Catholic District School Board Writing Partnership

Science

Course Profile

Chemistry

Grade 12
University Preparation
SCH4U

- *for teachers by teachers*

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Course Overview
Chemistry, SCH4U, Grade 12, University Preparation

Policy Document: *The Ontario Curriculum, Grades 11 to 12, Science, 2000.*
Prerequisite: Chemistry, SCH3U, Grade 11, University Preparation

Course Description

This course enables students to deepen their understanding of chemistry through the study of organic chemistry, energy changes and rates of reactions, chemical systems and equilibrium, electrochemistry, and atomic and molecular structure. Students will further develop problem-solving and laboratory skills as they investigate chemical processes, at the same time refining their ability to communicate scientific information. Emphasis will be placed on the importance of chemistry in daily life, and on evaluating the impact of chemical technology on the environment.

How This Course Supports the Ontario Catholic Graduate Expectations

This course seeks to further the achievement of Ontario Catholic Graduate Expectations through integrating Scripture, Catholic Church teaching, and moral and ethical reflection. Students are encouraged to become discerning believers who integrate faith with life. Students develop their decision-making skills and critically reflect on the spiritual, moral, and ethical dimensions of issues addressed in this course. They use and integrate the Catholic faith tradition in the critical analysis of chemistry in everyday life and evaluate the impact of chemical technology on the environment. As informed Catholic citizens, students acknowledge and accept their responsibility as stewards of the earth and use their knowledge to address pressing environmental issues.

Course Notes

This course provides students with the prerequisite knowledge and skills needed to meet the entrance requirements for university chemistry. In planning, teachers must deliver the rigorous provincial curriculum, emphasizing the theoretical aspects of the course content, and including relevant and concrete applications. Emphasis should be placed on the development and demonstration of both independent research skills and learning skills. Teachers must incorporate the skills essential for scientific investigation (*The Ontario Curriculum, Grade 11 and 12 Science, p. 55*). These skills, coded SIS.01 to SIS.10, must be developed in all course units. Assessment of these skills must be included in the evaluation of students' achievement. Throughout the course, students should maintain a Data Book to help develop inquiry skills.

Teachers are encouraged to give a diagnostic assessment at the beginning of each unit, and should include a test at the end of each unit in addition to any end-of-unit task. Students build on their prior knowledge from *The Ontario Curriculum, Grades 9 and 10 Science* (Atoms and Elements in Grade 9, Chemical Processes and Weather Dynamics in Grade 10), and *The Ontario Curriculum, Grade 11 and 12 Science* (Chemistry SCH3U Grade 11, University Preparation).

This course is organized into six units, which match the strands used in the Grades 11 and 12 Science document; however, the units have been reordered to provide a logical development of knowledge, theories, and skills, and a meaningful and relevant framework for studying chemistry in a faith-filled context. The units are Structure and Properties, Electrochemistry I (Oxidation and Reduction), Organic Chemistry, Energy Changes and Rates of Reaction, Chemical Systems in Equilibrium, and Electrochemistry II (Electrochemical and Electrolytic Cells). The course begins with Structure and Properties, which builds on students' prior knowledge of chemistry from the SCH3U Matter and Chemical Bonding unit, and gives students the background knowledge they require to understand and explain the major concepts developed throughout the course.

Next, the expectations relating to oxidation and reduction from the Electrochemistry strand are clustered as a unit to provide a basis for concepts required for the Organic Chemistry strand. Students develop an understanding of oxidation and reduction, and the skills for writing balanced equations for oxidation-reduction systems. They then apply the knowledge and skills from this unit when studying the oxidation-reduction reactions that are an important class of organic reactions, e.g., oxidation of primary and secondary alcohols. Next, in the Organic Chemistry unit, students build on the knowledge they gained in the SCH3U Hydrocarbons and Energy unit, and apply concepts and skills developed in the first two units. This Course Profile develops this unit since it provides students opportunities to research and acquire knowledge, practice and develop inquiry skills, and serves as the perfect medium to deal with the impact of science on society and the environment. Students use and integrate the Catholic faith tradition in the critical analysis of chemistry in everyday life. They evaluate the impact of chemistry and chemical technology on our standard of living and the environment, and as a result make informed and ethical decisions. The next unit, Energy Changes and Rates of Reactions, builds on these concepts. It allows the students to demonstrate an understanding of the dependence of chemical technologies and processes on the energetics of chemical reactions. The Chemical Systems and Equilibrium unit applies and builds on the concepts from Rates of Reactions. Students apply the importance of chemical equilibrium to various systems, including technological, ecological, and biological systems. The course ends with Electrochemistry II (Electrochemical and Electrolytic Cells), where students apply the knowledge and concepts gained and demonstrate the inquiry and connection-making skills they developed throughout the course. If teachers wish to cluster the expectations differently than suggested in this Course Profile, they must address all learning expectations, the different categories of learning, and carefully consider the time spent on each unit. When using the Unit Overview Charts, teachers should note that within each cluster one or more of the categories of learning may have a greater focus — this category has been printed in bold.

Throughout the course, teachers must provide ample opportunities for students to engage in safe, relevant laboratory activities. The health and safety of teachers and students must be routinely addressed when conducting laboratory activities, using safe laboratory practices and following Workplace Hazardous Materials Information System (WHMIS) legislation. For a comprehensive list of safety measures, see Unit 3 p.14

It is critical that students develop strong communication skills, including the use of information technology for collecting, organizing, and presenting information. Furthermore, science cannot be taught in isolation but must be linked to other disciplines. Encouraging students to develop an awareness of controversial issues involving science and technology will allow them to make connections to society and the environment. These are the skills that will foster the qualities of responsible citizens. Students should be encouraged to keep a Journal for reflections to further the achievement of the Ontario Catholic Graduate expectations. (**Note:** The Ontario Catholic Graduate Expectations and the journal are not to be assessed.) Teachers are encouraged to incorporate the use of computer technologies such as computer-based simulations, multimedia applications, and computer-assisted laboratory apparatus in the delivery of this course. However, care must be taken to ensure that computer-assisted laboratory programs are not used as a substitute in cases where students' essential scientific skills should be developed.

Units: Titles and Time

Unit 1	Structure and Properties	19 hours
Unit 2	Electrochemistry I (Oxidation and Reduction)	8 hours
* Unit 3	Organic Chemistry	20 hours
Unit 4	Energy Changes and Rates of Reaction	22 hours
Unit 5	Chemical Systems and Equilibrium	27 hours
Unit 6	Electrochemistry II (Electrochemical and Electrolytic Cells)	14 hours

* This unit is fully developed in this Course Profile.

Unit Overviews

Unit 1: Structure and Properties

Time: 19 hours

Unit Description

Students build on the knowledge they gained in the SCH3U Matter and Chemical Bonding unit. They develop an elementary understanding of a few basic quantum mechanical ideas and explain how types of chemical bonding account for the properties of ionic, molecular, covalent network, and metallic substances. Students investigate and compare the properties of solids and liquids, and use bonding theory to predict the shape of simple molecules. Through research they describe products and technologies whose development has depended on understanding molecular structure, and technologies that have advanced the knowledge of atomic and molecular theory.

In the first cluster of expectations, after a diagnostic activity and review of required concepts from SCH3U, the teacher groups students for the jigsaw activity to research and present the contributions of scientists associated with the development of atomic structure. They explain the experimental observations made by Rutherford and Bohr in the development of the planetary model of the hydrogen atom. They describe the quantum mechanical model of the atom and the contributions of individuals such as Planck, de Broglie, Einstein, Heisenberg, and Schrödinger to this model. (**Note:** Teachers should recognize that the most that students will have at the end of this unit is an elementary understanding of a few quantum mechanical ideas. Any real understanding of quantum mechanical theory will not come until an advanced undergraduate course.) In addition, students highlight the contributions of Canadian scientists to atomic and molecular theory, e.g., the contributions of Ronald Gillespie to the Valence Shell Electron Pair Repulsion (VSEPR) model of molecular geometry, which plays a prominent role in this course. Students practise writing the electron configurations for elements in the periodic table, using the Pauli exclusion principle and Hund's rule. By examining and describing a variety of elements representative of the s, p, d, and f blocks of the periodic table, students explain the relationship between position of elements in the periodic table, their properties, and their electron configurations.

In the second cluster, students review the concepts of chemical bonding from SCH3U. Focusing on molecular compounds, students construct models to explain how the VSEPR model can be used to predict molecular geometry (molecular shape). Students carry out an activity where they predict molecular geometry for simple molecules and ions using the VSEPR model. Using the molecular geometry and electronegativity values of the elements in each molecule studied, they predict the polarity of each molecule or ion and construct models of each structure.

In the third cluster, through a lab investigation, students describe the physical properties of a variety of solids and liquids and use text or Internet sources to find each substance's melting points and boiling points. Students then prepare a written lab report explaining how the properties of each substance studied depend on the nature of the particles present and the types of forces between them. As a follow up activity, students predict the type of solid formed by a substance, e.g., ionic, molecular, covalent network or metallic, and describe and summarize its properties.

In the last cluster, students extend their knowledge of structure and properties of matter. Students brainstorm various specialized new materials; for example, Kevlar. They investigate and describe specialized new materials that have been created on the basis of research findings about the structure of matter, chemical bonding, and other properties of matter. In addition, they describe applications of principles relating to atomic and molecular structure in the fields of analytical chemistry and medical diagnosis, and investigate possible careers related to these fields. As a conclusion to this unit, students are invited to read the First Creation Story (Genesis 1:1 – 2:4a) and reflect in their journals how the story of the creation of the universe relates to the study of the world of atoms and molecules.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	SPV.01, .02, .03, SP1.01, 1.02, 1.03, 2.01, 2.02, 3.03 SIS.05, .06 CGE2b	**Knowledge/ Understanding** **Communication** **Making Connections**	• Diagnostic activity • Small group jigsaw activity on scientists' contributions to the Quantum Mechanical Model and Canadian research on atomic and molecular theory • Writing electron configurations • Electron configuration and the Periodic Table
2	SPV.01, .02, SP1.05, 2.03, 2.04 SIS.05, .06 CGE2b, e, 4g	**Knowledge/ Understanding** **Communication**	• VSEPR Theory • Bonding and intermolecular forces • Quiz
3	SPV.01, .02, SP1.04, 2.05, 2.06 SIS.01, .02, .03, .04, .05, .06, .07, .09 CGE2b, c, e, 5a, b, e, f, g	Knowledge/ Understanding **Communication** **Inquiry**	• Lab investigation on physical properties of substances and types of bonding present
4	SPV.03, SP3.01, 3.02 SIS.05, .06, .07, .10 CGE2b, c, e, 5a, b, e, f, g	**Communication** **Making Connections**	• End-of-unit task: new materials based on structure of matter • Applications of atomic and molecular structure and related careers • Unit test

Unit 2: Electrochemistry I (Oxidation and Reduction)

Time: 8 hours

Unit Description

Students build on the knowledge they gained in the SCH3U Matter and Chemical Bonding unit to demonstrate an understanding of fundamental concepts related to oxidation and reduction.

In the first cluster, students learn how to determine the oxidation number for atoms and ions. They examine oxidation-reduction reactions, a process where electrons are lost during oxidation and gained during reduction. Understanding that oxidation number is simply a theoretical concept that allows one to track the transfer of electrons between different types of atoms in a chemical reaction, students are able to view oxidation-reduction reactions as a pair of two half-cell reactions. Students write and balance chemical equations for oxidation-reduction systems such as those involved in organic chemistry, which will be studied in Unit 3.

In the second cluster, students demonstrate oxidation-reduction reactions through experimentation. Students compare the reactivity of selected metals by arranging them in order of their ease of oxidation. This can be determined through observation of their ability to displace other metals from compounds. Students prepare a report explaining corrosion as an electrochemical process, and describe a variety of corrosion-inhibiting techniques. Students use their experimental results along with textbook and Internet sources to determine which metals could provide cathodic protection to iron and investigate preferred metals.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	ELV.01, .02, EL1.01, 2.01, 2.03 SIS.05 CGE2b	**Knowledge/ Understanding** **Communication**	• Diagnostic Activity • Determination of oxidation number • Definition of reduction and oxidation • Half cell reactions • Balancing oxidation-reduction (redox) reactions
2	ELV.01, .02, EL1.06, 2.01, 2.02 SIS.01, .02, .03, .04, .05, .06, .07 CGE2b, c, e, 3c, 5a, b, e, f, g	**Knowledge/ Understanding** **Communication** **Inquiry**	• Conduct a lab to demonstrate and analyse redox reactions • End-of-unit task: corrosion • Unit test

Unit 3: Organic Chemistry

Time: 20 hours

Unit Description

Students build on the knowledge they gained in the SCH3U Hydrocarbons and Energy unit to study the structure of various organic compounds and the chemical reactions involving these compounds. They name and represent the structures of organic compounds using the IUPAC (International Union of Pure and Applied Chemistry) system. Through research and experimentation, students investigate organic compounds. They describe the physical properties of classes of organic compounds, predict the products of organic reactions, and evaluate the impact of organic compounds on society.

In the first cluster, students recognize the vast variety of organic compounds that touch their lives, e.g., medicines, dyes, polymers, synthetic fibres, food additives, pesticides, etc. They are introduced to the different organic functional groups, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides. Students recall the IUPAC system for organic nomenclature introduced in the SCH3U Hydrocarbons and Energy unit, and build on their skills to name and write the appropriate structures for the different classes of organic compounds. They distinguish between the terms organic, natural, and chemical, and critically evaluate the accuracy of the use of these terms in the promotion of consumer goods by compiling an advertisement portfolio (*Caveat Emptor* – Buyer Beware – Portfolio).

In the second cluster, students apply the concepts learned in Unit 1, Structure and Properties, to describe and explain the physical properties of the different classes of organic compounds in terms of molecular polarity, melting point, boiling point, solubility in different solvents, and odour. They demonstrate their knowledge by performing a physical property model building activity, where they build models of a variety of aliphatic (both open chain and cyclic) and aromatic organic compounds, and make predictions about their physical properties based on their structures. (**Note:** Teachers should recognize that organic compounds are divided into two broad classes: aliphatic compounds and aromatic compounds. Aliphatic compounds are the alkanes, alkenes, and alkynes, and all the compounds that can be derived from them by replacing the hydrogen atoms with other atoms or groups of atoms). Students are introduced to the end-of-unit task, A “PRESS”ing Concern.

In the third cluster, students apply their knowledge of the concepts related to oxidation-reduction studied in the Electrochemistry Part 1 unit and build on their knowledge of functional groups from the first cluster of this unit. Through teacher-directed presentations, students examine the chemical properties of the different organic functional groups and describe the different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis. Students predict and name the products of the various organic reactions. Through experimentation, students synthesize various organic compounds, such as esters and simple polymers.

In the fourth cluster, through a teacher-directed class discussion, students build on their knowledge from Cluster 1 to recognize that all living organisms are made of organic compounds. Through a cooperative group activity, students research the importance of naturally occurring organic compounds such as carbohydrates, proteins, and nucleic acids. They recognize and reflect on the greatness of God's creativity in the transformation of these complex molecules into forms of life. In addition, students research and create a database to provide examples of organic compounds used to improve existing health, safety, and environmental problems.

