</b>		
<b>3. 2.0 credits in:</b>		<b>2.0</b>
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	
or MATH 2007 [0.5]	Elementary Calculus II	
MATH 2008 [0.5]	Intermediate Calculus	
<b>4. 1.0 credit from:</b>		<b>1.0</b>
PHYS 1003 [0.5]	Introductory Mechanics and	
& PHYS 1004 [0.5]	Thermodynamics	
	Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5]	Elementary University Physics I	
& PHYS 1008 [0.5]	Elementary University Physics II	
<b>5. 0.5 credit in science at the 2000-level or higher (not CHEM)</b>		<b>0.5</b>
<b>6. 2.5 credits in Science</b>		<b>2.5</b>
<b>7. 0.5 credit in:</b>		<b>0.5</b>
ISAP 1000 [0.5]	Seminar in Science	
<b>8. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design</b>		<b>1.5</b>
<b>9. 1.0 credit in free electives.</b>		<b>1.0</b>
<b>Total Credits</b>		<b>20.0</b>

## Chemistry B.Sc. (15.0 credits)

<b>A. Credits Included in the Major CGPA (6.0 credits)</b>		
<b>1. 5.0 credits in:</b>		<b>5.0</b>
CHEM 1011 [0.5]	Enriched General Chemistry 1	
CHEM 1012 [0.5]	Enriched General Chemistry 2	
CHEM 2103 [0.5]	Physical Chemistry I	
CHEM 2104 [0.5]	Physical Chemistry II	
CHEM 2203 [0.5]	Organic Chemistry I	
CHEM 2204 [0.5]	Organic Chemistry II	
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 3101 [0.5]	Quantum Chemistry	
<b>2. 0.5 credit from:</b>		<b>0.5</b>
CHEM 3205 [0.5]	Experimental Organic Chemistry	

CHEM 3305 [0.5]	Advanced Analytical Chemistry Laboratory	
CHEM 3503 [0.5]	Inorganic Chemistry I	
CHEM 3107 [0.5]	Experimental Methods in Nanoscience	
<b>3. 0.5 credit in CHEM at the 3000-level</b>		<b>0.5</b>
<b>B. Credits Not Included in the Major CGPA (9.0 credits)</b>		
<b>4. 2.0 credits in:</b>		<b>2.0</b>
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	
or MATH 2007 [0.5]	Elementary Calculus II	
MATH 2008 [0.5]	Intermediate Calculus	
<b>5. 1.0 credit from:</b>		<b>1.0</b>
PHYS 1003 [0.5]	Introductory Mechanics and	
& PHYS 1004 [0.5]	Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5]	Elementary University Physics I	
& PHYS 1008 [0.5]	Elementary University Physics II	
<b>6. 0.5 credit in science at the 2000-level or higher (not CHEM)</b>		<b>0.5</b>
<b>7. 2.5 credits in science</b>		<b>2.5</b>
<b>8. 0.5 credit in:</b>		<b>0.5</b>
ISAP 1000 [0.5]	Seminar in Science	
<b>9. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design</b>		<b>1.5</b>
<b>10. 1.0 credit in free electives.</b>		<b>1.0</b>
<b>Total Credits</b>		<b>15.0</b>

