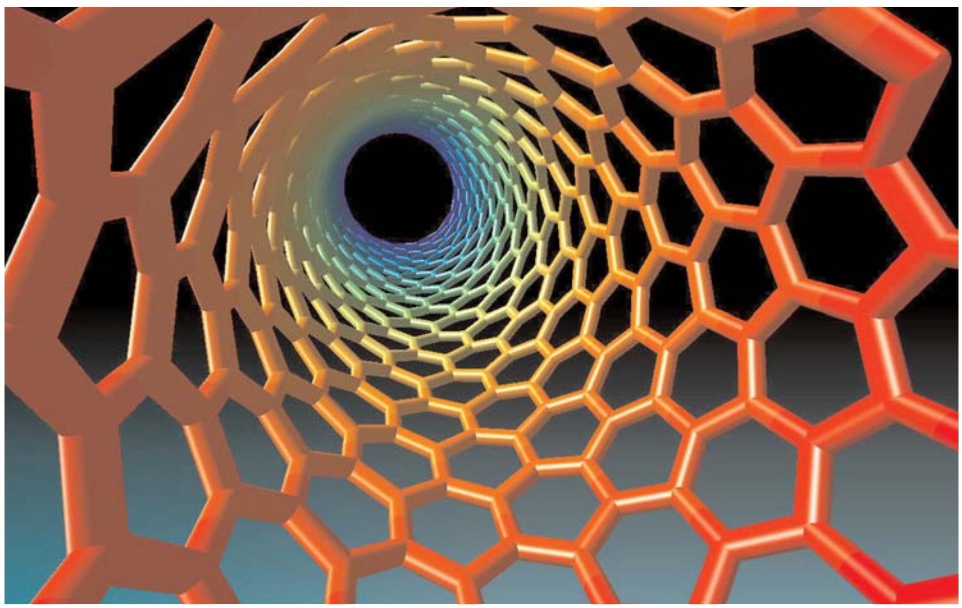
TOPIC 5:
ORGANIC CHEMISTRY



Topic 5: Organic Chemistry

C11-5-01 Compare and contrast inorganic and organic chemistry.
Include: the contributions of Friedrich Wöhler to the overturn of vitalism

C11-5-02 Identify the origins and major sources of hydrocarbons and other organic compounds.
Include: natural and synthetic sources

C11-5-03 Describe the structural characteristics of carbon.
Include: bonding characteristics of the carbon atom in hydrocarbons (single, double, triple bonds)

C11-5-04 Compare and contrast the molecular structures of alkanes, alkenes, and alkynes.
Include: trends in melting points and boiling points of alkanes only

C11-5-05 Name, draw, and construct structural models of the first 10 alkanes.
Include: IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula $C_nH_{(2n+2)}$

C11-5-06 Name, draw, and construct structural models of branched alkanes.
Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature

C11-5-07 Name, draw, and construct structural models of isomers for alkanes up to six-carbon atoms.
Include: condensed structural formulas

C11-5-08 Outline the transformation of alkanes to alkenes and vice versa.
Include: dehydrogenation/hydrogenation, molecular models

C11-5-09 Name, draw, and construct molecular models of alkenes and branched alkenes.
Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula C_nH_{2n}

C11-5-10 Differentiate between saturated and unsaturated hydrocarbons.

C11-5-11 Outline the transformation of alkenes to alkynes and vice versa.
Include: dehydrogenation/hydrogenation, molecular models

C11-5-12 Name, draw, and construct structural models of alkynes and branched alkynes.
Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula C_nH_{2n-2}

C11-5-13 Compare and contrast the structure of aromatic and aliphatic hydrocarbons.
Include: molecular models, condensed structural formulas

C11-5-14 Describe uses of aromatic hydrocarbons.
Examples: polychlorinated biphenyls, caffeine, steroids, organic solvents (toluene, xylene)…

C11-5-15 Write condensed structural formulas for and name common alcohols.
Include: maximum of six-carbon parent chain, IUPAC nomenclature

C11-5-16 Describe uses of methyl, ethyl, and isopropyl alcohols.

C11-5-17 Write condensed structural formulas for and name organic acids.
Include: maximum of six-carbon parent chain, IUPAC nomenclature

C11-5-18 Describe uses or functions of common organic acids.
Examples: acetic, ascorbic, citric, formic, acetylsalicylic (ASA), lactic…

C11-5-19 Perform a lab involving the formation of esters, and examine the process of esterification.