In the fifth cluster, students carry out the end-of-unit task, A "PRESS'ing Concern. They research various organic synthetic products and analyse the risks and benefits involved in their development and application. Each group's research is presented in the form of a press conference. At the press conference, students share their research by answering questions posed to them by another group who assume the role of reporters. As reporters, students use their findings to write an editorial where they evaluate the impact that organic synthetic compounds have on society and the environment. In their journals, students reflect and recognize their role as stewards of the earth in addressing environmental concerns and issues, thereby acquiring an appreciation for the need to protect God's Creation. (**Note:** Expectations OC3.02 and OC3.04 are introduced in Cluster 2 but assessed in Cluster 4.)

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	OCV.01, .02, .03, OC1.01, 2.01, 2.02, 2.04, 3.01, 3.02 SIS.05 CGE2b	**Knowledge/ Understanding Inquiry Communication** Making Connections	• Diagnostic activity • Organic compounds in everyday life • Nomenclature flash card activity • Quiz on organic nomenclature • *Caveat Emptor* Portfolio
2	OCV.01, .02, .03, OC1.02, 2.01, 2.03, 3.03 SIS.05 CGE2b	**Knowledge/ Understanding Inquiry Communication** Making Connections	• Physical property model building activity • Quiz on the physical properties of organic compounds • A "PRESS"ing Concern assignment introduction
3	OCV.01, .02, OC1.03, 1.04, 2.01, 2.05, 2.06 SIS.01, .02, .03, .04, .05, .06, .07 CGE2b, e, 5a, b, e, f, g	**Knowledge/ Understanding Inquiry Communication**	• Worksheets on organic reactions • Quiz on organic reactions • Experiment: synthesis of organic compounds

4	OCV.01, .03, OC1.05, 3.02, 3.04 SIS.05, .06, .10 CGE1e, 2b, c, e, 4g; 7h, i, j	**Knowledge/ Understanding Inquiry Communication Making Connections**	• Jigsaw activity on compounds of life • Reflection • Database of solutions to health and environmental problems • Unit test
5	OCV.03, OC2.01, 3.02, 3.03 SIS.05, .06 CGE1d, 2b, c, e, 3c, d, e, f; 4a, c, e, f, g; 5e; 7a, b, e, h, i, j	Knowledge/ Understanding Inquiry **Communication Making Connections**	• End-of-unit task: press conference • Fact sheet • Editorial

Unit 4: Energy Changes and Rates of Reaction

Time: 22 hours

Unit Description

Students build on their knowledge from the SCH3U Hydrocarbons and Energy unit to further develop an understanding of the energy transformations and kinetics of chemical changes. Using experimental data and calculations, they determine energy changes for physical and chemical processes and rates of reaction. Through research, students demonstrate an understanding of the dependence of chemical technologies and processes on the energetics of chemical reactions.

In the first cluster, students review the terms and conventions that were used to study energy changes in chemical reactions in the SCH3U Hydrocarbons and Energy unit. Using this information, students write thermochemical equations, expressing the energy change as a ΔH value or as a heat term in the equation. Students research and describe technologies that depend on exothermic or endothermic changes. Through a lab investigation, students determine the heat of reaction using a calorimeter, and use their experimental data to calculate the enthalpy change for the observed reaction. Through a teacher-led discussion, students compare the energy changes resulting from physical change, chemical reactions, and nuclear reactions (fission and fusion). Students research and compare conventional and alternative sources of energy with respect to efficiency and environmental impact. In their journals, students reflect on the wonder of God's Creation and on their ability to use resources responsibly and efficiently.

In the second cluster, Hess's Law is introduced through a teacher-directed lesson. Students perform an experiment to demonstrate and explain Hess's Law. They apply Hess's Law to solve problems and to calculate heat of reaction using tabulated enthalpies of formation.

In the third cluster, through an activity or demonstration, students review the various factors that affect the rate of a reaction (from SNC2D). With the aid of a graph, students describe the rate of a reaction as a function of the change of concentration of a reactant or product with respect to time. They express the rate of a reaction as a rate law equation (first or second order reactions only), and explain the concept of half-life as another means of comparing the rates of reactions. Using the collision theory and potential energy diagrams, students explain how factors such as temperature, surface area, nature of reactants, catalysts, and concentration all control the rate of chemical reactions. Through a lab investigation, students determine the rate of reaction and measure the effect of temperature, concentration, and catalysis on the rate.

In the fourth cluster, students analyse simple potential energy diagrams of chemical reactions and use them to demonstrate an understanding that most reactions occur as a series of elementary steps in a reaction mechanism.

In the fifth cluster, students use textbook and Internet sources to research and present factors used to inhibit or enhance the rate of a reaction, and specific reactions whose rates can be controlled. Research should include applications of catalysts used in industry and biochemical systems. Teachers should assign the activity when rates of reaction are introduced at the end of Cluster 3.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	ECV.01, .02, .03, EC1.01, 2.02, 2.03, 3.01, 3.02 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09 CGE2b, e, 5a, b, e, f, g, 7i	**Knowledge/ Understanding** **Inquiry** **Communication** **Making Connections**	• Thermochemical equations • Applications of thermochemistry to industry • Calorimetry lab • Alternate Sources of Energy
2	ECV.01, .02, EC1.02, 2.04, 2.05 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09, .10 CGE2b, e, 5a, b, e, f, g; 7i	**Knowledge/ Understanding** **Inquiry** **Communication**	• Hess's Law • Hess's Law lab • Calculations using enthalpy of formation tables
3	ECV.01, .02, EC1.03 1.04, 2.01, 2.06 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09 CGE2b, 5a, b, e, f, g	**Knowledge/ Understanding** **Inquiry** **Communication**	• Reaction rate definition • Reactions rate graphs • Collision theory as it applies to the rate of a reaction • Lab to measure the effect of temperature, concentration, and catalysts on reaction rates
4	ECV.01, EC1.05, 1.06 SIS.05, .08, .09 CGE2b	**Knowledge/ Understanding** **Communication**	• Potential energy diagrams for chemical reactions • Reactions mechanisms • Unit test
5	ECV.03, EC3.03, 3.04 SIS.06, .10 CGE2b, c, e, 4g	**Knowledge/ Understanding** **Inquiry** **Communication** **Making Connections**	• End-of-unit task: catalysts

Unit 5: Chemical Systems in Equilibrium

Time: 27 hours

Unit Description

Students develop an understanding of the concept of chemical equilibrium, Le Châtelier's Principle, and solution equilibria. Through experimentation, they investigate the behaviour of different equilibrium systems, and build their problem-solving skills as they solve problems involving the law of chemical equilibrium. In addition, they research and explain the importance of chemical equilibrium in various systems, including ecological, biological, and technological systems.

In the first cluster, through a lab investigation, students are introduced to dynamic equilibrium and Le Châtelier's Principle. Students examine and illustrate the concept of dynamic equilibrium with reference to systems such as liquid-vapour equilibrium, weak electrolytes in solutions, and chemical reactions. They use Le Châtelier's Principle to predict the direction a system at equilibrium will shift when a stress such as volume, pressure, concentration, or temperature is applied. Students then perform an experiment where they predict and test how various factors affect a chemical system in equilibrium. Through research of a particular industry, students explain how equilibrium principles may be applied to optimize the production of industrial chemicals. A suggestion would be to study the Haber Process. As a follow-up activity to a class discussion on the Haber Process and how chemicals can be misused, students make a journal entry reflecting on their responsibilities to make ethical choices as informed Catholic citizens.

In the second cluster, students build on their knowledge from the Energy Changes and Rates of Reaction unit as they are introduced to the concept of entropy. They identify entropy changes associated with chemical and physical processes and recognize that reactions tend to achieve minimum energy and maximum entropy. The students examine the quantitative relationship of a system in equilibrium, apply the law of chemical equilibrium to the concentrations of the reactants and products in equilibrium, and define the constant expressions for K_{eq}. Students solve equilibrium problems involving concentrations of reactants and products.

In the third cluster, students apply equilibrium concepts to solutions. By solving word problems dealing with K_{sp} and the common ion effect, students apply the concept of equilibrium to solutions. Students perform an experiment to determine K_{sp} of an ionic salt such as calcium hydroxide.

In the fourth cluster, students apply equilibrium concepts to acids and bases. Students review the concepts of acids and bases learned in SCH3U. Students compare strong and weak acids or bases and their ability to ionize or dissociate in varying degrees in water, and apply the concepts of equilibrium to these systems. Students predict whether an aqueous salt solution forms an acidic, basic, or neutral solution by studying the equilibrium between salts and water. Students examine and describe the characteristics and components of buffer solutions, and explain how buffering action affects our daily lives. Finally, the concept of equilibrium is applied to acids and bases through the mathematical study of K_a, K_b, pH, and pOH, including titration reactions.

As an end-of-unit task, students brainstorm and identify the many examples of the effects of solubility on biological systems. By studying one of these systems in detail (e.g., the quality of eggshells, or the carbonate/bicarbonate buffer system in the human body), students investigate the complexity of God's creations.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	CSV.01, .02, .03, CS1.01, 1.03, 2.01, 2.02, 3.01 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09, .10 CGE2b, e, 5a, b, e, f, g, 4g	**Knowledge/ Understanding** **Inquiry** **Communication** **Making Connections**	• Diagnostic assessment • Dynamic equilibrium • Le Châtelier's Principle • Lab to demonstrate Le Châtelier's Principle • Applications of Le Châtelier's Principle to industry
2	CSV.01, .02, CS1.02, 1.04, 1.05, 1.07, 2.03, 2.06 SIS.05, .06, .08, .09 CGE2b, e	**Knowledge/ Understanding** **Inquiry** **Communication**	• Law of chemical equilibrium • Entropy and enthalpy • Define and solve problems for K_{eq}

3	CSV.01, .02, .03, CS1.06, 2.04, 2.05, 2.06 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09 CGE1e, 2b, e, 5a, b, e, f, g, 7d, j	**Knowledge/ Understanding** **Inquiry** **Communication**	• Solutions and equilibrium • Molar solubility • Solve K_{sp} problems • Carry out lab to determine K_{sp}
4	CSV.01, .02, .03, CS1.08, 1.09, 2.07, 2.08, 2.06, 3.02, 3.03 SIS.05, .06, .07, .08, .09 CGE1e, 2b, e, 5a, b, e, f, g, 7d, j	**Knowledge/ Understanding** **Inquiry** **Communication** **Making Connections**	• Acids and bases and equilibrium • Acidity of salts • Buffer solutions and their applications • Solve problems involving K_a, K_b, pH and pOH • Solve problems using acid-base titration data • End-of-unit task: the effect of solubility on biological systems • Unit test

Unit 6: Electrochemistry II (Electrochemical and Electrolytic Cells)

Time: 14 hours

Unit Description

Students review the major concepts learned in the Electrochemistry I unit, and build on their knowledge of fundamental concepts related to oxidation-reduction and the interconversion of chemical and electrical energy. Through lab investigations they build and explain the functioning of simple galvanic and electrolytic cells and use equations to describe these cells. They research and describe some uses of batteries and fuel cells, and assess environmental and safety issues associated with these technologies.

In the first cluster, students learn about spontaneous reactions through the construction of galvanic cells. Students determine oxidation and reduction half-cell reactions, direction of current flow, electrode polarity, cell potential, and ion movement. They describe electrochemical cells in terms of oxidation and reduction half-cells whose voltages can be used to determine overall cell potential. By building galvanic cells and measuring the corresponding voltage put out by the cells, students compare their experimental values with the calculated/theoretical values obtained from the standard reduction potentials table. Using the standard reduction potential values, students recognize that the reduction potentials are not direct measurements, but measurements that are relative to the reduction potential of the hydrogen half-cell. Students use standard reduction potential values to predict the spontaneity of an electrochemical reaction, and use this concept to explain the activity series of metals. Students research and design a brochure to advertise a common galvanic cell and evaluate its environmental and societal impact.

In the second cluster, students learn that non-spontaneous reactions occur when voltage is applied to an electrolytic cell. They identify and describe the functioning of the components of electrolytic cells. Through the construction of electrolytic cells, students determine oxidation and reduction half-cell reactions, direction of current flow, electrode polarity, cell potential, and ion movement. Students study and explain how electrolytic processes are involved in industrial processes.

In the third cluster, students apply quantitative aspects of electrolysis to electrochemical cells by studying Faraday's Law and the physical factors involved. Students perform an experiment where they measure the mass of metal deposited by electroplating, and apply Faraday's Law to relate the mass of metal deposited to the amount of charge passed. Due to the complexity of the experiment and the safety issues involved, it is recommended that this be done through a computer-based lab if possible.

In the fourth cluster, through use of text and Internet sources, students research and assess environmental, health, and safety issues involving electrochemistry, e.g., the use of hydrogen cells in cars. As stewards, students reflect on the wonder of God's Creation and their role in addressing environmental concerns and issues and the responsible use of resources.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	ELV.01, .02, .03, EL1.03, 1.04, 2.01, 2.04, 2.05, 3.01 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09 CGE2b, e, 4f; 5a, b, e, f, g, 7h, i, j	**Knowledge/ Understanding Inquiry Communication Making Connections**	• Half-cells, electrochemical cells and cell potential • Lab to assemble and describe galvanic cells • Hydrogen half-cell • Reduction potential values • Spontaneity • Brochure advertising Galvanic cells and their impact on the environment
2	ELV.01, .02, .03, EL1.02, 2.01, 2.04, 3.02 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09, .10 CGE2b, e, 4f; 5a, b, e, f, g, 7h, i, j	**Knowledge/ Understanding Inquiry Communication Making Connections**	• Electrolytic cells • Lab to assemble and describe electrolytic cells • Applications of electrolytic processes in industry
3	ELV.01, .02, EL1.05, 2.01, 2.06, 2.07 SIS.01, .02, .03, .04, .05, .06, .07, .08, .09 CGE2b, e, 5a, b, e, f, g	**Knowledge/ Understanding Inquiry Communication**	• Faraday's Law • Solve problems with Faraday's Law • Lab applying Faraday's Law to the mass of metal deposited by electroplating
4	ELV.01, .03, EL2.01, 3.03 SIS.05, .06 CGE1d, 2b, c, e, 3c, d, e, f; 4a, c, e, f, g, 5e, 7a, b, e, h, i, j	**Knowledge/ Understanding Communication Making Connections**	• End-of-unit task: report on environmental health and safety issues in electrochemistry • Unit test

Teaching/Learning Strategies

In planning this course, consideration should be given to both the course expectations and the needs of individual students. The teacher should provide learning experiences which promote interest, understanding, and excellence. In order for this course to prepare students to meet the university entrance requirements, the teacher must deliver the rigorous provincial curriculum emphasizing the theoretical aspects of the course, while incorporating relevant applications. The role of the teacher is to establish the conceptual framework to help the students develop specific skills and attitudes while considering the student's individual learning style. By fostering an atmosphere where learning is meaningful, integrative, challenging, active, and value-based, teachers can help their students become excited about learning.

Throughout this course, students should be given numerous and varied opportunities to acquire knowledge and develop skills and attitudes through a variety of teaching and learning strategies. The strategies that the teacher uses should provide students with multiple opportunities to develop and demonstrate their learning and skills across all four categories of the Achievement Chart.