## Chemistry and Earth Sciences

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

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

<b>1. 4.0 credits in:</b>		<b>4.0</b>
CHEM 1011 [0.5]	Enriched General Chemistry 1	
CHEM 1012 [0.5]	Enriched General Chemistry 2	
CHEM 2103 [0.5]	Physical Chemistry I	
CHEM 2104 [0.5]	Physical Chemistry II	
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 3503 [0.5]	Inorganic Chemistry I	
<b>2. 1.0 credit in CHEM at the 4000-level</b>		<b>1.0</b>
<b>3. 0.5 credit in:</b>		<b>0.5</b>
ERTH 1002 [0.5]	The Earth and Life Odyssey: A Journey Through Billions of Years	
<b>4. 3.5 credits in:</b>		<b>3.5</b>
ERTH 2102 [0.5]	Mineralogy to Petrology	
ERTH 2105 [0.5]	Geodynamics	
ERTH 2106 [0.5]	Geochemistry	
ERTH 2314 [0.5]	Sedimentation and Stratigraphy	
ERTH 2407 [0.5]	Structural Geology	
ERTH 2419 [0.5]	On the Origin of Planets	
ERTH 2802 [0.5]	Field Geology I	
<b>5. 2.0 credits in:</b>		<b>2.0</b>
ERTH 3004 [0.5]	Igneous Petrology	
ERTH 3204 [0.5]	Mineral Deposits	

ERTH 3207 [0.5]	Metamorphic Petrology and Processes	
ERTH 3703 [0.5]	Isotope Geochemistry and Geochronology	
<b>6. 0.5 credit from:</b>		<b>0.5</b>
ERTH 4006 [0.5]	Field Environmental Geobiology	
ERTH 4209 [0.5]	Mineral Exploration Field Geology	
ERTH 4807 [0.5]	Field Geology II	
<b>7. 1.0 credit in EARTH at the 4000-level</b>		<b>1.0</b>
<b>8. 1.0 credit from:</b>		<b>1.0</b>
CHEM 4907 [1.0]	Honours Essay and Research Proposal	
CHEM 4908 [1.0]	Research Project and Seminar	
ERTH 4908 [1.0]	Honours Thesis	
<b>B. Credits Not Included in the Major CGPA (6.5 credits)</b>		
<b>9. 1.0 credit in:</b>		<b>1.0</b>
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1107 [0.5]	Linear Algebra I	
<b>10. 0.5 credit from:</b>		<b>0.5</b>
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 2007 [0.5]	Elementary Calculus II	
<b>11. 0.5 credit in:</b>		<b>0.5</b>
STAT 2507 [0.5]	Introduction to Statistical Modeling I	
<b>12. 0.5 credit in:</b>		<b>0.5</b>
ERTH 2004 [0.5]	Maps, Satellites and the Geospatial Revolution	
<b>13. 1.0 credit from:</b>		<b>1.0</b>
PHYS 1003 [0.5]	Introductory Mechanics and	
& PHYS 1004 [0.5]	Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5]	Elementary University Physics I	
& PHYS 1008 [0.5]	Elementary University Physics II	
<b>14. 0.5 credit in:</b>		<b>0.5</b>
BIOL 1104 [0.5]	Foundations of Biology II	
<b>15. 0.5 credit in Science Faculty Electives (not CHEM or EARTH)</b>		<b>0.5</b>
<b>16. 0.5 credit in:</b>		<b>0.5</b>
ISAP 1000 [0.5]	Seminar in Science	
<b>17. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design</b>		<b>1.5</b>
<b>Total Credits</b>		<b>20.0</b>

## Chemistry and Physics

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

#### A. Credits Included in the Major CGPA (13.0 credits)

<b>1. 1.0 credit from:</b>		<b>1.0</b>
PHYS 1001 [0.5]	Foundations of Physics I	
& PHYS 1002 [0.5]	Foundations of Physics II (recommended)	
PHYS 1003 [0.5]	Introductory Mechanics and	
& PHYS 1004 [0.5]	Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5]	Elementary University Physics I	
& PHYS 1008 [0.5]	Elementary University Physics II (with an average grade of B- or higher)	
<b>2. 3.5 credits in:</b>		<b>3.5</b>