C11-5-20 Write condensed structural formulas for and name esters.
Include: up to 6-C alcohols and 6-C organic acids, IUPAC nomenclature

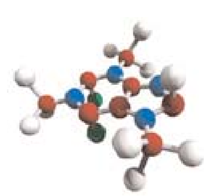
C11-5-21 Describe uses of common esters.
Examples: pheromones, artificial flavourings…

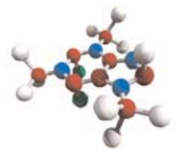
C11-5-22 Describe the process of polymerization and identify important natural and synthetic polymers.
Examples: polyethylene, polypropylene, polystyrene, polytetrafluoroethylene (Teflon®)…

C11-5-23 Describe how the products of organic chemistry have influenced quality of life.
Examples: synthetic rubber, nylon, medicines, polytetrafluoroethylene (Teflon®)…

C11-5-24 Use the decision-making process to investigate an issue related to organic chemistry.
Examples: gasohol production, alternative energy sources, recycling of plastics…

Suggested Time: 17.0 hours





SPECIFIC LEARNING OUTCOME

C11-5-01: Compare and contrast inorganic and organic chemistry.

Include: the contributions of Friedrich Wöhler to the overturn of vitalism

(1.0 hour)

SLO: C11-5-01

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students should know many organic compounds but they may not know that these substances fall under the general category of *organic*. Students may say that *organic* means grown without the aid of fertilizers or chemical enhancements.

TEACHER NOTES

During the 1950s, plant splicing occurred to improve resistance to diseases, such as rust. M.S. Joseph Murachy, from Shoal Lake, Manitoba, is credited with the development of a wheat strain that was resistant to rust 15B. He then crossed this variety of wheat with Exchange and Redman varieties to create a strongly resistant form of wheat that became famous. The new strain was commonly called Selkirk wheat.

The following website can be used to collect information concerning the history of the introduction of resistant strains of cereal grains into the Prairie region.

Agriculture and Agri-Food Canada. Cereal Research Centre, Winnipeg: <http://res2.agr.ca/winnipeg/v1_e.htm>

Activating Activity

Provide students with a definition of an organic compound and then have them list as many compounds as they can. Ask students to write, in their journals, how their life would change if suddenly all the organic compounds they presently use ceased to exist. Students could sketch a picture of a world without organic materials.

General Learning Outcome Connections

GLO A2: Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

GLO A4: Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

GLO B1: Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

GLO B2: Recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

Laboratory Activity/Demonstration

Appendix 3.8: Indications of Chemical Reactions outlines a demonstration on the typical reaction of concentrated sulphuric acid with sugar to produce solid carbon and a number of other products that are toxic. This demonstration should be done in a fume hood, with all the necessary safety precautions noted in Appendix 3.8. The Material Safety Data Sheet for concentrated sulphuric acid should be available before the lab activity/demonstration occurs.

TEACHER NOTES

By 1800, chemistry had firmly become established as a science, and for the next decade scientists became keenly interested in studying the composition of substances and the manner in which they could be changed. As a result of investigations, scientists began to distinguish two types of compounds. Those derived from plant or animal sources became known as *organic compounds* and those obtained from mineral constituents of the Earth were called *inorganic compounds*.

Chemists were aware of a very large number of organic compounds (such as dyes, soaps, vinegars, sugars, perfumes, gums, and rubber, to mention a few) but were unable to explain how so many compounds could be made from only a few elements. Swedish chemist Jöns Jakob Berzelius (1779–1848) had just explained inorganic compounds as being formed by oppositely charged atoms. However, this did not explain organic compounds such as C_2H_6, C_2H_4, C_3H_8, C_4H_{10}, and so on. It was common knowledge that Cl_2 could be substituted for H in C_2H_6 to produce C_2Cl_6. This meant, however, that a negative Cl could be substituted for a positive H. This was not consistent with Berzelius's idea of oppositely charged atoms attracting.

Up to this point, no organic compound had been synthesized from inorganic materials and, as a result, many scientists believed that organic compounds were formed only under the influence of a *vital force*. It was Friedrich Wöhler (1800–1882) who, in 1828, made a remarkable discovery at the University of Göttingham in Germany. He attempted to prepare ammonium cyanate by means of a double decomposition reaction in a solution of ammonium chloride and silver cyanate. Both of these compounds were considered to be *inorganic*. Instead of producing ammonium cyanate, however, he obtained crystals of urea, an organic compound.

$$NH_4Cl + AgCHO \longrightarrow AgCl + \underset{\text{Urea}}{CH_4N_2O}$$

SPECIFIC LEARNING OUTCOME

C11-5-01: Compare and contrast inorganic and organic chemistry.