Expectations that require Knowledge/Understanding can be developed through:

- brainstorming, e.g., SP3.02, OC3.01, OC3.02;
- teacher-directed lessons and discussions, e.g., EC1.02, CSE3.01;
- small group instruction, e.g., OC3.02, OC3.O4;
- independent research, e.g., SP1.01, SP1.02, SP1.03, OC3.01, OC3.03;
- self-directed learning, etc., e.g., EC1.05.

Expectations that involve Inquiry can be met by:

- conducting and analysing experiments, e.g., EC2.03, HE2.04, HE2.05;
- designing lab investigations, e.g., OC2.06, EL2.04;
- formulating questions, e.g., SP3.02;
- solving problems, e.g., CS2.06, CS2.04, EL2.06.

Expectations that encourage Communication can be demonstrated by:

- written reports, e.g., EL 2.01, EL3.03, EC3.03, EC3.04;
- group discussions, e.g., SP3.02;
- debates, e.g., EC3.01, EC3.02, OC3.01, OC3.03;
- seminars, e.g., EC3.03, EC3.04, OC3.02, OC3.04;
- student presentations, e.g., oral presentations, video and audio presentations, skits, photo essays, etc. (OC3.01, OC3.03).

Expectations where students expand their knowledge to Make Connections can be developed through:

- independent research, e.g., EC3.01, EC3.02, OC3.01, OC3.03;
- exposure to experts in their field (e.g., listening to guest speakers or attending university lectures), e.g., OC3.04;
- reflective papers, e.g., EC3.01;
- portfolios, e.g., OC3.01, OC3.03;
- participation in science fairs, e.g., EC3.03;
- reading Church documents (see Resources), e.g., ECG.

Assessment & Evaluation of Student Achievement

In order for students to demonstrate their mastery of the knowledge and skills required for university entrance, the teacher should establish a balanced assessment plan for the course and select appropriate methods, strategies, and tools. Students must demonstrate that they have developed independent research skills and independent learning skills, as well as having learned the value of collaboration to work effectively as interdependent team members.

Assessment is the process of gathering information from a variety of sources that accurately reflect how well a student is achieving the curriculum expectations. As part of assessment, teachers must provide students with descriptive feedback that guides their efforts towards improvement. Evaluation refers to the process of judging the quality of student work on the basis of established criteria, and assigning a value that represents that quality. The primary purpose of assessment and evaluation is to improve student learning. Information gathered through assessment helps teachers to determine students' strengths and weaknesses in their achievement of the curriculum expectations.

Assessment and evaluation must be based on the learning expectations for this course and the achievement levels outlined in the *Program Planning and Assessment, 2000* document. During the design and planning of this course, the Learning Expectations were clustered to balance the categories within the Achievement Chart. Teachers are encouraged at the beginning and throughout the course to share the assessment criteria with the students and their parents, and to give feedback that guides the students' efforts towards improvement.

The assessment results should be used to motivate students and help them establish next steps in their learning goals. To ensure that assessment and evaluations are valid and reliable, the teacher should use assessment and evaluation strategies that:

- address both what the students learn and how well they learn it;
- are based both on the categories of knowledge and skills and on the achievement levels;
- are varied in nature, are administered over a period of time, and demonstrate the full range of learning;
- promote the students' ability to assess their own learning and to set specific goals.

Assessment practices should provide information on what students write, say, and do.

Possible assessment strategies include:

- paper-and-pencil: tests, quizzes, concept maps, essays, written reports/lab reports, research papers;
- personal communication: interviews, conferences, journals, classroom discussions;
- performance task: individual presentations, plays/skits, lab performance.

The tools used to effectively measure students' learning and mastery of skills include:

- checklist;
- marking scheme;
- rating scale;
- rubric.

As this is a university preparation course, we recommend that teachers carefully consider a balanced weighting of the four categories of achievement — Knowledge/Understanding, Inquiry, Communication, and Making Connections — throughout all the units and in the final evaluation. This helps to ensure that the students have the opportunity to develop and demonstrate their achievement of the knowledge and the independent research and learning skills necessary for this university preparation course.

The Provincial Report Card contains separate sections for reporting on achievement of the curriculum expectations and for reporting on demonstrated skills required for effective learning. The student's final grade for this course will be determined as follows:

- Seventy per cent (70%) of the grade will be based on evaluations conducted throughout this course. This portion of the grade should reflect the students' most consistent level of achievement throughout the course, although special consideration should be given to the most recent evidence of achievement.
- Thirty per cent (30%) of the grade will be based on a final evaluation administered towards the end of the course. The weighting of each of the four categories in the final evaluation should be consistent with the assessment/evaluation practices used throughout the course. It is recommended that the final evaluation for this university preparation course take the form of a final examination comprised of both a written and a lab-based component. Teachers may choose to use a final written exam along with a course culminating task.

Teachers may choose to encourage students to design and conduct a Science Fair project, which would allow them to further develop their independent research and learning skills. This project could be considered as part of the final thirty percent of the students' grade; however, it must address expectations from several units and represent individual student achievement.

Accommodations

Teachers must consider the needs of exceptional students in the planning of the science curriculum. Accommodation to the program activities and/or the working environment may be necessary. Teachers should consult individual student's Individual Education Plan (IEP) for specific direction on accommodation for individuals. Where the student has an IEP the teacher must meet the needs of the student as outlined in the Plan.

Exceptional students, as well as other students who are not identified as exceptional but who have an IEP and are receiving special education programs and services, should be given every opportunity to achieve the curriculum expectations set out for this course.

A variety of teaching approaches may need to be used to help exceptional students achieve the learning expectations of this course. Examples of such approaches may include:

- using special resources, e.g., reading material consistent with students' reading levels and learning styles, audio tapes of difficult chapters, adapted computers;
- using specialized equipment and assistance specific to the chemistry lab, e.g., providing access to sinks, burners, balances, etc., and assistance with the handling of chemicals and reagents;
- using a variety of Teaching/Learning strategies, e.g., special interest groupings for research projects, collaborative groups, mentorship programs, independent study plans;
- collaborating with resource teachers, teacher-librarians, and other professionals;
- consulting with parents about providing an appropriate study environment in the home;
- allowing more time for completion of assignments or achievement of the learning expectations;
- providing alternative ways of completing tasks or presenting information, e.g., taped answers;
- simplifying the language of instruction;
- providing alternative homework assignments;
- providing alternative tasks for highly motivated and gifted students, e.g., encouraging participation in Science Fair competitions; subject-specific university-founded competitions such as the University of Waterloo Chemistry Contests or the Chemical Institute of Canada Crystal Growing Competition; attendance at university-sponsored activities/lectures; and establishing mentorship programs with local colleges and universities.

Accommodations to assessment procedures and strategies may also be required. Examples include:

- adjustment of time requirements for assignments or assessment tasks;
- format of the assessment material, e.g., Braille;
- use of scribes, tape recorders, word processors, etc.

For English as a Second Language (ESL) students or English Literacy Development (ELD) students, teachers should provide opportunities for the students to demonstrate their learning by alternate means, such as pairing written instructions with verbal instructions; using key visuals to illustrate definitions; allowing extra time for reading or written assignments; and encouraging the use of first-language dictionaries for assignments.

For students with physical or learning impairments, classroom and laboratory activities should be altered to permit maximum participation.

Resources

The URLs for the websites were verified by the writer prior to publication. Given the frequency with which these designations change, teachers should always verify the websites prior to assigning them for student use.

Units in this Course Profile make reference to the use of specific texts, magazines, films, videos, and websites. Teachers need to consult their board policies regarding use of any copyrighted materials. Before reproducing materials for student use from printed publications, teachers need to ensure that their board has a Cancopy licence and that this licence covers the resources they wish to use. Before screening videos/films with their students, teachers need to ensure that their board/school has obtained the appropriate public performance videocassette licence from an authorized distributor, e.g., Audio Cine Films Inc. Teachers are reminded that much of the material on the Internet is protected by copyright. The copyright is usually owned by the person or organization that created the work. Reproduction of any work or substantial part of any work on the Internet is not allowed without the permission of the owner

Print

Burton, G., J. Holman, G. Pilling, and D. Waddington. *Salters Advanced Chemistry – Chemical Storylines.* Oxford: Heinemann Educational Publishers, 1994. ISBN 0-435-63106-3

Catechism of the Catholic Church. Canadian Conference of Catholic Bishops, 1994. ISBN 088997-281-8

Chang, Raymond. *Chemistry*. Toronto: McGraw-Hill, Inc., 1994. ISBN 0-07-011003-4

Gillespie, R., D. Eaton, D. Humphreys, and E. Robinson. *Atoms, Molecules, and Reactions.* Scarborough Prentice Hall, 1994. ISBN 0-13088790-0

Groome, T. *Educating for Life.* Allen, Texas: Thomas More, 1998. ISBN 0-88347-383-6

McFague, Sallie. *Super, Natural Christians.* Minneapolis: Fortress Press, 1997. ISBN 0-8006-3076-9

Royal Society of Chemistry. *The Age of the Molecule.* ISBN 0-85404-945-2

Snyder, C. *The Extraordinary Chemistry of Ordinary Things.* New York: John Wiley and Sons, Inc., 1998. ISBN 0-471-17905-1

Journals/Magazines

Crucible, Magazine of the Science Teachers' Association of Ontario. ISSN –381-8047

Discover Canadian Chemistry, A newsletter for high school chemistry students. Published by the Chemical Institute of Canada (Telephone: 1-613-232-6252)

Journal of Chemical Education. ISSN 0021-9584

Chem13 News, University of Waterloo

Origins. Catholic News Service, 3211 4th Str. N.E. Washington D.C. ISBN 200017-1100

Documents from the Ontario Conference of Catholic Bishops:

a) For the Good of All (1992).
b) The People of the Land (1989).

Videotapes

Environmental Ethics: Ideas for Classrooms Discussion. Durango Col. Group for Telly Productions, 1994. CBC. News for Review: 1996 – 1998.

Computer Software

Chemistry Explorer 3.04. Lewiston: Tangent Scientific, 1999.

Chemistry with Computers, Using Logger Pro. Dan D. Holmquist and Donald L. Volz, Vernier Software.

Interactive General Chemistry, Lewiston: Tangent Scientific, 1999.

Internet Sites

A comprehensive listing of science sites – www.enc.org

Chemical Institute of Canada – http://www.chem-ist-can.org

ChemEd: Chemistry Education Resources – http://www.hpcc.astro.washington.edu/scied/chemistry.html

Chemistry Lesson Plans – http://www.teach-nology.com

Chemistry Resources – http://www.dist214.k12il/users/asander/chemhome2.html

Interactive Chemistry – http://hamer.chem.wisc.edu/chapman/index.html

Journal of Chemical Education – http://www.JChemEd.chem.wisc.edu

Science Resource Centre – http://chem.lapeer.org

Annotated list of websites for science educators

STAO Classroom Resources for Science Teachers
– http://www.yorku.ca/faculty/academic/jlibman/staopage.htm

OSS Considerations

Students can benefit from experiences in chemistry-related activities through a Cooperative Education placement related to this course. Students should explore chemistry-related careers throughout the course and consider them when they are developing their Annual Education Plan (AEP).

Students may choose to job-shadow. This gives them an opportunity to observe and gain a better understanding of chemistry-related careers, for example, in the area of chemical research, environmental sciences, health services, etc.

Students should have a safe environment for learning free from harassment of all types, violence, and expressions of hate. Learning activities should be designed to help students develop respect for human rights and dignity, and to develop a sense of personal, social, and civic responsibility.

Students graduating from Ontario schools are expected to be technologically literate. Through the study of this science course, students should be able to understand and apply technological concepts to use computers in various applications and to analyse the implications of technology on individuals and society.

Coded Expectations, Chemistry, Grade 12, University, SCH4U

Scientific Investigation Skills

SIS.01 - demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., safely disposing of organic solutions; correctly interpreting Workplace Hazardous Materials Information System [WHMIS] symbols), and using appropriate personal protection (e.g., wearing safety goggles);
SIS.02 - select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., use a calorimeter in heat transfer experiments);
SIS.03 - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., select and use apparatus safely in an experiment to determine the mass of a metal deposited by electroplating);
SIS.04 - demonstrate a knowledge of emergency laboratory procedures;
SIS.05 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use the Valence Shell Electron Pair Repulsion [VSEPR] model to predict the shapes of molecules);
SIS.06 - compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion (e.g., research the uses of the most commonly synthesized organic compounds);
SIS.07 - communicate the procedures and results of investigations for specific purposes by displaying evidence and information, either in writing or using a computer, in various forms, including flow charts, tables, graphs, and laboratory reports (e.g., construct visual models that explain intermolecular and intramolecular forces);
SIS.08 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.09 - select and use appropriate SI units;
SIS.10 - identify and describe science- and technology-based careers related to the subject area under study (e.g., describe careers related to thermochemistry, such as chemical engineering).

Organic Chemistry

Overall Expectations

OCV.01 · demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
OCV.02 · investigate various organic compounds through research and experimentation, predict the products of organic reactions, and name and represent the structures of organic compounds using the IUPAC system and molecular models;
OCV.03 · evaluate the impact of organic compounds on our standard of living and the environment.

Specific Expectations

Understanding Basic Concepts

OC1.01 – distinguish among the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides, by name and by structural formula;
OC1.02 – describe some physical properties of the classes of organic compounds in terms of solubility in different solvents, molecular polarity, odour, and melting and boiling points;
OC1.03 – describe different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis;

OC1.04 – demonstrate an understanding of the processes of addition and condensation polymerization;
OC1.05 – describe a variety of organic compounds present in living organisms, and explain their importance to those organisms (e.g., proteins, carbohydrates, fats, nucleic acids).

Developing Skills of Inquiry and Communication

OC2.01 – use appropriate scientific vocabulary to communicate ideas related to organic chemistry (e.g., *functional group, polymer*);
OC2.02 – use the IUPAC system to name and write appropriate structures for the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, amides, and simple aromatic compounds;
OC2.03 – build molecular models of a variety of aliphatic, cyclic, and aromatic organic compounds;
OC2.04 – identify some nonsystematic names for organic compounds (e.g., *acetone, isopropyl alcohol, acetic acid*);
OC2.05 – predict and correctly name the products of organic reactions, including substitution, addition, elimination, esterification, hydrolysis, oxidation, and polymerization reactions (e.g., preparation of an ester, oxidation of alcohols with permanganate);
OC2.06 – carry out laboratory procedures to synthesize organic compounds (e.g., preparation of an ester, polymerization).

Relating Science to Technology, Society, and the Environment

OC3.01 – present informed opinions on the validity of the use of the terms organic, natural, and chemical in the promotion of consumer goods;
OC3.02 – describe the variety and importance of organic compounds in our lives (e.g., plastics, synthetic fibres, pharmaceutical products);
OC3.03 – analyse the risks and benefits of the development and application of synthetic products (e.g., polystyrene, aspartame, pesticides, solvents);
OC3.04 – provide examples of the use of organic chemistry to improve technical solutions to existing or newly identified health, safety, and environmental problems (e.g., leaded versus unleaded gasoline; hydrocarbon propellants versus chlorofluorocarbons [CFCs]).