PHYS 2007 [0.5]	Second Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 2212 [0.5]	Wave Mechanics and Thermodynamics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2605 [0.5]	Modern Physics I	
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3807 [0.5]	Mathematical Physics I	
<b>3. 1.5 credits from:</b>		<b>1.5</b>
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
<b>4. 4.5 credits in:</b>		<b>4.5</b>
CHEM 1011 [0.5]	Enriched General Chemistry 1	
CHEM 1012 [0.5]	Enriched General Chemistry 2	
CHEM 2103 [0.5]	Physical Chemistry I	
CHEM 2104 [0.5]	Physical Chemistry II	
CHEM 2203 [0.5]	Organic Chemistry I	
CHEM 2204 [0.5]	Organic Chemistry II	
CHEM 2501 [0.5]	Introduction to Inorganic and Bioinorganic Chemistry	
CHEM 3102 [0.5]	Methods in Computational Chemistry	
CHEM 3503 [0.5]	Inorganic Chemistry I	
<b>5. 0.5 credit in:</b>		<b>0.5</b>
CHEM 3107 [0.5]	Experimental Methods in Nanoscience	
<b>6. 1.0 credit in CHEM at the 4000-level</b>		<b>1.0</b>
<b>7. 1.0 credit from:</b>		<b>1.0</b>
CHEM 4908 [1.0]	Research Project and Seminar	
PHYS 4909 [1.0]	Fourth-Year Project	
PHYS 4907 plus 0.5 credit in PHYS at the 4000-level		
PHYS 4908 plus 0.5 credit in PHYS at the 4000-level		
<b>B. Credits Not Included in the Major CGPA (7.0 credits)</b>		
<b>8. 3.0 credits in:</b>		<b>3.0</b>
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
STAT 3502 [0.5]	Probability and Statistics	
MATH 3705 [0.5]	Mathematical Methods I	
<b>9. 0.5 credit from:</b>		<b>0.5</b>
COMP 1005 [0.5]	Introduction to Computer Science I	
ECOR 1606 [0.5]	Problem Solving and Computers	
<b>10. 0.5 credit from:</b>		<b>0.5</b>
MATH 3800 [0.5]	Mathematical Modeling and Computational Methods	
ECOR 2606 [0.5]	Numerical Methods	
<b>11. 0.5 credit in:</b>		<b>0.5</b>
ISAP 1000 [0.5]	Seminar in Science	

Approved courses outside the faculties of Science and Engineering and Design

**12. 1.5 credits in** approved courses outside the faculties of Science and Engineering and Design **1.5**

**13. 1.0 credit in** free electives. **1.0**

**Total Credits** **20.0**

### Minor in Chemistry (4.0 credits)

The Minor in Chemistry is available to degree students registered in programs other than those associated with the Department of Chemistry.

Students are required to present a Minor CGPA of 4.00 or higher at graduation in order to be awarded a Minor in Chemistry.

#### Requirements:

**1. 1.0 credit from:** **1.0**

CHEM 1001 [0.5] General Chemistry I  
& General Chemistry II

CHEM 1002 [0.5]

or

CHEM 1011 [0.5] Enriched General Chemistry 1  
& Enriched General Chemistry 2

CHEM 1012 [0.5]

**2. 3.0 credits in** Chemistry at 2000-level or higher **3.0**

3. The remaining requirements of the major discipline(s) and degree must be satisfied.

**Total Credits** **4.0**

### B.Sc. Regulations

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 Continuation Evaluation (see the *Academic Regulations of the University* section of this Calendar).

#### Breadth Requirement for the B.Sc.

Students in a Bachelor of Science program must present the following credits at graduation:

- 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;**
- 2.0 credits in courses outside of the faculties of Science and Engineering and Design (may include ISAP 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):

- 2.0 credits in courses outside of the faculties of Science and Engineering and Design (may include ISAP 1000) if the student received fewer than 10.0 transfer credits; or,

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

### Declared and Undeclared Students

Degree students are considered "Undeclared" if they have been admitted to a degree, but have not yet selected and been accepted into a program within that degree. The status "Undeclared" is available only in the B.A. and B.Sc. degrees. Undeclared students must apply to enter a program upon or before completing 3.5 credits.