Include: the contributions of Friedrich Wöhler to the overturn of vitalism

(continued)

Within a few years of this event, when acetic acid and several other organic compounds had been prepared from inorganic materials, the validity of the *vital force* was questioned. As time passed, more and more organic compounds were synthesized from inorganic materials. It became obvious that it was not necessary for all organic compounds to be associated with living organisms. In the mid-1800s, it became apparent that the one factor common to all organic compounds was the element *carbon*. Chemists now simply say that organic compounds are compounds containing carbon.

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Journal Writing

Students should comment about the lab activity/demonstration.

Laboratory Reports

The lab activities suggested for this learning outcome could be assessed as formal lab reports using the Laboratory Report Outline or the Laboratory Report Format (see *SYSTH* 11.38, 14.12) or by using questions and answers from the data collected from the activities.

Paper-and-Pencil Task

Students could outline Friedrich Wöhler's contributions to the understanding of organic chemistry.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

LEARNING RESOURCES LINKS

Chemistry (Chang 979)

Chemistry (Zumdahl and Zumdahl 1043)

Chemistry: The Central Science (Brown, *et al.* 983)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 607)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 698)

Introductory Chemistry: A Foundation (Zumdahl 575)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 321)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 534)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 506)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 6)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 810)

SPECIFIC LEARNING OUTCOME

C11-5-02: Identify the origins and major sources of hydrocarbons and other organic compounds.

Include: natural and synthetic sources

(0.5 hour)

SLO: C11-5-02

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

The formation of fossil fuels was discussed in detail in Grade 7 Science:

- 7-4-06: Identify geological resources that are used by humans as sources of energy, and describe their method of formation.

  Include: fossil fuels, geothermal energy

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

Many texts provide information about the origin of and major sources of hydrocarbons. Through the review process, remind students that naturally occurring hydrocarbon compounds have resulted from the decay of prehistoric animals and vegetation. The hydrocarbon fuels resulting from the compaction of organic material are generally called *fossil fuels* or *petroleum* products. The word *petroleum* is derived from the Latin roots *petra*, meaning rock, and *oleum*, for oil.

Introduce students to the process of refining crude oil. This is a large topic that could easily become unmanageable. Students should know the general idea behind the process of fractional distillation and how heavy crude oil is "cracked" into lighter, smaller-chain carbonaceous fuels to be used as petroleum products.

Petroleum products are also produced synthetically. Synthetic hydrocarbons are constructed by starting with a petrochemical compound and adding to it, thus creating longer-chain hydrocarbons.

General Learning Outcome Connections

GLO A2: Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

GLO A4: Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

GLO B1: Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

GLO B2: Recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

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Many synthetic products are more stable at higher temperatures and are very insoluble in most liquids (especially water), making them excellent lubricants.

There are many patented methods of producing petroleum-like products. A few of these methods are provided as examples below:

- Syntroleum® is a patented process for converting natural gas into synthetic hydrocarbon liquids that have both fuel and lubricant properties.
- There is a Russian patent on a process that determines the production of synthetic substances such as methane. The process uses a static field and ultraviolet light to catalyze the following reactions:

  $CO + 3H_2 \longrightarrow CH_4 + H_2O_{(g)}$

  $2CH_4 \longrightarrow C_2H_2 + 3H_2$

  The acetylene reacts with hydrogen to produce a number of saturated and unsaturated hydrocarbons that transform to a petroleum-like mixture after condensing.
- The Alberta tar sand material is called *bitumen*. In the extraction process, the larger-chain, complex bitumen is cracked into synthetic crude oil.

  The following website provides further information on the process.

  Alberta. Oil Sands Discovery Centre. The Oil Sands Story: Upgrading: <http://www.oilsandsdiscovery.com/oil_sands_story/upgrade.html>

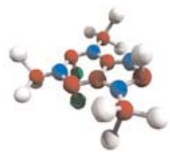
Research Activities

1. Have students research the world producers of crude oil, including the daily capacity in barrels of oil produced. Also have them research crude oil production in Canada, as well as the projected consumption of oil for North America and the rest of the world.
2. Have students research the advertised characteristics of synthetic oils, compared to natural crude oil products.

STSE Decision-Making Issue

A detailed history of the development of synthetic products from the perspective of a major producer is available on the following website.

SynLube™: <http://www.synlube.com/synthetic.htm>



SPECIFIC LEARNING OUTCOME

C11-5-02: Identify the origins and major sources of hydrocarbons and other organic compounds.