Energy Changes and Rates of Reaction

Overall Expectations

ECV.01 · demonstrate an understanding of the energy transformations and kinetics of chemical changes;
ECV.02 · determine energy changes for physical and chemical processes and rates of reaction, using experimental data and calculations;
ECV.03 · demonstrate an understanding of the dependence of chemical technologies and processes on the energetics of chemical reactions.

Specific Expectations

Understanding Basic Concepts

EC1.01 – compare the energy changes resulting from physical change, chemical reactions, and nuclear reactions (fission and fusion);
EC1.02 – explain Hess's law, using examples;
EC1.03 – describe, with the aid of a graph, the rate of reaction as a function of the change of concentration of a reactant or product with respect to time; express the rate of reaction as a rate law equation (first- or second-order reactions only); and explain the concept of half-life for a reaction;
EC1.04 – explain, using collision theory and potential energy diagrams, how factors such as temperature, surface area, nature of reactants, catalysts, and concentration control the rate of chemical reactions;

EC1.05 – analyse simple potential energy diagrams of chemical reactions (e.g., potential energy diagrams showing the relative energies of reactants, products, and activated complex);
EC1.06 – demonstrate understanding that most reactions occur as a series of elementary steps in a reaction mechanism.

Developing Skills of Inquiry and Communication
EC2.01 – use appropriate scientific vocabulary to communicate ideas related to the energetics of chemical reactions (e.g., *enthalpy, activated complex*);
EC2.02 – write thermochemical equations, expressing the energy change as an ΔH value or as a heat term in the equation;
EC2.03 – determine heat of reaction using a calorimeter, and use the data obtained to calculate the enthalpy change for a reaction (e.g., neutralization of sodium hydroxide and hydrochloric acid);
EC2.04 – apply Hess's law to solve problems, including problems that involve data obtained through experimentation (e.g., measure heats of reaction that can be combined to yield the ΔH of combustion of magnesium);
EC2.05 – calculate heat of reaction using tabulated enthalpies of formation;
EC2.06 – determine through experimentation a rate of reaction (e.g., of hydrogen peroxide decomposition), and measure the effect on it of temperature, concentration, and catalysis.

Relating Science to Technology, Society, and the Environment
EC3.01 – compare conventional and alternative sources of energy with respect to efficiency and environmental impact (e.g., burning fossil fuels, solar energy, nuclear fission);
EC3.02 – describe examples of technologies that depend on exothermic or endothermic changes (e.g., hydrogen rocket fuel, hot and cold packs);
EC3.03 – describe the use of catalysts in industry (e.g., catalytic converters) and in biochemical systems (e.g., enzymes) on the basis of information gathered from print and electronic sources;
EC3.04 – describe examples of slow chemical reactions (e.g., rusting), rapid reactions (e.g., explosions), and reactions whose rates can be controlled (e.g., food decay, catalytic decomposition of automobile exhaust).

Chemical Systems and Equilibrium

Overall Expectations
CSV.01 · demonstrate an understanding of the concept of chemical equilibrium, Le Châtelier's principle, and solution equilibria;
CSV.02 · investigate the behaviour of different equilibrium systems, and solve problems involving the law of chemical equilibrium;
CSV.03 · explain the importance of chemical equilibrium in various systems, including ecological, biological, and technological systems.

Specific Expectations
Understanding Basic Concepts
CS1.01 – illustrate the concept of dynamic equilibrium with reference to systems such as liquid-vapour equilibrium, weak electrolytes in solution, and chemical reactions;
CS1.02 – demonstrate an understanding of the law of chemical equilibrium as it applies to the concentrations of the reactants and products at equilibrium;
CS1.03 – demonstrate an understanding of how Le Châtelier's principle can predict the direction in which a system at equilibrium will shift when volume, pressure, concentration, or temperature is changed;
CS1.04 – identify, in qualitative terms, entropy changes associated with chemical and physical processes;

CS1.05 – describe the tendency of reactions to achieve minimum energy and maximum entropy;
CS1.06 – describe, using the concept of equilibrium, the behaviour of ionic solutes in solutions that are unsaturated, saturated, and supersaturated;
CS1.07 – define constant expressions, such as K_{sp}, K_w, K_a, and K_b;
CS1.08 – compare strong and weak acids and bases using the concept of equilibrium;
CS1.09 – describe the characteristics and components of a buffer solution.

Developing Skills of Inquiry and Communication
CS2.01 – use appropriate vocabulary to communicate ideas, procedures, and results related to chemical systems and equilibrium (e.g., *homogeneous, common ion, K_a value*);
CS2.02 – apply Le Châtelier's principle to predict how various factors affect a chemical system at equilibrium, and confirm their predictions through experimentation;
CS2.03 – carry out experiments to determine equilibrium constants (e.g., K_{eq} for iron[III] thiocyanate, K_{sp} for calcium hydroxide, K_a for acetic acid);
CS2.04 – calculate the molar solubility of a pure substance in water or in a solution of a common ion, given the solubility product constant (K_{sp}), and vice versa;
CS2.05 – predict the formation of precipitates by using the solubility product constant;
CS2.06 – solve equilibrium problems involving concentrations of reactants and products and the following quantities: K_{eq}, K_{sp}, K_a, K_b, pH, pOH;
CS2.07 – predict, in qualitative terms, whether a solution of a specific salt will be acidic, basic, or neutral;
CS2.08 – solve problems involving acid-base titration data and the pH at the equivalence point.

Relating Science to Technology, Society, and the Environment
CS3.01 – explain how equilibrium principles may be applied to optimize the production of industrial chemicals (e.g., production of sulfuric acid, ammonia);
CS3.02 – identify effects of solubility on biological systems (e.g., kidney stones, dissolved gases in the circulatory system of divers, the use of barium sulfate in medical diagnosis);
CS3.03 – explain how buffering action affects our daily lives, using examples (e.g., the components in blood that help it to maintain a constant pH level; buffered medications).

Electrochemistry

Overall Expectations

ELV.01 · demonstrate an understanding of fundamental concepts related to oxidation-reduction and the interconversion of chemical and electrical energy;
ELV.02 · build and explain the functioning of simple galvanic and electrolytic cells; use equations to describe these cells; and solve quantitative problems related to electrolysis;
ELV.03 · describe some uses of batteries and fuel cells; explain the importance of electrochemical technology to the production and protection of metals; and assess environmental and safety issues associated with these technologies.

Specific Expectations

Understanding Basic Concepts
EL1.01 – demonstrate an understanding of oxidation and reduction in terms of the loss and the gain of electrons or change in oxidation number;
EL1.02 – identify and describe the functioning of the components in galvanic and electrolytic cells;
EL1.03 – describe electrochemical cells in terms of oxidation and reduction half-cells whose voltages can be used to determine overall cell potential;

EL1.04 – describe the function of the hydrogen half-cell as a reference in assigning reduction potential values;

EL1.05 – demonstrate an understanding of the interrelationship of time, current, and the amount of substance produced or consumed in an electrolytic process (Faraday's law);

EL1.06 – explain corrosion as an electrochemical process, and describe corrosion-inhibiting techniques (e.g., painting, galvanizing, cathodic protection).

Developing Skills of Inquiry and Communication

EL2.01 – use appropriate scientific vocabulary to communicate ideas related to electrochemistry (e.g., *half-reaction, electrochemical cell, reducing agent, redox reaction, oxidation number*);

EL2.02 – demonstrate oxidation-reduction reactions through experiments, and analyse these reactions (e.g., compare the reactivity of some metals by arranging them in order of their ease of oxidation, which can be determined through observation of their ability to displace other metals from compounds; investigate the reactivity of oxidizing agents such as oxygen and various acids);

EL2.03 – write balanced chemical equations for oxidation-reduction systems, including half-cell reactions;

EL2.04 – determine oxidation and reduction half-cell reactions, direction of current flow, electrode polarity, cell potential, and ion movement in typical galvanic and electrolytic cells, including those assembled in the laboratory;

EL2.05 – predict the spontaneity of redox reactions and overall cell potentials by studying a table of half-cell reduction potentials;

EL2.06 – solve problems based on Faraday's law;

EL2.07 – measure through experimentation the mass of metal deposited by electroplating (e.g., copper from copper II sulfate), and apply Faraday's law to relate the mass of metal deposited to the amount of charge passed.

Relating Science to Technology, Society, and the Environment

EL3.01 – describe examples of common galvanic cells (e.g., lead-acid, nickel-cadmium) and evaluate their environmental and social impact (e.g., describe how advances in the hydrogen fuel cell have facilitated the introduction of electric cars);

EL3.02 – explain how electrolytic processes are involved in industrial processes (e.g., refining of metals, production of chlorine);

EL3.03 – research and assess environmental, health, and safety issues involving electrochemistry (e.g., the corrosion of metal structures by oxidizing agents; industrial production of chlorine by electrolysis and its use in the purification of water).

Structure and Properties

Overall Expectations

SPV.01 · demonstrate an understanding of quantum mechanical theory, and explain how types of chemical bonding account for the properties of ionic, molecular, covalent network, and metallic substances;

SPV.02 · investigate and compare the properties of solids and liquids, and use bonding theory to predict the shape of simple molecules;

SPV.03 · describe products and technologies whose development has depended on understanding molecular structure, and technologies that have advanced the knowledge of atomic and molecular theory.

Specific Expectations

Understanding Basic Concepts

SP1.01 – explain the experimental observations and inferences made by Rutherford and Bohr in developing the planetary model of the hydrogen atom;

SP1.02 – describe the quantum mechanical model of the atom (e.g., orbitals, electron probability density) and the contributions of individuals to this model (e.g., those of Planck, de Broglie, Einstein, Heisenberg, and Schrödinger);

SP1.03 – list characteristics of the *s*, *p*, *d*, and *f* blocks of elements, and explain the relationship between position of elements in the periodic table, their properties, and their electron configurations;

SP1.04 – explain how the properties of a solid or liquid (e.g., hardness, electrical conductivity, surface tension) depend on the nature of the particles present and the types of forces between them (e.g., covalent bonds, Van der Waals forces, dipole forces, and metallic bonds);

SP1.05 – explain how the Valence Shell Electron Pair Repulsion (VSEPR) model can be used to predict molecular shape.

Developing Skills of Inquiry and Communication

SP2.01 – use appropriate scientific vocabulary to communicate ideas related to structure and bonding (e.g., *orbital, absorption spectrum, quantum, photon, dipole*);

SP2.02 – write electron configurations for elements in the periodic table, using the Pauli exclusion principle and Hund's rule;

SP2.03 – predict molecular shape for simple molecules and ions, using the VSEPR model;

SP2.04 – predict the polarity of various substances, using molecular shape and the electronegativity values of the elements of the substances;

SP2.05 – predict the type of solid (ionic, molecular, covalent network, or metallic) formed by a substance, and describe its properties;

SP2.06 – conduct experiments to observe and analyse the physical properties of different substances, and to determine the type of bonding present.

Relating Science to Technology, Society, and the Environment

SP3.01 – describe some applications of principles relating to atomic and molecular structure in analytical chemistry and medical diagnosis (e.g., infrared spectroscopy, X-ray crystallography, nuclear medicine, medical applications of spectroscopy);

SP3.02 – describe some specialized new materials that have been created on the basis of the findings of research on the structure of matter, chemical bonding, and other properties of matter (e.g., bulletproof fabric, superconductors, superglue);

SP3.03 – describe advances in Canadian research on atomic and molecular theory (e.g., the work of Richard Bader at McMaster University in developing electron-density maps for small molecules; the work of R.J. LeRoy at the University of Waterloo in developing the mathematical technique for determining the radius of molecules called the LeRoy Radius).

Ontario Catholic School Graduate Expectations

The graduate is expected to be:

A Discerning Believer Formed in the Catholic Faith Community who

CGE1a -illustrates a basic understanding of the **saving story** of our Christian faith;
CGE1b -participates in the **sacramental life** of the church and demonstrates an understanding of the centrality of the Eucharist to our Catholic story;
CGE1c -actively reflects on **God's Word** as communicated through the Hebrew and Christian scriptures;
CGE1d -develops attitudes and values founded on Catholic **social teaching** and acts to promote social responsibility, human solidarity and the common good;
CGE1e -speaks the **language of life**... "recognizing that life is an unearned gift and that a person entrusted with life does not own it but that one is called to protect and cherish it." (Witnesses to Faith)
CGE1f -seeks intimacy with God and celebrates **communion** with God, others and creation through prayer and worship;
CGE1g -understands that one's purpose or **call in life** comes from God and strives to discern and live out this call throughout life's journey;
CGE1h -respects the **faith traditions**, world religions and the life-journeys **of all people of good will**;
CGE1i -integrates faith with life;
CGE1j -recognizes that "sin, human weakness, conflict and forgiveness are part of the human journey" and that the cross, the ultimate sign of forgiveness is at the heart of **redemption**. (Witnesses to Faith)

An Effective Communicator who
CGE2a -listens actively and critically to understand and learn in light of gospel values;
CGE2b -reads, understands and uses written materials effectively;
CGE2c -presents information and ideas clearly and honestly and with sensitivity to others;
CGE2d -writes and speaks fluently one or both of Canada's official languages;
CGE2e -uses and integrates the Catholic faith tradition, in the critical analysis of the arts, media, technology and information systems to enhance the quality of life.

A Reflective and Creative Thinker who
CGE3a -recognizes there is more grace in our world than sin and that hope is essential in facing all challenges;
CGE3b -creates, adapts, evaluates new ideas in light of the common good;
CGE3c -thinks reflectively and creatively to evaluate situations and solve problems;
CGE3d -makes decisions in light of gospel values with an informed moral conscience;
CGE3e -adopts a holistic approach to life by integrating learning from various subject areas and experience;
CGE3f -examines, evaluates and applies knowledge of interdependent systems (physical, political, ethical, socio-economic and ecological) for the development of a just and compassionate society.

A Self-Directed, Responsible, Life Long Learner who

CGE4a -demonstrates a confident and positive sense of self and respect for the dignity and welfare of others;
CGE4b -demonstrates flexibility and adaptability;
CGE4c -takes initiative and demonstrates Christian leadership;
CGE4d -responds to, manages and constructively influences change in a discerning manner;
CGE4e -sets appropriate goals and priorities in school, work and personal life;
CGE4f -applies effective communication, decision-making, problem-solving, time and resource management skills;
CGE4g -examines and reflects on one's personal values, abilities and aspirations influencing life's choices and opportunities;
CGE4h -participates in leisure and fitness activities for a balanced and healthy lifestyle.

A Collaborative Contributor who

CGE5a -works effectively as an interdependent team member;
CGE5b -thinks critically about the meaning and purpose of work;
CGE5c -develops one's God-given potential and makes a meaningful contribution to society;
CGE5d -finds meaning, dignity, fulfillment and vocation in work which contributes to the common good;
CGE5e -respects the rights, responsibilities and contributions of self and others;
CGE5f -exercises Christian leadership in the achievement of individual and group goals;
CGE5g -achieves excellence, originality, and integrity in one's own work and supports these qualities in the work of others;
CGE5h -applies skills for employability, self-employment and entrepreneurship relative to Christian vocation.

A Caring Family Member who

CGE6a -relates to family members in a loving, compassionate and respectful manner;
CGE6b -recognizes human intimacy and sexuality as God given gifts, to be used as the creator intended;
CGE6c -values and honours the important role of the family in society;
CGE6d -values and nurtures opportunities for family prayer;
CGE6e -ministers to the family, school, parish, and wider community through service.