### Change of Program within the B.Sc. Degree

To transfer to a program within the B.Sc. degree, applicants must normally be *Eligible to Continue* (EC) in the new program, by meeting the CGPA thresholds described in Section 3.1.9 of the *Academic Regulations of the University*.

Applications to declare or change programs 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 limitations, 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 normally requires that the student be *Eligible to Continue* (EC) and is meeting the minimum CGPAs described in Section 3.1.9 of the *Academic Regulations of the University*, as well as being subject to any specific requirements of the intended Minor, Concentration, or Specialization as published in the relevant Calendar entry.

### Experimental Science Requirement

Students in a B.Sc. degree program 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

##### Biochemistry

BIOC 2200 [0.5]	Cellular Biochemistry
BIOC 4001 [0.5]	Methods in Biochemistry
BIOC 4201 [0.5]	Advanced Cell Culture and Tissue Engineering

##### Biology

BIOL 1103 [0.5]	Foundations of Biology I
BIOL 1104 [0.5]	Foundations of Biology II
BIOL 2001 [0.5]	Animals: Form and Function
BIOL 2002 [0.5]	Plants: Form and Function
BIOL 2104 [0.5]	Introductory Genetics
BIOL 2200 [0.5]	Cellular Biochemistry
BIOL 2600 [0.5]	Ecology

##### Chemistry

CHEM 1001 [0.5]	General Chemistry I
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CHEM 1002 [0.5]	General Chemistry II
CHEM 2103 [0.5]	Physical Chemistry I
CHEM 2203 [0.5]	Organic Chemistry I
CHEM 2204 [0.5]	Organic Chemistry II
CHEM 2302 [0.5]	Analytical Chemistry I
CHEM 2303 [0.5]	Analytical Chemistry II
CHEM 2800 [0.5]	Foundations for Environmental Chemistry

##### Earth Sciences

ERTH 1002 [0.5]	The Earth and Life Odyssey: A Journey Through Billions of Years
ERTH 2102 [0.5]	Mineralogy to Petrology
ERTH 2404 [0.5]	Engineering Geoscience
ERTH 2802 [0.5]	Field Geology I
ERTH 3111 [0.5]	Vertebrate Evolution: Mammals, Reptiles, and Birds
ERTH 3112 [0.5]	Vertebrate Evolution: Fish and Amphibians
ERTH 3204 [0.5]	Mineral Deposits
ERTH 3205 [0.5]	Physical Hydrogeology

##### Food Sciences

FOOD 3001 [0.5]	Food Chemistry
FOOD 3002 [0.5]	Food Analysis
FOOD 3005 [0.5]	Food Microbiology

##### Geography

GEOG 1010 [0.5]	Global Environmental Systems
GEOG 3108 [0.5]	Soil Properties

##### Neuroscience

NEUR 3206 [0.5]	Sensory and Motor Neuroscience
NEUR 3207 [0.5]	Systems Neuroscience
NEUR 4600 [0.5]	Advanced Lab in Neuroanatomy

##### Physics

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

### 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 Biogeochemical 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

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) Biochemistry students may use BIOL 2005 only as a free elective.

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)

ISAP (Interdisciplinary Science Practice)

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) except TSES 2305. Biology students may use these courses only as free electives. Integrated Science and Environmental Science students may include these courses in their programs but may not count them as part of the Science Sequence.

### Science Faculty Electives

Science Faculty Electives are courses at the 1000-4000 level chosen from:

BIOC (Biochemistry)

BIOL (Biology) Biology & Biochemistry students may use BIOL 1010 and BIOL 2005 only as free electives

CHEM (Chemistry) except CHEM 1003, CHEM 1004 and CHEM 1007

COMP (Computer Science) except COMP 1001

ERTH (Earth Sciences) except ERTH 1004 and ERTH 2415. Earth Sciences students may use ERTH 2401, ERTH 2402 and ERTH 2403 only as free electives.

Engineering

ENSC 2001

FOOD (Food Science and Nutrition)

GEOM (Geomatics)

HLTH (Health Science)

ISAP (Interdisciplinary Science Practice)

MATH (Mathematics)

NEUR (Neuroscience)

PHYS (Physics) except PHYS 1901, PHYS 1902, PHYS 1905, PHYS 2903

Science Geography (see list above)

Science Psychology (see list above)

STAT (Statistics)

TSES (Technology, Society, Environment) Biology 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 ISAP 1000)

All courses offered by the Faculty of Arts and Social Sciences, the Faculty of Public and Global 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). ISAP 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

BIOL 4810 [0.5]	Education Research in Undergraduate Science
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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 1004 [0.5]	Earth's Epic Tale: A Story Across Billions of Years
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
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 1009 [0.5]	Mathematics for 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

all 0000-level courses

### 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 applies to a degree program with a Co-op option from high school, their university grades will be reviewed two terms to one year prior to their first work term to ensure they meet the academic requirements after their first or second year of study. The time at which the evaluation takes place depends on the program of study. Students will automatically receive an admission decision via their Carleton email account.

Students who did not request Co-op at the time they applied to Carleton can request Co-op after they begin their university studies. To view application instructions and deadlines, please visit [carleton.ca/co-op](http://carleton.ca/co-op).

To be admitted to Co-op, a student must successfully complete 5.0 or more credits that count towards their degree, meet the minimum CGPA requirement(s) for the student's Co-op option, and fulfil any specified

course prerequisites. To see the unique admission and continuation requirements for each Co-op option, please refer to the specific degree programs listed in the Undergraduate Calendar.

### Participation Requirements

#### Co-op Participation Agreement

All students must adhere to the policies found within the Co-op Participation Agreement.

#### COOP 1000

Once a student has been admitted to the Co-op Program, they will be given access to register in COOP 1000. This zero-credit online course must be completed at least two terms prior to the student's first work term.

#### 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 Co-op students, no guarantee of employment can be made. The Co-op job search process is competitive, and success is dependent upon factors such as current market conditions, academic performance, skills, motivation, and level of commitment to the job search. It is the student's responsibility to apply for positions via the Co-op job board in addition to actively conducting a self-directed job search. Students who do not obtain a co-op work term are expected to continue with their academic studies. It should be noted that hiring priority for positions within the Federal Government of Canada is given to Canadian citizens.

#### Registration

- Students must be registered as full-time during all fall and winter study terms beginning the term in which they enroll in COOP 1000.
- Students will be registered in a Co-op Work Term course while at work. This course does not carry academic course credit, but is noted on academic transcripts.
- Students may register in a 0.5 credit during a work term, provided the course is offered during the evening or is offered asynchronously online.
- Students must have at least one term of full-time studies left to complete following their final co-op work term. Students cannot end their degree on a work term.

### Work Term Assessment and Evaluation

#### Work Term Evaluation

Employers are responsible for submitting to Carleton University final performance evaluations for their Co-op students at the end of their work terms.

#### Work Term Assessment

In order to successfully complete the co-op work term, students must receive a Satisfactory (SAT) grade on their

Co-op Work Term Report, which they must submit at the completion of each four-month work term.

### Graduation with the Co-op Designation

In order to graduate with the Co-op Designation, students must satisfy all requirements of the degree program in addition to the successful completion of three or four work terms (the number is dependent upon the student's academic program). Students found in violation of the Co-op Participation Agreement may have the Co-op Designation withheld.

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 who are currently on a co-op work term or who have already committed to a co-op work term either verbally or in writing may not leave the position and/or withdraw from the co-op option until they have completed the work term and all related requirements.