A Responsible Citizen who

CGE7a -acts morally and legally as a person formed in Catholic traditions;
CGE7b -accepts accountability for one's own actions;
CGE7c -seeks and grants forgiveness;
CGE7d -promotes the sacredness of life;
CGE7e -witnesses Catholic social teaching by promoting equality, democracy, and solidarity for a just, peaceful and compassionate society;
CGE7f -respects and affirms the diversity and interdependence of the world's peoples and cultures;
CGE7g -respects and understands the history, cultural heritage and pluralism of today's contemporary society;
CGE7h -exercises the rights and responsibilities of Canadian citizenship;
CGE7i -respects the environment and uses resources wisely;
CGE7j -contributes to the common good.

Unit 3: Organic Chemistry

Time: 20 hours

Unit Description

Students build on the knowledge they gained in the SCH3U Hydrocarbons and Energy unit to study the structure of various organic compounds and the chemical reactions involving these compounds. They name and represent the structures of organic compounds using the IUPAC system. Through research and experimentation, students investigate organic compounds. They describe the physical properties of classes of organic compounds, predict the products of organic reactions, and evaluate the impact of organic compounds on society.

In the first cluster, students recognize the vast variety of organic compounds that touch their lives, e.g., medicines, dyes, polymers, synthetic fibres, food additives, pesticides, etc. They are introduced to the different organic functional groups, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides. Students recall the IUPAC system for organic nomenclature introduced in the SCH3U Hydrocarbons and Energy unit, and build on their skills to name and write the appropriate structures for the different classes of organic compounds. They distinguish between the terms organic, natural and chemical, and critically evaluate the accuracy of the use of these terms in the promotion of consumer goods by compiling an advertisement portfolio (*Caveat Emptor* portfolio).

In the second cluster, students apply the concepts learned in Unit 1, Structure and Properties, to describe and explain the physical properties of the different classes of organic compounds in terms of molecular polarity, melting point, boiling point, solubility in different solvents, and odour. They demonstrate their knowledge by performing a physical property model building activity, where they build models of a variety of aliphatic (both open chain and cyclic) and aromatic organic compounds, and make predictions about their physical properties based on their structures. (**Note:** Teachers should recognize that organic compounds are divided into two broad classes: aliphatic compounds and aromatic compounds. Aliphatic compounds are the alkanes, alkenes, and alkynes and all the compounds that can be derived from them by replacing the hydrogen atoms with other atoms or groups of atoms). Students are introduced to the end-of-unit task, A "PRESS'ing Concern.

In the third cluster, students apply their knowledge of the concepts related to oxidation-reduction studied in the Electrochemistry Part 1 unit and build on their knowledge of functional groups from the first cluster of this unit. Through teacher-directed presentations, students examine the chemical properties of the different organic functional groups and describe the different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis. Students predict and name the products of the various organic reactions. Through experimentation, students synthesize various organic compounds, such as esters and simple polymers.

In the fourth cluster, through a teacher-directed class discussion, students build on their knowledge from Cluster 1 to recognize that all living organisms are made of organic compounds. Through a cooperative group activity, students research the importance of naturally occurring organic compounds such as carbohydrates, proteins, and nucleic acids. They recognize and reflect on the greatness of God's creativity in the transformation of these complex molecules into forms of life. In addition, students research and create a database to provide examples of organic compounds used to improve existing health, safety, and environmental problems.

In the fifth cluster, students carry out the end-of-unit task, A "PRESS'ing Concern. They research various organic synthetic products and analyse the risks and benefits involved in their development and application. Each group's research is presented in the form of a press conference. At the press conference, students share their research by answering questions posed to them by another group who assume the role of reporters. As reporters, students use their findings to write an editorial in which they evaluate the impact that organic synthetic compounds have on society and the environment.

Students reflect and recognize their role as stewards of the earth in addressing environmental concerns and issues, thereby acquiring an appreciation for the need to protect God's creation.
(**Note:** Expectations OC3.02 and OC3.04 are introduced in Cluster 2 but assessed in Cluster 4.)

Unit Synopsis Chart

Activity	Learning Expectations	Assessment Categories	Task
1.1 Introduction to functional groups 1.2 Nomenclature of functional groups 3.75 hours	OCV.01, .02, .03, OC1.01, 2.01, 2.02, 2.04, 3.01, 3.02 SIS.05 CGE2b	**Knowledge/ Understanding** **Inquiry** **Communication** Making Connections	- Brainstorming organic compounds used in everyday life - Worksheet: on identifying functional groups in organic molecules - Nomenclature flash card activity - Quiz on organic nomenclature - *Caveat Emptor* Portfolio
2.1 Organic compounds and their physical properties2.2 Introducing the end-of-unit task, A "PRESS"ing Concern 4 hours	OCV.01, .02, .03, OC1.02, 2.01, 2.03, 3.03 SIS.05 CGE2b	**Knowledge/ Understanding** **Inquiry** **Communication** Making Connections	- Physical property model building activity - Quiz on the physical properties of organic compounds - A "PRESS"ing Concern Assignment introduction
3.1 Functional groups and their chemical properties 3.2 Synthesis of organic compounds 5.5 hours	OCV.01, .02, OC1.03, 1.04, 2.01, 2.05, 2.06 SIS.01, .02, .03, .04, .05, .06, .07 CGE2b, e, 5a, b, e, f, g	**Knowledge/ Understanding** **Inquiry** **Communication**	- Worksheets on organic reactions - Quiz on organic reactions - Experiment: synthesis of organic compounds
4.1 Introduction to compounds of life 4.2 There is a solution 4.5 hours	OCV.01, .03, OC1.05, 3.02, 3.04 SIS.05, .06, .10 CGE1e, 2b, c, e, 4g, 7h, i, j	**Knowledge/ Understanding** **Inquiry** Communication **Making Connections**	- Jigsaw activity on compounds of life - Reflection - Database of solutions to health and environmental problems - Unit Test
5. A "PRESS"ing Concern 3 hours	OCV.03, OC2.01, 3.02, 3.03 SIS.05, .06 CGE1d, 2b, c, e, 3c, d, e, f; 4a, c, e, f, g, 5e, 7a, b, e, h, i, j	Knowledge/ Understanding Inquiry **Communication** **Making Connections**	- End-of-unit task: press conference - Fact sheet - Editorial

Activity 1: Organic Functional Groups and Nomenclature

Time: 3 hours

Description

Following a review of the Hydrocarbons and Energy unit studied in SCH3U, students participate in a class discussion and recognize the vast number of organic compounds and their importance to everyday life. They are introduced to the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amine, and amides. Students recall the IUPAC system for organic nomenclature introduced in the SCH3U Hydrocarbons and Energy unit, and build on their skills to name and write the appropriate structures for the different classes of organic compounds. They name and draw organic compounds containing various functional groups using the IUPAC system. In addition, they name common organic compounds using non-systematic names. For example, the non-systematic name for ethanoic acid is acetic acid or vinegar. Students distinguish between the terms organic, natural, and chemical, and correctly use the terms to determine the accuracy of the use of these terms in the promotion of consumer goods by compiling an advertisement portfolio (*Caveat Emptor* portfolio).

Strand(s) & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE2b - reads, understands, and uses written materials effectively.

Strand(s): Organic Chemistry

Overall Expectations

OCV.01 - demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
OCV.02 - investigate various organic compounds through research and experimentation, predict the products of organic reactions, and name and represent the structures of organic compounds using the IUPAC system and molecular models;
OCV.03 - evaluate the impact of organic compounds on our standard of living and the environment.

Specific Expectations

OC1.01 - distinguish among the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides, by name and by structural formula;
OC2.01 - use appropriate scientific vocabulary to communicate ideas related to organic chemistry;
OC2.02 - use the IUPAC system to name and write appropriate structures for the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, amides, and simple aromatic compounds;
OC2.04 - identify some non-systematic names for organic compounds;
OC3.01 - present informed opinions on the validity of the use of the terms organic, natural, and chemical in the promotion of consumer goods;
OC3.02 - describe the variety and importance of organic compounds in our lives.

Scientific Investigations Skills

SIS.05 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results.

Prior Knowledge & Skills

SCH3U: Hydrocarbons and Energy

Planning Notes

- There are two possible approaches when teaching this unit.
  - The first approach is to teach the nomenclature, physical properties, and chemical reactions for each organic functional group individually. Using alcohols as an example, the teacher introduces the alcohol functional group and teaches its physical properties, nomenclature, and chemical properties. This is then repeated for each organic functional group.
  - In the second approach, the teacher introduces all the organic functional groups. Students build on their knowledge and skills of IUPAC organic nomenclature studied in SCH3U to name and write structures of the different organic functional groups using the IUPAC system. They apply their knowledge of intermolecular forces to explain the physical properties of each of the functional groups, and compare between the physical properties of the different functional groups. Finally, the chemical properties of different classes of organic compounds are introduced through the study of the different types of organic chemical reactions.
  - This Course Profile uses the second approach, since it provides students with numerous opportunities to practice and build on their knowledge and skills to recognize functional groups, practice nomenclature, and predict and describe the physical and chemical properties of the different functional groups.
- Homework should be assigned daily to provide students with the opportunity to practice and develop their knowledge and problem-solving skills in organic chemistry.
- It is recommended that the unit test be administered before Activity 5.

Activity 1.1 Introduction to Functional Groups

- Prepare a diagnostic assessment tool to assess students' knowledge and skills developed in the SCH3U Hydrocarbons and Energy unit.
- Students may not be aware of the vast number of organic compounds and that organic chemistry is a science that touches the lives of everyone. Thus, a brainstorming session provides students with an opportunity to become aware of the importance of organic compounds in their lives.
- Prepare worksheets to provide students with practice identifying functional groups in simple and complex organic compounds. Structural formulae of complex organic molecules containing multiple functional groups can be found in various sources including the Merck Index, CRC Handbook of Physics and Chemistry, Internet.

Activity 1.2 Nomenclature of Functional Groups

- Prepare a diagnostic assessment tool to assess students' knowledge and skills relating to the IUPAC system for naming and writing structures of hydrocarbons covered in SCH3U, and prepare the appropriate remedial work.
- Prepare a list of common organic compounds and their non-systematic names. The teacher may want to conference with the biology teacher to compile a list of non-systematic names used in the biology courses.
- Search websites for tutorials on organic nomenclature and keep a list which may be shared with students.
- Prepare worksheets to provide students with numerous and varied opportunities to practise and use the IUPAC system to name and draw structures for the different classes of organic compounds.
- To reinforce student learning and give students opportunities for peer assessment, students prepare a flash card activity. For this activity, the class is arranged into groups of four; each group represents a different class of organic compounds (functional group). Within each group, students individually prepare three to five flash cards, each containing the full structural formula on one side and the IUPAC name and non-systematic name (if applicable) on the other side. Within the group of four, students exchange flash cards and correct each flash card for accuracy, variety, and possible duplication. The students should consult with the teacher about any concerns. The teacher collects

and assesses all flash cards, compiles sets with different functional groups, and redistributes the sets to students to practise and improve their nomenclature skills, either in pairs or individually. The flash cards can also be used for self and peer formative assessment throughout the unit whenever time permits.

- Prepare a paper/pencil quiz on organic nomenclature.
- Collect samples of consumer goods promoted as organic, natural, and chemical (e.g., organic shampoo, natural spring water) to use when introducing the *Caveat Emptor* portfolio. *Caveat Emptor* is a term students are introduced to in a business class. (**Note:** *Caveat Emptor* is a Latin phrase which means, "Let the buyer beware" and is used in business to express the principle that it is the buyer's responsibility to satisfy herself/himself about the quality of the goods received).
- The teacher may want to conference with the business teacher regarding ethical advertising practices.
- Prepare a handout outlining the *Caveat Emptor* portfolio. Students collect samples of advertisements promoting consumer goods as organic, natural, and chemical from various sources, e.g., labels, commercials, advertisements, storefronts, and business cards. The teacher determines the number and variety of samples to be collected. Students gain consumer awareness by completing the portfolio. Students apply their knowledge of the accurate definitions of the terms organic, natural, and chemical to identify the advertisements as accurate or misleading. They communicate their understanding by writing informed opinions on the validity of each of the advertisements collected. Students submit their portfolio at the end of the unit.

Teaching/Learning Strategies

Activity 1.1 Introduction to Functional Groups

The teacher:

- administers a diagnostic assessment tool to assess students' knowledge and skills developed in the SCH3U Hydrocarbons and Energy unit, and provides appropriate remedial material;
- leads a class discussion on the vast number of organic compounds and the importance of organic chemistry as a science that touches everyone's lives;
- directs students to brainstorm and compile a list of different classes of organic compounds they use in a day, for example, plastics, synthetic fibers, pesticides, household products, beauty industry products, and fuels;
- presents a Socratic lesson and distinguishes among the different classes of organic compounds in terms of the functional group present, using relevant examples to recognize functional groups of each class, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides;
- provides worksheets for students to practise identifying functional groups in simple and complex organic compounds containing multiple functional groups.

Students:

- participate in a class discussion on the variety and the importance of organic compounds;
- brainstorm to create a list of different organic compounds used in a day, and recognize the vast variety of organic compounds that play a major role in their lives, e.g., plastics, synthetic fibres, pesticides, household products, beauty industry products, and fuels;
- recognize the need to organize organic compounds into groups that can be studied for similar physical and chemical properties;
- record in their notebook the teacher's presentation on the different classes of organic compounds in terms of the functional group present, and identify the organic compounds in terms of their functional group;
- practise identifying the organic functional groups present in simple and complex organic compounds containing multiple functional groups.

Activity 1.2 Nomenclature of Functional Groups

The teacher:

- reviews the IUPAC system rules learned in the SCH3U Hydrocarbons and Energy unit as a basis for this unit;
- through a Socratic lesson, presents the IUPAC system for naming and writing the structures for the different classes of organic compounds; as well, provides a list of some non-systematic names and structures for organic compounds. The presentation of the IUPAC system can be done in the following order:
    - alcohols: including primary, seconday and tertiary alcohols, glycols (contain two hydroxyl groups), and glycerols (contain three hydroxyl groups). Some non-systematic names include isopropyl (rubbing) alcohol for 2-propanol, ethylene glycol (antifreeze) for 1,2-ethanediol, and glycerin for 1,2,3-ethanetriol;
    - carboxylic acids: Some non-systematic names include acetic acid (vinegar) for ethanoic acid;
    - esters;
    - ethers: Make students aware that there is a non-systematic method as well as the IUPAC method for naming ethers, and that they are responsible for the IUPAC method. Some non-systematic names include the anesthetic "ether" for ethoxy ethane;
    - aldehydes: Some non-systematic names include formaldehyde for methanal; - ketones. Some non-systematic names include acetone for propanone;
    - amines: Make students aware that there is a non-systematic method as well as the IUPAC method for naming amines, and that they are responsible for the IUPAC method;
    - amides.
- provides students with worksheets to practise and use the IUPAC system to name and draw structures for the different classes of organic compounds;
- conferences with students while they practise and use the IUPAC system, answering questions and providing feedback;
- arranges students in groups of four and assigns each group a different class of organic compounds and instructs students to carry out the flash card activity (see Planning Notes);
- collects and assesses all flash cards, compiles sets with different functional groups, and redistributes the sets to students to practise either in pairs or individually, whenever time permits;
- prepares, administers, and assesses a paper/pencil quiz on the nomenclature of organic compounds;
- introduces the *Caveat Emptor* portfolio by
    - providing students with clear definitions of the terms organic, natural, and chemical compounds;
    - leading a class discussion, using examples collected (see Planning Notes) to determine whether advertisements for consumer goods are accurate or misleading.