### Involuntary or Required Withdrawal from the Co-op Option

Students may be removed from the Co-op Program for any of the following reasons:

1. Failure to achieve a grade of SAT in COOP 1000;
2. Failure to attend all interviews for positions to which the student has applied;
3. Declining more than one job offer during the job search;
4. Reneging on a co-op position that the student has accepted either verbally or in writing;
5. Continuing a job search after accepting a co-op position;
6. Dismissal from a work term by the co-op employer;
7. Leaving a work term without approval from the Co-op Management Team;
8. Receipt of an unsatisfactory work term evaluation;
9. Receiving a grade of UNS on the work term report.

### 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. The Co-operative Education Office will provide students with a letter of support to accompany their Co-op Work Permit application. Students are advised to discuss the application process and application requirements with the International Student Services Office.

### Co-op Fees

All participating Co-op students are required to pay Co-op fees. For full details, please see the Co-op website.

### B.Sc. Honours Chemistry: Co-op Admission and Continuation Requirements

- Maintain full-time status in each study term;
- Be eligible to work in Canada (for off-campus work);
- Have successfully completed COOP 1000 .

In addition to the following:

1. Registered as a full-time student in the B.Sc. Honours Chemistry program;
2. Successfully completed 5.0 or more credits;
3. Obtained an Overall CGPA of at least 6.50 and a Major CGPA of at least 8.00. These CGPAs must be maintained throughout the duration of the degree.

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:**

Year 1		Year 2		Year 3		Year 4		Year 5	
Term	Pattern	Term	Pattern	Term	Pattern	Term	Pattern	Term	Pattern
Fall	S	Fall	S	Fall	S	Fall	W	Fall	S
Winter	S	Winter	S	Winter	S	Winter	W	Winter	S
Summer		Summer	W	Summer	W	Summer	W		

- Maintain full-time status in each study term;
- Be eligible to work in Canada (for off-campus work);
- Have successfully completed COOP 1000 .

### Admissions Information

Admission Requirements are for the 2025-26 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](http://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.

### Admissions Information

Admission requirements are based on the Ontario High School System. Prospective students can view the admission requirements through the Admissions website at [admissions.carleton.ca](http://admissions.carleton.ca). The overall average required for admission is determined each year on a program-by-program basis. Holding the minimum admission requirements only establishes eligibility for consideration; higher averages are required for admission to programs for which the demand for places by qualified applicants exceeds the number of places available. All programs have limited enrolment and admission is not guaranteed. Some programs may also require specific course prerequisites and prerequisite

averages and/or supplementary admission portfolios. Consult [admissions.carleton.ca](http://admissions.carleton.ca) for further details.

**Note:** If a course is listed as recommended, it is 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. (Major)
- B.Sc.

## Admission Requirements

### B. Sc. Honours

#### 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 and Biology, 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, Integrated Science, 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 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

Applications for admission beyond first year will be assessed on their merits. Applicants must normally be *Eligible to Continue* in their year level, in addition to meeting the CGPA thresholds described in Section 3.1.9 of the Academic Regulations of the University. Advanced standing will be granted only for those subjects deemed appropriate for the program and stream selected.

### B.Sc. Major and B.Sc.

#### First Year

The Ontario Secondary School Diploma (OSSD) or equivalent including a minimum of six 4U or M courses. The six 4U or M courses must include Advanced Functions and two of Calculus and Vectors, Biology, Chemistry, Earth and Space Science, or Physics (Calculus

and Vectors is strongly recommended). For the B.Sc. Major in Physics, 4U Physics is strongly recommended.

#### Advanced Standing

Applications for admission beyond first year will be assessed on their merits. Applicants must normally be *Eligible to Continue* (EC) in their year level. Advanced standing will be granted only for those subjects deemed appropriate for the program and stream selected.

#### 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 1001 [0.5 credit]

#### General Chemistry I

Topics include atomic structure, periodic trends, structure and bonding, gas laws, intermolecular forces, equilibrium, acids and bases, and buffers. Examples relate to health, energy, materials, and the environment.

Includes: Experiential Learning Activity

Precludes additional credit for CHEM 1005 (no longer offered), CHEM 1011, CHEM 1101.