Students:

- complete the diagnostic assessment and the required remedial work to review organic nomenclature studied in SCH3U;
- record in their notebook the IUPAC rules used to name and write structures for the different classes of organic compounds, including some non-systematic names;
- complete worksheets to practise and use the IUPAC system, and conference with the teacher to clear any problems;
- individually prepare 3-5 flash cards representing the assigned class of organic compounds. Once completed, exchange flash cards with other group members to check for accuracy, variety, and duplication, and consult with the teacher about any concerns;
- submit their flash cards for assessment;
- in pairs or individually, use flash cards for practice and self and peer assessment, whenever time permits;

- write a paper/pencil quiz on the nomenclature of organic compounds;
- participate in a class discussion on the accurate use of the terms organic, natural, and chemical in the promotion of consumer goods;
- collect advertisements promoting consumer goods as organic, natural or chemical from various sources for their *Caveat Emptor* portfolio.

Assessment & Evaluation of Student Achievement

- The paper-and-pencil quiz on organic nomenclature may be assessed for Knowledge/Understanding and Communication using a marking scheme (OC1.01, 2.01, 2.02, 2.04).
- The *Caveat Emptor* portfolio is collected and assessed at the end of the unit for Communication and Making Connections using a rubric (OC2.01, 3.01).

Accommodations

See course overview for general accommodations.
Possible enrichment activities:

- Prepare a chart of household organic compounds. Give their IUPAC name, their non-systematic name(s) and draw their structures (e.g., pesticides, pharmaceuticals, cosmetics, and cleaners). To further enhance this activity, students prepare a pamphlet on safe and dangerous household organic compounds, their use, and their storage in the home.
- Research and prepare a chart containing the structures of large organic molecules containing multiple functional groups.
- Prepare a pamphlet on esters and their uses in industry.
- Design a webpage, media presentation, or tutorial on organic nomenclature.
- Produce a game that allows students to practise organic nomenclature.
- Computerize the flash card activity.

Resources

Textbooks

Budavari, Susan, et al. *Merck Index, An Encyclopedia of Chemicals, Drugs and Biologicals.* Rahway: Merck and Co. Inc., 1996. ISBN 0911910123

Hill, John W., S. Baum and D. Feigl. *Chemistry and Life: An Introduction to General, Organic, and Biological Chemistry Fifth Edition.* Upper Saddle River: Prentice-Hall, Inc., 1997. ISBN 0-13-569294-6

Lide, David R. CRC *Handbook of Chemistry and Physics.* Boca Raton: CRC Press Inc., 2000. ISBN 0849304814

Smith, John E., et al. *ALCHEM Chemistry.* Toronto: The Bryant Press, 1990. ISBN 0-920008-31-3

Snyder, C. *The Extraordinary Chemistry of Ordinary Things.* New York: John Wiley and Sons, Inc., 1998. ISBN 0-471-17905-1

The Catholic School. Rome, 1977

The Religious Dimension of Education in a Catholic School. Rome, 1988.

This Moment of Promise. Ontario Conference Of Catholic Bishops, 1989.

Internet Sites

Molecules, nomenclature – www.biochemlinks.com

Molecules, remedial work – www.chemistrycoach.com/high.htm

Nomenclature – www.acdlabs.com/iupac/nomenclature

Links – www.organicworldwide.net

Videos

Carbon Chemistry. Burnaby: Classroom Video. 43 minutes

Activity 2: Naming Compounds Containing Functional Groups

Time: 4.5 hours

Description

Students apply the concepts learned in Unit 1, Structures and Properties, to describe and explain the physical properties of the different classes of organic compounds in terms of molecular polarity, melting points, boiling points, solubility in different solvents, and odour. They demonstrate their knowledge by performing a physical property model building activity where they build models of various organic compounds and predict their physical properties based on their structure. In addition, students are introduced to the end-of-unit task, A "PRESS"ing Concern. In this end-of-unit task, students further their study of organic consumer products by analysing the risks and benefits of the development and application of synthetic products such as pesticides, polymers, and food additives, and present their findings in the form of a press conference. As a result, students evaluate the impact that organic compounds have on society and the environment through written editorials.

Strand(s) & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE2b - reads, understands, and uses written materials effectively.

Strand(s): Organic Chemistry

Overall Expectations

OCV.01 - demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
OCV.02 - investigate various organic compounds through research and experimentation, predict the products of organic reactions, and name and represent the structures of organic compounds using the IUPAC system and molecular models;
OCV.03 - evaluate the impact of organic compounds on our standard of living and the environment.

Specific Expectations

OC1.02 - describe some physical properties of the classes of organic compounds in terms of solubility in different solvents, molecular polarity, odour, and melting and boiling points;
OC2.01 - use appropriate scientific vocabulary to communicate ideas related to organic chemistry;
OC2.03 - build molecular models of a variety of aliphatic, cyclic, and aromatic organic compounds;
OC3.03 - analyse the risks and benefits of the development and application of synthetic products.

Scientific Investigations Skills

SIS.05 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results.

Planning Notes

Activity 2.1 Organic Compounds and their Physical Properties

- To review the concepts of intermolecular forces from Unit 1, Structure and Properties, the teacher prepares a review activity.
- Possible misconception among students are as follows:
  - solubility is a chemical property;
  - the hydroxyl group (-OH) is confused with the hydroxide ion (OH^-);
  - all alcohols, carboxylic acids, esters, amines, and amides are soluble in water;
  - there are hydrogen bonding interactions between aldehydes, ketones, and ethers.

- **Safety Notes**
  - Teachers should be aware of all the safety precautions involved with the use of organic compounds and must follow school board regulations.
  - alcohols are extremely flammable and should not be used near open flame;
  - Esters and short straight chained carboxylic acids are volatile and must not be inhaled; these chemicals should be used with a fume hood;
  - Many aromatic compounds are carcinogenic.
- To reinforce the physical properties of the organic functional groups studied, prepare a physical property model building activity. In this activity, students build molecular models of assigned groups of organic compounds using model-building kits provided by the teacher. The students use their molecular models to predict the physical properties of the assigned organic compounds, give reasons for their predictions, and then verify their predictions using resource materials the teacher makes available. The teacher prepares a marking scheme for the activity. Students' models can be assessed using a checklist. The physical property model building activity may contain the following procedures:
  - Build molecular models for ethanol and hexanol. Predict their relative melting points and boiling points, and their solubility in polar and non-polar solvents;
  - Build molecular models for propanol, propanal, propanoic acid, propanone, aminopropane, propanamide, methoxypropane, methyl propanoate;
  - Predict their molecular polarity;
  - Rank them from lowest to highest boiling point and melting point;
  - Predict their solubility in polar and non-polar solvents;
  - Predict their odour;
  - Draw and build molecular models for all structural isomers for C_3H_8O;
  - Rank them from lowest to highest melting point and boiling point;
  - Predict their solubility in polar and non-polar solvents.
- Prepare an assessment tool for the physical property model building activity.
- Homework should be assigned daily to provide ample opportunities for the students to practise and develop their knowledge and problem-solving skills related to organic structure and physical properties.
- Prepare a pencil/paper quiz to assess students' understanding of the physical properties of organic functional groups.

Activity 2.2 Introducing the End-of-Unit Task, A "PRESS"ing Concern

- Prepare an example of a synthetic product and the risks/benefits associated with (i) the reactants used to prepare it and the methods used to obtain the reactants, (ii) its chemical synthesis and the byproducts formed, and (iii) its use in society. An example is rubber tires. One benefit of rubber tires is that they are durable and essential for various modes of transportation; however, tires are not biodegradable and pose a serious health problem if burned.
- Prepare a handout describing the end-of-unit task, A "PRESS"ing Concern – see Appendix I. In this activity each group has two roles. The first is to research the risks and benefits of the development and application of a synthetic product. Students present this information in the form of a press conference. The second is to assume the role of reporters who interview another group researching a different synthetic product. Students use the information obtained from the interview to write an editorial on the risks and benefits associated with that product.
- Compile a list of different organic compounds students can choose from to complete the end-of-unit task, A "PRESS"ing Concern. The list could include the compounds listed by the students during their brainstorming in Activity 1, as well as any other organic compounds decided on by the teacher.

- Arrange students in groups of three.
- Remind students that they should compile information on their chosen synthetic organic compound throughout the unit, e.g., students determine the functional groups present using their knowledge from Activity 1, the physical properties using their knowledge from Activity 2, and the chemical properties using their knowledge from Activity 3.
- Make arrangements to have the students visit the library/resource centre for 75 minutes so that they can select their synthetic organic compound and begin their research as a group. If this is not possible, collect resources for classroom use or arrange Internet access through your computer department.
- Review the ethical use of the Internet with students.
- Each student in a group must participate in the presentation. Students are assessed and evaluated individually. Group marks are not to be assigned.
- The questions for the press conference prepared by the reporters should be collected and assessed for completion and appropriate content prior to the press conference. This ensures that students are prepared.
- Prepare a checklist for students to assess their group members' work before the presentation.
- Prepare a rubric for the A "PRESS"ing Concern conference presentation. This rubric should assess each student in their role as both a presenter and a reporter. **Note:** a rubric for the editorial is available in Appendix II.

Teaching/Learning Strategies

Activity 2.1 Organic Compounds and their Physical Properties

The teacher:

- reviews from Unit 1, Structure and Properties, the intermolecular forces of attraction including London dispersion, dipole-dipole and hydrogen bonding interactions, and how these affect physical properties, e.g., melting points, boiling points, solubility and odour;
- through a class discussion and a Socratic lesson, summarizes the physical properties of the different classes of organic compounds. For each class, the functional group is drawn and the intermolecular forces present are identified to determine the resulting physical properties. The functional groups are presented in the following order: alcohols (including primary, secondary, tertiary, diols/glycols, and triols/glycerols), ethers, aldehydes, ketones, carboxylic acids, esters, amines, and amides. In addition to the general physical properties of organic functional groups, the teacher's presentation should also include:
    - properties of compounds containing hydrogen bonding interactions that change as the carbon chains gets longer, e.g., solubility in polar solvents;
    - the difference in physical properties between organic compounds that have a hydrogen atom bonded to an oxygen atom, as opposed to a hydrogen atom bonded to a nitrogen atom, e.g., methanol has a higher boiling point than aminomethane;
    - safety concerns associated with physical properties;
    - structural isomers and their corresponding physical properties, e.g., methoxy methane and ethanol both have the formula C_2H_6O but have different physical properties;
- organizes students into groups of two and directs students to apply their knowledge of intermolecular forces from Unit 1, as well as the lesson on physical properties of the different classes of organic compounds, to build molecular models of the organic molecules assigned in the physical property model building activity (see Planning Notes for examples). The students are asked to make the required predictions about physical properties of the different classes of organic compounds, verify their predictions using resources available, and correct and explain any incorrect predictions;

- collects and assesses the physical property model building activity;
- administers and assesses a paper/pencil quiz on the physical properties of the classes of organic compounds.

Students:

- recall intermolecular forces of attraction including London dispersion, dipole-dipole, and hydrogen bonding interactions and apply their knowledge to explain variations in melting point, boiling point, solubility, and odour;
- record in their notebook the teacher presentation on the intermolecular force interactions present as a result of the different functional groups, and the resulting physical properties of the different classes of organic compounds;
- in pairs, build the required molecular models of the organic molecules assigned in the physical property model building activity, predict the compounds' physical properties, verify their predictions using available resources, and correct and explain any incorrect predictions made. They submit the physical property model building activity for assessment;
- write a paper-and-pencil quiz on the physical properties of the classes of organic compounds.

Activity 2.2 Introducing the End-of-Unit Task, A "PRESS'ing Concern

The teacher:

- through a class discussion, discusses the term synthetic product and gives an example of a synthetic product and the risks and benefits associated with (i) the reactants used to prepare it and the methods used to obtain the reactants, (ii) its chemical synthesis and byproducts formed, and (iii) its use in society, e.g., rubber tires;
- introduces the end-of-unit task, A "PRESS'ing Concern – see Appendix I;
- arranges students in groups of three to carry out the end-of-unit task;
- assigns which group takes on the role of reporter for each presentation;
- introduces the assessment tools for the end-of-unit task. These include a peer assessment checklist, a presentation rubric, and an editorial rubric;
- provides class time for the assigned groups to choose the organic compound (synthetic product), assign roles, and complete preliminary research either in the library/resource centre or classroom;
- conferences with each group to make sure they are proceeding in the appropriate direction.

Students:

- in their assigned groups, review the project, select the organic compound (synthetic product), and assign roles;
- meet throughout the unit to research and conference with each other and the teacher;
- work collaboratively to gather information for the assigned task.

Assessment & Evaluation of Student Achievement

The physical property model building activity may be assessed for Knowledge/Understanding and Inquiry using a marking scheme (OC1.02, OC2.03).

The paper/pencil quiz on physical properties may be assessed for Knowledge/Understanding, Inquiry and Communication using a marking scheme (OC1.02, OC2.01, OC2.02, OC2.03).

Accommodations

- See Course Overview for general accommodations.
- Possible enrichment activities:
  - Research how the physical properties of the organic compounds make them suitable for various uses in the home, industry, hospitals, toymaking, etc.

Resources

Textbooks

Budavari, Susan et al. *Merck Index, An Encyclopedia of Chemicals, Drugs and Biologicals.* Rahway: Merck and Co. Inc, 1996. ISBN 0911910123

Frankel, Art and John Li. *Chemistry: A Second Course: Teacher's Manual*. Don Mills: Addison Wesley, 1989. ISBN 0-201-51302-1

Herron, J., et al. *Heath Chemistry.* Canada: D.C. Heath Canada Ltd., 1987. ISBN 0-669-95289-3

Lide, David R. *CRC Handbook of Chemistry and Physics*. Boca Raton: CRC Press Inc., 2000. ISBN 0849304814

Rayner-Canham, Geoff et al. *Chemistry: A Second Course*. Don Mills: Addison Wesley, 1989. ISBN 0-201-17885-0

Smith, John E., et al. *ALCHEM Chemistry.* Toronto: The Bryant Press, 1990. ISBN 0-920008-31-3

Snyder, C. *The Extraordinary Chemistry of Ordinary Things.* New York: John Wiley and Sons, Inc., 1998. ISBN 0-471-17905-1

Internet Sites

Drawing program – www.mdli.com/downloads/isis.draw/isisdraw.html

Models, molecules, properties – www.biochemlinks.com

Molecules, remedial work – www.chemistrycoach.com/high.htm

Molecules, properties – www.bris.ac.uk/Depts/Chemistry/MOTM/motm.htm

Links – www.organicworldwide.net

CD-ROMs

"Chem Matters CD 1993-1998 Version 2.0." Washington: American Chemical Society, 1998.

"Saunders Interactive General Chemistry CD-ROM, Ch. 11-21." USA: Archipelago Productions, 1996.

"The Electric Chemistry Building Phase III: Organic Chemistry." Hamilton: Snowbird Software, 1990.

Videos

Carbon Chemistry. Burnaby: Classroom Video. 43 minutes

The Magic of Chemistry. Burnaby: Classroom Video. 60 minutes

Activity 3: Chemical Properties of Functional Groups

Time: 5 hours

Description

Students build on their knowledge of chemical reactions, addition, and combustion, taught in the SCH3U Hydrocarbons and Energy unit, as well as their knowledge of the concepts related to oxidation-reduction studied in Unit 2, Electrochemistry I. They investigate how functional groups determine an organic compound's chemical properties. Students examine the different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis. Students continue to practise nomenclature of organic functional groups by predicting and naming the products in the various organic reactions. Through experimentation, students carry out procedures to synthesize various organic compounds, such as esters and simple polymers, and submit a laboratory report.

Strand(s) & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE2b - reads, understands, and uses written materials effectively;
CGE2e - uses and integrates the Catholic faith tradition, in the critical analysis of the arts, media, technology, and information systems, to enhance the quality of life;
CGE5a - works effectively as an interdependent team member;
CGE5b - thinks critically about the meaning and purpose of work;
CGE5e - respects the rights, responsibilities and contributions of self and others;
CGE5f - exercises Christian leadership in the achievement of individual and group goals;
CGE5g - achieves excellence, originality, and integrity in one's own work and supports these qualities in the work of others.

Strand(s): Organic Chemistry

Overall Expectations

OCV.01 - demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
OCV.02 - investigate various organic compounds through research and experimentation, predict the products of organic reactions, and name and represent the structures of organic compounds using the IUPAC system and molecular models.

Specific Expectations

OC1.03 - describe different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis;
OC1.04 - demonstrate an understanding of the processes of addition and condensation polymerization;
OC2.01 - use appropriate scientific vocabulary to communicate ideas related to organic chemistry;
OC2.05 - predict and correctly name the products of organic reactions, including substitution, addition, elimination, esterification, hydrolysis, oxidation, and polymerization reactions;
OC2.06 - carry out laboratory procedures to synthesize organic compounds.

Scientific Investigations Skills

SIS.01 - demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials, and using appropriate personal protection;
SIS.02 - select appropriate instruments and use them effectively and accurately for collecting observations and data;
SIS.03 - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately;
SIS.04 - demonstrate a knowledge of emergency laboratory procedures;
SIS.05 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results;
SIS.06 - compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion;
SIS.07 - communicate the procedures and results of investigations for specific purposes by displaying evidence and information, either in writing or using a computer, in various forms, including flow charts, tables, graphs, and laboratory reports.

Planning Notes

Safety Notes:

- Safety regarding organic compounds is a major issue. It is important to be aware of the dangers and safety precautions involved with the use of organic compounds. The health and safety of the teacher and students must be addressed when conducting laboratory activities by using safe laboratory practices and following Workplace Hazardous Materials Information System (WHMIS) legislation;
- When dealing with organic chemistry, it is the teacher's responsibility to seek out and follow their Board policy;
- Open flames must not be used near organic compounds;
- Aromatic compounds, for example xylene, must not be used since they are carcinogenic;
- A fume hood must be used with volatile organic liquids since most organic vapours are dangerous. Students/staff must not inhale organic vapours;
- Contact lenses must not be worn by students/staff;
- Students must wear lab aprons/coats when performing organic experiments;
- If using concentrated acid, e.g., in an esterification lab, caution students to be extremely careful when pouring the acid;
- If the nylon rope experiment is performed, it is strongly recommended that the teacher demonstrate this experiment in a well-ventilated area due to the corrosive nature of the chemicals involved;
- All wastes must be disposed of in a properly labelled organic waste container, e.g., a glass Winchester bottle, which should be kept in a fume hood;
- MSDS sheets give information on compounds;
- WHMIS and STAO safety rules must be reviewed.

Activity 3.1 Functional Groups and Their Chemical Reactions

- Prepare worksheets on organic reactions. Build on the reactions studied in the SCH3U Hydrocarbons and Energy unit. The worksheets should include chemical equations where students predict the product(s) formed given the reactants. The types of reactions studied include substitution, addition, elimination, oxidation, esterification, hydrolysis, addition polymerization, and condensation polymerization.
- Homework should be assigned to provide students with enough opportunity to practise and develop their knowledge and problem solving-skills related to organic reactions.
- When discussing oxidation reactions, students recall and apply their knowledge of oxidation-reduction concepts studied in Unit 2, Electrochemistry I.
- In organic chemistry, oxidation is also defined as the addition of oxygen or the elimination of hydrogen.
- Prepare a quiz to assess students' understanding of organic chemical reactions.

Activity 3.2 Synthesis of Organic Compounds

- Use professional judgment to determine which reactions are appropriate to perform for the synthesis of organic compounds lab, based on chemical availability and safety.
- Esterification, polymerization, and the oxidation of primary, secondary, and tertiary alcohols are three types of experiments recommended. Some possible reactions are listed below:
    - Synthesis of an ester, e.g., ethanoic acid and 1-octanol will form octyl ethanoate, which has the fragrance of an orange;
    - Synthesis of a putty-like substance – see Internet Resources;
    - Oxidation of a primary, secondary, and tertiary alcohol to show that tertiary alcohols do not undergo an oxidation reaction.

- If esters are prepared, it is suggested that the students add blue dehydrating chips (drierite) 3-4 at a time into the reaction vessel until the blue colour remains. The drierite chips serve as boiling chips and in addition, drive the equilibrium established between the product and reactants towards the product side.
- If demonstrating polymerization, an environmentally friendly synthesis should be shown, e.g., the preparation of slime. If you choose to use a nylon kit for the synthesis of nylon, make sure to follow all safety precautions enclosed. A common polymerization lab students can perform is the preparation of slime or putty. This lab can easily be found on the Internet and prepared using common household items, e.g., washing soda, white glue, and water. You may wish to ask your students to find a polymer lab on the Internet.
- Prepare pre-lab questions for the synthesis of organic compounds lab that guide and direct students in writing structural formula equations for the organic reactions performed during the lab activity (reactants and products only). It may be too difficult for students to write the structural formula equation for the formation of a slime or a putty-like polymer.
- Use a microscale lab whenever possible, since this type of lab requires only very small amounts of chemicals (The Microscale Laboratory Manual by Slater is listed in the Resources list.).
- Prepare an appropriate assessment tool, e.g., rubric, to assess the Synthesis of Organic Compounds lab report.

Teaching/Learning Strategies

Activity 3.1 Functional Groups and Their Chemical Reactions

The teacher:

- reviews and builds on the organic reactions studied in the SCH3U Hydrocarbons and Energy unit, and the oxidation-reduction concepts studied in Unit 2, Electrochemistry I;
- through a teacher-directed lesson, defines and describes the following general type of organic reactions: substitution, addition, elimination, oxidation, reduction, esterification, and hydrolysis;
- through a Socratic lesson, introduces the different types of organic reactions based on the organic functional group present. The lesson includes the functional groups involved, general equation including any special conditions, the type of reaction, and examples. The reactions for each organic family can be grouped as follows:
    - alcohols:
        - are prepared by adding water to an alkene;
        - react with carboxylic acids to form an ester;
        - undergo dehydration to form an alkene;
        - primary alcohols undergo oxidation to form aldehydes;
        - secondary alcohols undergo oxidation to form ketones;
    - carboxylic acids:
        - undergo esterification reactions with alcohols;
        - undergo neutralization reactions to form an acid and a salt;
    - esters:
        - are prepared through the reaction of an alcohol and a carboxylic acid;
    - aldehydes:
        - undergo hydrogenation to form a primary alcohol;
        - undergo oxidation to form a carboxylic acid;

    - ketones:
        - undergo hydrogenation to form a secondary alcohol;
    - amines:
        - react with carboxylic acids to form amides;
    - amides:
        - are hydrolyzed to acids;
        - are converted to amines through reduction with lithium aluminum hydride, $LiAlH_4$ in ether, followed by reaction with water;
- through a teacher-directed lesson, introduces the terms monomer and polymer and gives examples of natural and synthetic polymers, such as rubber and Dacron. Defines, provides examples of, and compares addition polymerization reactions and condensation polymerization reactions. For example, addition polymerization involves unsaturated monomer units and no byproducts are formed, whereas condensation polymerization involves the joining of two different monomers and a byproduct is formed, usually water;
- assigns and assesses worksheet(s) on organic chemical reactions;
- administers and assesses a paper/pencil quiz on organic chemical reactions.

Students:

- record in their notebook the teacher's presentation on the various types of organic reactions of the different classes of organic compounds;
- complete and make corrections to the worksheet(s) on organic chemical reactions;
- write a paper/pencil quiz on organic chemical reactions.

Activity 3.2 Synthesis of Organic Compounds

The teacher:

- introduces and assigns the synthesis of organic compounds lab;
- assigns pre-lab questions for the synthesis of organic compounds lab;
- ensures students are aware of all safety concerns and precautions associated with the lab procedures;
- reviews proper lab skills and procedures associated with the laboratory activity;
- reviews procedures for writing a lab report;
- reviews the rubric for the lab report evaluation with the students;
- directs students to carry out the prepared laboratory activity to synthesize organic compounds;
- assesses the students' lab skills during the experiment;
- collects and assesses the laboratory report.

Students:

- prepare to perform the synthesis of organic compounds lab (students should be familiar with procedures and any safety concerns related to the experiment);
- complete pre-lab activity by drawing the structural formula equations for the appropriate reactions in the synthesis of organic compounds lab;
- review the safety concerns associated with the lab procedures, the proper procedures for writing a lab report, and the rubric for the lab report evaluation;
- perform a laboratory activity investigating various organic reactions, following proper lab procedures and safety rules;
- complete and submit the lab report.

Assessment & Evaluation of Student Achievement

- The student prepared lab report may be assessed for Knowledge/Understanding, Inquiry, and Communication using a rubric (OC1.03, OC2.01, OC2.05, OC2.06).
- The paper/pencil quiz may be evaluated for Knowledge/Understanding and Communication using a marking scheme (OC1.03, OC1.04, OC2.01, OC2.05, OC2.06).

Accommodations

See Course Overview for general accommodations.

- A lab station can be set up for wheelchair access.
- Large print can be used on all containers for visually challenged students.

Possible enrichment activities:

- Investigate organic reactions of the functional groups that occur under special conditions or with special reagants, e.g., Markovnikov and anti-Markovnikov type reactions, Friedel-Crafts alkylation, S_N1 and S_N2 mechanisms, chirality, and Grignard reactions.
- Research and write a short biography on chemists who have made substantial contributions to the understanding of chemical reactions of functional groups, e.g., Vladimir Markovnikov and Victor Grignard.
- Devise reaction schemes for the synthesis of single organic molecules, e.g., alcohols from alkanes.
- Investigate polymers used in toymaking.
- Investigate various polymers produced through condensation and addition polymerization.
- Investigate how some polymer products are used in our homes, e.g., Teflon, Dacron, nylon.
- Build a simple Breathalyzer to mimic those used to detect alcohol in a person's breath.

Resources

Textbooks

Beran, Jo A. *Laboratory Manual for Fundamentals of Chemistry.* Kingsville: John Wiley and Sons, 1987. ISBN 0-471-62798-4

Frankel, Art and John Li. *Chemistry: A Second Course: Teacher's Manual.* Don Mills: Addison Wesley, 1989. ISBN 0-201-51302-1

Herron, J., et al. *Heath Chemistry*. Canada: D.C. Heath Canada Ltd., 1987. ISBN 0-669-95289-3

Slater, Alan, and Geoff Rayner-Canham. *Microscale Chemistry Laboratory Manual: Student's Edition.* Don Mills: Addison-Wesley, 1994. ISBN 0-201-60215-6

Rayner-Canham, Geoff et al. *Chemistry: A Second Course.* Don Mills: Addison Wesley, 1989. ISBN 0-201-17885-0

Slater, Alan, and, Geoff Rayner-Canham. *Microscale Chemistry Laboratory Manual: Teacher's Edition.* Don Mills: Addison-Wesley, 1994. ISBN 0-201-60216-4

Smith, John E. et al. *ALCHEM Chemistry.* Toronto: The Bryant Press, 1990. ISBN: 0-920008-31-3

Toon, Ernest R., Ellis, George L., et al. *Foundations of Chemistry.* Toronto: Holt, Rinehard and Winston of Canada, 1991. ISBN 0-03-922500-3

Internet Sites

Organic reactions, remedial work – http://www.chemhelper.com

Organic reactions, remedial work – http://www.chemistrycoach.com/high.htm

Polymer experiments – http://matse1.mse.uiuc.edu/~tw/polymers/f.html

Activity 4: Organic Molecules of Importance

Time: 3.5 hours

Description

Through a teacher-directed class discussion, students build on their knowledge from Activity 1 to recognize that all living organisms are made of organic compounds, and that not all organic compounds are synthetically produced, as was demonstrated in Activity 3. Through a cooperative group activity, students research the importance of naturally occurring organic compounds such as carbohydrates, proteins, and nucleic acids. Students read and reflect on the magnitude of God's work in the transformation of these complex molecules into forms of life. They recognize the power of God, as stated in Psalm 8: "O Lord, our Lord, your greatness is seen in all the world." Students research and create a database to provide examples of organic compounds used to improve existing health, safety, and environmental problems.

Strand(s) & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE1e - speaks the language of life... "recognizing that life is an unearned gift and that a person entrusted with life does not own it but that one is called to protect and cherish it." (Witnesses to Faith);
CGE2b - reads, understands, and uses written materials effectively;
CGE2c - presents information and ideas clearly and honestly and with sensitivity to others;
CGE2e - uses and integrates the Catholic faith tradition in the critical analysis of the arts, media, technology, and information systems, to enhance the quality of life;
CGE4g - examines and reflects on one's personal values, abilities, and aspirations influencing life's choices and opportunities;
CGE7d - promotes the sacredness of life;
CGE7h - exercises the rights and responsibilities of Canadian citizenship;
CGE7i - respects the environment and uses resources wisely;
CGE7j - contributes to the common good.

Strand(s): Organic Chemistry

Overall Expectations

OCV.01 - demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
OCV.03 - evaluate the impact of organic compounds on our standard of living and on the environment.

Specific Expectations

OC1.05 - describe a variety of organic compounds present in living organisms, and explain their importance to those organisms;
OC3.02 - describe the variety and importance of organic compounds in our lives;
OC3.04 - provide examples of the use of organic chemistry to improve technical solutions to existing or newly identified health, safety, and environmental problems.

Scientific Investigations Skills

SIS.05 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results;
SIS.06 - compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion;
SIS.10 - identify and describe science- and technology-based careers related to the subject area under study.

Planning Notes

- A unit test should be administered at the end of this activity. Determine which expectations need to be assessed, and use these as a guide to prepare the unit test.
- **Note:** It is suggested that a checklist of the unit expectations be given to students at the beginning of every unit. Students can use the checklist to assess their own knowledge and skills throughout the unit and to prepare for the unit test. This checklist can further be used to help students prepare for the final examination.