Prerequisite(s): Ontario 4U/M in Chemistry (or equivalent) strongly recommended.

Lectures and tutorial four hours a week, laboratory three hours every other week.

### CHEM 1002 [0.5 credit]

#### General Chemistry II

Topics include thermodynamics and spontaneity, kinetics, electrochemistry, organic chemistry, transition metal complexes, and green chemistry. Examples relate to health, energy, materials, and the environment.

Includes: Experiential Learning Activity

Precludes additional credit for CHEM 1006 (no longer offered), CHEM 1012.

Prerequisite(s): 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 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 1008 [0.5 credit]****Inquiry in Chemistry Research**

Students experience the journey of research in chemistry by using inquiry-based principles to answer complex societal questions. Students practice developing research questions and study designs, perform data analysis, and are introduced to scientific literacy and communication, EDI, and meta-cognition.

Includes: Experiential Learning Activity

Prerequisite(s): first year standing in Chemistry.

Workshop 3 hours a week

**CHEM 1011 [0.5 credit]****Enriched General Chemistry 1**

This is a maths-intensive specialist course intended for chemistry majors or students planning to pursue courses in chemistry at the 3000-level and above. Topics include atomic structure, periodic trends, structure and bonding, gas laws, intermolecular forces, equilibrium, acids and bases, and buffers.

Includes: Experiential Learning Activity

Precludes additional credit for CHEM 1001, CHEM 1005 (no longer offered), CHEM 1101.

Lectures and tutorial four hours a week, laboratory three hours every other week.

**CHEM 1012 [0.5 credit]****Enriched General Chemistry 2**

This is a maths-intensive specialist course intended for chemistry majors or students planning to pursue courses in chemistry at the 3000-level and above. Topics include thermodynamics and spontaneity, kinetics, electrochemistry, organic chemistry, transition metal complexes, and green chemistry.

Includes: Experiential Learning Activity

Precludes additional credit for CHEM 1002, CHEM 1006 (no longer offered).

Prerequisite(s): CHEM 1011.

Lectures and tutorial four hours a week, laboratory three hours every other 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, CHEM 1005 (no longer offered), CHEM 1011.

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.

Prerequisite(s): CHEM 1006 (no longer offered) with a minimum grade of B-, or CHEM 1002 or CHEM 1012, MATH 1004, MATH 1104 or MATH 1107, (PHYS 1001 and PHYS 1002) or (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 2104 [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 3100 (no longer offered).

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 2203 [0.5 credit]****Organic Chemistry I**

Introduction to stereochemistry, spectroscopy and chemical reactions of alkanes, alkenes, alkynes, and alkyl halides. Reaction mechanisms and the interpretation of IR, NMR and mass spectra is explored. 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 (no longer offered) with a minimum grade of B-, or CHEM 1002 or CHEM 1012.

Lectures three hours a week and laboratory three hours a week.

**CHEM 2204 [0.5 credit]****Organic Chemistry II**

Introduction to stereochemistry, spectroscopy, mechanisms, and chemical reactions of alcohols, ethers, epoxides, conjugated pi-systems, aromatic compounds, aldehydes, ketones, amines and carboxylic acids and their derivatives. Further 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 2208.

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**

Introduction to stereochemistry, spectroscopy and chemical reactions of alkanes, alkenes, alkynes, and alkyl halides. Reaction mechanisms and the interpretation of IR, NMR and mass spectra is explored.

Precludes additional credit for CHEM 2203.

Prerequisite(s): CHEM 1006 (no longer offered) with a minimum grade of B-, or CHEM 1002 or CHEM 1012.

Lectures three hours a week.

**CHEM 2208 [0.5 credit]****Introduction to Organic Chemistry II**

Introduction to stereochemistry, spectroscopy, mechanisms, and chemical reactions of alcohols, ethers, epoxides, conjugated pi-systems, aromatic compounds, aldehydes, ketones, amines and carboxylic acids and their derivatives.

Precludes additional credit for CHEM 2204.

Prerequisite(s): CHEM 2207 or CHEM 2203.

Lectures three hours a week.

**CHEM 2302 [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

Prerequisite(s): CHEM 1006 (no longer offered) with a minimum grade of B-, or CHEM 1002 or CHEM 1012 or CHEM 1101 and (MATH 1007 or MATH 1004).

Lectures three hours a week, laboratory three hours a week.

**CHEM 2303 [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

Prerequisite(s): CHEM 1006 (no longer offered) with a minimum grade of B-, or CHEM 1002, or CHEM 1012, 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.

Prerequisite(s): CHEM 1006 (no longer offered) with a minimum grade of B-, or CHEM 1002 or CHEM 1012.

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 (no longer offered) with a minimum grade of B- or CHEM 1002, or CHEM 1012, or CHEM 1101, (MATH 1007 or MATH 1004).

Lectures three hours 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 and MATH 2008.

Lectures three hours a week, tutorial one hour per week.

**CHEM 3102 [0.5 credit]****Methods in Computational Chemistry**

Use of computers in the modeling and simulation of chemistry. Introduction to computer programming for analysis and visualization of chemical data. Calculation of chemical properties and modeling of chemical reactions using quantum chemistry.

Includes: Experiential Learning Activity

Prerequisite(s): CHEM 3101 or PHYS 3701.

Lectures and problems 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 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 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 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 3701 [0.5 credit]****Chemistry in Practice for the 21st Century**

Students explore different sectors of chemical industry; developments in sustainability; principles, analytical frameworks, and applications of green chemistry; environmental protections; and Canadian regulatory frameworks. Students investigate novel issues in industrial chemistry, build scientific literacy skills, and practice communicating scientific information to diverse audiences.

Prerequisite(s): third-year standing in a BSc or BHSc program.

Workshop 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 4101 [0.5 credit]****Advanced Topics in Computational Chemistry**

Computer simulation of materials, liquids, and biomolecules in the framework of intermolecular forces and statistical thermodynamics. Introduction to chemoinformatics and machine learning methods in chemistry.

Includes: Experiential Learning Activity

Prerequisite(s): CHEM 3102.

Also offered at the graduate level, with different requirements, as CHEM 5122, for which additional credit is precluded.

Lectures 3 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 <sup>1</sup>H and <sup>13</sup>CNMR 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 of 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 4207 [0.5 credit]****Bio-Organic Chemistry**

The course covers chemical and biosynthetic methods applied to the major classes of biomolecules and their derivatives, including: carbohydrates, amino acids, peptides, proteins, nucleic acids, lipids, terpenes, heterocycles and natural products. Content will focus on reactions and mechanisms that contribute to their biological activities.

Also listed as BIOC 4207.

Prerequisite(s): CHEM 3201 or permission of the department.

Also offered at the graduate level, with different requirements, as CHEM 5010., for which additional credit is precluded.

Lectures three hours a week.

**CHEM 4301 [0.5 credit]****Advanced Topics in Analytical Chemistry I**

Analytical chemistry of trace and ultratrace elements/compounds. Special requirements for quantitative determination by various instrumental methods. Control of contamination and blanks. Analytical method development to improve selectivity, sensitivity and detection limit. Strength and limitations of each instrument. Optimization of all operating parameters.

Prerequisite(s): CHEM 2103 and one of CHEM 2302 or CHEM 2303.

Also offered at the graduate level, with different requirements, as CHEM 5607, for which additional credit is precluded.

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 4401 [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.

Includes: Experiential Learning Activity

Precludes additional credit for BIOC 2200, BIOL 2200, BIOC 3101, CHEM 3401 (no longer offered).

Prerequisite(s): CHEM 2103 and CHEM 2204.

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 (i.e. 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 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.