Activity 4.1 Introduction to Compounds of Life

- Provide Bibles or copies of the First Creation Story (Genesis 1:1-2:4a) and Psalm 8.
- The teacher may want to conference with the SBI4U teacher to provide some synchrony between both classes with regard to the different classes of organic compounds present in living organisms.
- Provide resources on the different classes of organic compounds present in living organisms for classroom use. One method might be to book the library/resource centre or a computer classroom. If this is done, proper use of the Internet should be discussed with the students.
- The jigsaw method can be used to cover the different classes of organic compounds present in living organisms, e.g., proteins, carbohydrates, fats, nucleic acids, steroids, hormones, and cholesterol-based molecules. The expert group is responsible for one class of these organic compounds. The size of the groups is dependent on the number of classes of organic compounds selected. The information the students obtain should include the organic compounds' general structure, functional group(s) present, and its function and importance in living organisms.
  Each student should prepare a summary sheet of all the naturally occurring organic compounds researched in the activity.
- Prepare a marking scheme to assess the summary sheet.

Activity 4.2 There is a Solution

- To give students clear directions for their database activity, prepare an example of an organic chemical with known safety, health, and environmental concerns and the technical solution (alternate product); for example, the alternate product for DDT is natural pheromones.
- Prepare and provide a list of organic compounds with known safety, health, and environmental concerns, (e.g., ether, carbon tetrachloride, PCB, CFC, leaded gas, saccharin, olestra, and formaldehyde) that students can choose from, or allow the students to research an organic compound of their choice. In the database activity, students produce a database on the product, its use, known safety/health/environmental concerns regarding this product, alternate products used in response to these concerns, and the reason for the use of alternates (Why is it better?) in table format as suggested below:

• Product • (Organic Compound)	• Uses	• Concerns Due to Uses of Product	• Alternate Product	• Reason for Use of Alternate Product

- The teacher decides on the format of this database, e.g., summary sheet, computer-generated presentation, or computer disk.
- Prepare a marking scheme to assess the database activity.
- Arrange to have students visit the library/resource centre. If it is not available, collect resources for classroom use or arrange Internet access through the computer department.
- Review the ethical use of the Internet with students.

Teaching/Learning Strategies

Activity 4.1 Introduction to Compounds of Life

The teacher:

- together with the students reads the First Story of Creation from the book of Genesis. The teacher facilitates a class discussion on the wonder of God and His ability to create;
- introduces naturally occurring organic compounds present in living organisms, such as carbohydrates, proteins, and nucleic acids;
- groups students for the jigsaw activity to research the importance of naturally occurring organic compounds present in a living organism, and assigns a different class of organic compounds to each expert group, e.g., proteins, carbohydrates, fats, nucleic acids;
- facilitates the jigsaw activity, and instructs students to prepare a summary sheet of all the naturally occurring organic compounds researched in the activity;
- together with the students reads Psalm 8 and instructs students to write a reflection in their journal on how they can, in the words of Psalm 8, detect "the finger of God" at work in the creation of living organisms.

Students:

- read the First Story of Creation from Genesis and participate in a class discussion on God's creations and on organic compounds present in living organisms;
- in their assigned expert groups, research one type of organic compounds present in a living organism, and determine its structure, functional groups present, and its function and importance in living organisms;
- present their findings to their home group and record the information researched by other members of their home group;
- write a summary sheet on the organic compounds present in living organisms and their importance to living organisms;
- write a reflection in their journal on God's impact on living organisms.

Activity 4.2 There is a Solution

The teacher:

- leads a class discussion on the risks and benefits to society of the use of an organic compound product, e.g., DDT. Where risks outweigh benefits, identify alternate organic solutions;
- introduces the database activity along with the assessment tool (see Planning Notes);
- collects and assesses the database activity;
- administers and assesses a paper/pencil test on the unit.

Students:

- participate in the class discussion;
- choose three organic compounds causing health, safety, and environmental problems in society, and research how organic chemistry has been used to solve the problems related to each of these three chemicals;
- compile their findings in a database and submit the completed database activity to be assessed;
- prepare for and write the unit test.

Assessment & Evaluation of Student Achievement

- The Summary Sheet may be assessed for Knowledge/Understanding using a marking scheme (OC1.05).
- The database activity may be assessed for Making Connections and Communication using a marking scheme (OC3.02, OC3.04).
- The unit test may be assessed for Knowledge/Understanding, Inquiry, Communication, and Making Connections using a marking scheme.

Accommodations

See course overview for general accommodation.
Possible enrichment activities:

- Create a website with their research information. (Board policies may govern this.)
- Investigate the chemical reactions that occur between biochemical compounds studied, e.g., condensation of amino acids to form proteins.
- Investigate the problems with the technical solutions presented.

Resources

Textbooks

The Holy Bible: New Revised Standard Version: Catholic Edition. Kansas: Fireside Bible Publishers, 1999. ISBN 0-310-90304-1

Stanitski, Conrad L., et al. *Chemistry in Context*. Boston: McGraw-Hill Higher Education, 2000. ISBN 0-697-36024-5

Pope John Paul II. *The Jubilee of Year 2000*. Sherbrooke, Quebec: Mediaspaul, 1994. ISBN 2-89420-269-5

Pope John Paul II. *The Millennium. Sherbrooke,* Quebec: Mediaspaul, 2001. ISBN 2-89420-452-3

Internet Sites

Compounds of Life – www.biochemlink.com

Organic compounds, remedial work – http://www.chemistrycoach.com/high.htm

Activity 5: A "Press"ing Concern

Time: 5hours

Description

The end-of-unit task, A "Press"ing Concern, gives students the opportunity to research and analyse the risks and benefits of the development and application of organic synthetic products. Students at a simulated press conference share their research by answering questions posed to them by a group of students acting as reporters. As reporters, students use their findings to write an editorial evaluating the impact of organic synthetic compounds on their lives and the environment. Students reflect on the information presented at the press conference and the editorials written, and recognize their role as stewards of the earth in addressing environmental concerns and issues, thereby acquiring an appreciation for the need to protect God's Creation.

Strand(s) & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE1d - develops attitudes and values founded on Catholic social teaching, and acts to promote social responsibility, human solidarity, and the common good;
CGE2b - reads, understands, and uses written materials effectively;

CGE2c - presents information and ideas clearly and honestly and with sensitivity to others;
CGE2e - uses and integrates the Catholic faith tradition, in the critical analysis of the arts, media, technology, and information systems, to enhance the quality of life;
CGE3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE3d - makes decisions in light of gospel values with an informed moral conscience;
CGE3e - adopts a holistic approach to life by integrating learning from various subject areas and experience;
CGE3f - examines, evaluates, and applies knowledge of interdependent systems (physical, political, ethical, socio-economic, and ecological) for the development of a just and compassionate society;
CGE4a - demonstrates a confident and positive sense of self, and respect for the dignity and welfare of others;
CGE4c - takes initiative and demonstrates Christian leadership;
CGE4e - sets appropriate goals and priorities in school, work, and personal life;
CGE4f - applies effective communication, decision making, problem solving, time and resource management skills;
CGE4g - examines and reflects on one's personal values, abilities, and aspirations influencing life's choices and opportunities;
CGE5e - respects the rights, responsibilities, and contributions of self and others;
CGE7a - acts morally and legally as a person formed in Catholic traditions;
CGE7b - accepts accountability for one's own actions;
CGE7e - witnesses Catholic social teaching by promoting equality, democracy, and solidarity for a just, peaceful, and compassionate society;
CGE7h - exercises the rights and responsibilities of Canadian citizenship;
CGE7i - respects the environment and uses resources wisely;
CGE7j - contributes to the common good.

Strand(s): Organic Chemistry

Overall Expectations
OCV.03 - evaluate the impact of organic compounds on our standard of living and the environment.

Specific Expectations
OC2.01 - use appropriate scientific vocabulary to communicate ideas related to organic chemistry;
OC3.02 - describe the variety and importance of organic compounds in our lives;
OC3.03 - analyse the risks and benefits of the development and application of synthetic products.

Scientific Investigations Skills
SIS.05 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results;
SIS.06 - compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion.

Planning Notes

- The *Caveat Emptor* portfolio is collected at this time.
- Refer to the Planning Notes in Activity 2 pertaining to the end-of-unit task, A "PRESS"ing Concern.
- Ensure that all audiovisual equipment and other technology items needed for presentations are available, and make all necessary arrangements.
- Prepare a schedule for presentations. The length of the presentation is to be determined by the teacher. The time available and the class size may be factors to consider.

- It is recommended students spend the first 75 minutes of the activity preparing their materials and presentations for the press conference. They must also collaborate in their groups to decide which questions they should ask during their sessions as reporters. The teacher may wish to inform them that a good journalist always attends a press conference prepared with some knowledge and questions on the topic investigated. The press conference takes place during the next 150 minutes. Students will write their editorial in class during the last 75 minutes.
- Students use their reporter notes to write their editorial. The reporter notes are to be attached to the editorial they submit.

Teaching/Learning Strategies

Activity 5: A "PRESS"ing Concern

The teacher:

- collects the *Caveat Emptor* portfolio;
- collects the reporter questions, assesses them for appropriate content, and gives feedback;
- facilitates the A "PRESS"ing Concern press conference;
- assesses the presentation and the editorial;
- instructs students to write a reflection in their journal on their role as stewards of the earth in addressing environmental concerns and issues, and the need to protect God's Creation.

Students:

- submit the *Caveat Emptor* portfolio;
- individually submit the questions that they are going to ask as they assume role of reporter;
- individually present their findings at the press conference by answering all questions asked and submitting their fact sheet;
- peer assess for group cooperation;
- assume the role of reporter and ask questions to a group presenting a different organic synthetic product. Use the answers to the questions to write an editorial on the synthetic product for which they were reporters;
- individually write and submit their editorial;
- write a reflection in their journal on their role as stewards of the earth in addressing environmental concerns and issues, and develop an appreciation for the need to protect God's Creation.

Assessment & Evaluation of Student Achievement

The *Caveat Emptor* portfolio may be assessed for Communication and Making Connection using a rubric (OC2.01, 3.01).

The presentation and fact sheet may be evaluated for Making Connections and Communication using a rubric – Appendix II (OC2.01, 3.02, 3.03).

The editorial for A "PRESS"ing Concern may be evaluated Making Connections and Communication using a rubric – Appendix II (OC2.01, 3.02, 3.03).

Accommodations

- See Course Overview for general accommodations.
- Possible enrichment activities:
  - Write an editorial in the school newspaper to share their findings with the school community.
  - Prepare a videotaped news report of their findings.

Resources

Textbooks

Catechism of the Catholic Church, Canadian Conference of Catholic Bishops. 1994. ISBN 088997-281-8

Stone, Peter. *Getting Assessment Right, Science Grade 9-10*. Barrie: Data Base Directions, 2000. ISBN 1-894369-06-8

Bowers, Ray, et al. *Biology 11 Teacher Resource Package*. Toronto: Addison Wesley, 2002. ISBN 0-201-70803-5

Appendix I – A "PRESS"ing Concern

As consumers, we use many different types of organic synthetic products daily, e.g., synthetic polymers, cosmetics, pharmaceuticals, insecticides, pesticides, plastics, and solvents. These compounds have an impact on our standard of living and on the environment. The development and application of these organic synthetic products has had both beneficial and harmful impacts on our lives and on the environment.

In this activity, students prepare and participate in a simulated press conference. They research, report (orally and in written form), and further investigate the risks and benefits associated with the development and application of organic synthetic products. Students take on two roles: first, as members of a research team and second, as members of investigative reporting team. As members of the research team, students research an assigned organic synthetic product, and present their findings at the simulated press conference. As a member of the investigative reporting team, students ascertain information on a different organic synthetic product through the use of (researched) probing questions directed at another research team. As reporters, students should remember that a good investigative reporter always attends a press conference with prior knowledge and prepared questions on the topic under investigation.

Role 1: Research Team

- As a group, choose an organic synthetic product;
- Delegate research responsibilities amongst the group members so that the following questions are researched:
    1. What are the reactants used to prepare the organic synthetic product? What methods are used to isolate these reactants?
    2. What methods are used to synthesize the organic synthetic product? List any byproducts produced for each method described.
    3. What uses does the organic synthetic product have in society?
    4. What are the risks and benefits associated with the production and use of the organic synthetic product?
    5. How does its production and use have an impact on our standard of living and on the environment?

Each member of the research team will:

- Meet and conference with the other group members to peer assess researched information, and plan and practise their presentation for the press conference;
- Produce and submit a fact sheet of the information s/he has researched to the teacher for assessment prior to the press conference;
- Present their findings and answer all reporters' questions at the press conference.

Role 2: Investigative Reporting Team

- You have been assigned to investigate a different organic synthetic product from the one your group has researched.
- Delegate research responsibilities to each group member and consolidate researched information on the organic synthetic product to be investigated. Use the questions in Role 1 as a guide.

Each member of the investigative reporting team will:

- Prepare four probing questions to be asked at the press conference. These questions will be peer assessed by members of the group.
- Submit questions to the teacher for assessment prior to the press conference.
- Use their own reporter notes to write a one-page editorial on the risks and benefits associated with the organic synthetic product investigated.
- Submit reporter notes and editorial to the teacher for assessment.

Appendix II

End-of-Unit Task Performance Rubric

K = Knowledge/Understanding I = Inquiry C = Communication MC = Making Connections

Criteria	Level 1 (50-59%)	Level 2 (60-61%)	Level 3 (70-79%)	Level 4 (80-100%)
Knowledge of the development and application of the synthetic products investigated **(K/U)**	- demonstrates limited knowledge	- demonstrates some knowledge	- demonstrates considerable knowledge	- demonstrates thorough knowledge
Use appropriate scientific vocabulary to communicate information and ideas **(C)**	- uses appropriate scientific vocabulary with limited clarity	- uses appropriate scientific vocabulary with moderate clarity	- uses appropriate scientific vocabulary with considerable clarity	- uses appropriate scientific vocabulary with high degree of clarity
Understanding of connections between organic synthetic compounds and their applications among science, technology, society, and the environment **(MC)**	- demonstrates limited understanding of connections	- demonstrates some understanding of connections	- demonstrates considerable understanding of connections	- demonstrates thorough understanding of connections
Identification of the risks and benefits of the development and application of synthetic products to society and the environment **(MC)**	- demonstrates limited understanding of the risks and benefits	- demonstrates moderate understanding of the risks and benefits	- demonstrates considerable understanding of the risks and benefits	- demonstrates thorough understanding of the risks and benefits
Analysis of the risks and benefits of the development and application of synthetic products to society and the environment **(MC)**	- analyses risks and benefits with limited effectiveness	- analyses risks and benefits with moderate effectiveness	- analyses risks and benefits with considerable effectiveness	- analyses risks and benefits with high degree of effectiveness
Evaluate the impact of organic compounds on the standard of living and the environment **(MC)**	- evaluates the impact with limited effectiveness	- evaluates the impact with moderate effectiveness	- evaluates the impact with considerable effectiveness	- evaluates the impact with high degree of effectiveness
Research, compile, and interpret data from various sources including the Internet **(C)**	- utilizes resources with limited effectiveness	- utilizes resources with moderate effectiveness	- utilizes appropriate and varied resources with considerable effectiveness	- utilizes appropriate and varied resources with high degree of effectiveness

Note: A student whose achievement is below Level 1 (50%) has not met the expectations for this assignment or activity.