Include: natural and synthetic sources

(continued)

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Research Reports

Have students conduct their research and report their findings either individually or in small groups. The information collected could be presented as

- written reports
- oral presentations
- bulletin board displays
- multimedia presentations

Visual Displays

Students could present the material they have collected using

- posters
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students prior to the assignment. Samples of presentation rubrics are provided in Appendix 10 of this document.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

LEARNING RESOURCES LINKS

Chemistry (Chang 1003)

Chemistry (Zumdahl and Zumdahl 267)

Chemistry: The Central Science (Brown, *et al.* 983)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 145, 638)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 725)

Introductory Chemistry: A Foundation (Zumdahl 588)

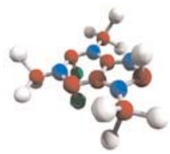
McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al. 332,* 579, 619)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 507)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 22)

Nelson Chemistry 12: College Preparation, Ontario Edition (Davies, *et al.* 193)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 823)



SPECIFIC LEARNING OUTCOMES

C11-5-03: Describe the structural characteristics of carbon.

Include: bonding characteristics of the carbon atom in hydrocarbons (single, double, triple bonds)

C11-5-04: Compare and contrast the molecular structures of alkanes, alkenes, and alkynes.

Include: trends in melting points and boiling points of alkanes only

(1.0 hour)

SLO: C11-5-03
SLO: C11-5-04

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students in Grade 9 Science (learning outcomes S1-2-03 to S1-2-08) were introduced to elements on the periodic table. They were also responsible for drawing Bohr models of atoms up to atomic number 18, including the element carbon (S1-2-03).

In Grade 10 Science, students were also introduced to periodicity, the combining capacity of elements, and the characteristics of common elements, including carbon (S2-2-01). They were also introduced to Lewis Dot Diagrams to illustrate the combining capacity of an atom to form both ionic and covalent bonds (S2-2-02). Synthesis and decomposition of simple organic compounds such as methane and propane would most likely have been addressed in Grade 10 Science (S2-2-07).

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

In reviewing prior knowledge, remind students that because of its position on the periodic table, carbon has four valence electrons that are available for chemical bonding. Since carbon is a non-metal, its preferred form of bonding is covalent with the sharing of four electrons.

$$\cdot\overset{\cdot}{\underset{\cdot}{\mathrm{C}}}\cdot$$

General Learning Outcome Connections

GLO D1: Understand essential life structures and processes pertaining to a wide variety of organisms, including humans.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO D5: Understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

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These four valence electrons easily bond to four hydrogen atoms, forming the simplest organic molecule methane.

$$\begin{array}{ccccc} & & H & & \\ & & \cdot\cdot & & \\ H & \cdot\cdot & C & \cdot\cdot & H \\ & & \cdot\cdot & & \\ & & H & & \end{array}$$

Note that there are eight electrons around the carbon atom for a complete octet. The double dots that represent two electrons or an electron pair will now be represented by a single covalent bond line.

Laboratory Demonstration: Preparation of Methane

This lab is best done as a demonstration either by the teacher or by selected students under the supervision of a teacher.

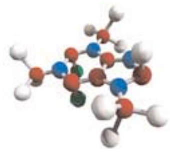
Place about 1 g of anhydrous sodium acetate and 2 g of soda lime in a large test tube and mix thoroughly. Heat the mixture. The gas is collected by the displacement of water. If two test tubes of methane are collected, the physical properties of the gas can be observed, as well as the flammability of the gas.

TEACHER NOTES

The reaction of sulphuric acid at 170°C with an alcohol of a single-bond hydrocarbon such as C_2H_5OH will release water and become C_2H_4 or $H_2C = CH_2$. The acid acts as a catalyst according to the following reaction:

$$C_2H_5OH \xrightarrow{H_2SO_4 \text{ at } 170°C} H_2C = CH_2 + H_2O$$

The structural formula: $\begin{array}{ccccccc} H & - & C & = & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$



SPECIFIC LEARNING OUTCOMES

C11-5-03: Describe the structural characteristics of carbon.

Include: bonding characteristics of the carbon atom in hydrocarbons (single, double, triple bonds)

C11-5-04: Compare and contrast the molecular structures of alkanes, alkenes, and alkynes.

Include: trends in melting points and boiling points of alkanes only

(continued)

Students may be familiar with the existence of, and arrangement of, a triple covalent bond if they discussed nitrogen gas in Grade 10 Science (learning outcome S2-2-04). To maintain the stable octet, three pairs of electrons are shared between the nitrogen atoms:

$$:N \equiv N:$$

This structure can then be related to a similar bond found in an alkyne. The first member of this series is ethyne or what is commonly called acetylene:

$$CH \equiv CH$$

Students should note that there are still four bonds connected to each carbon atom and the electronic octet is still intact.

Laboratory Demonstration: Preparation of Acetylene

This lab procedure is best done by the teacher or by selected students under the close supervision of the teacher.

Fill two large test tubes with water and invert them in a pneumatic trough also filled with water. Drop a lump of calcium carbide into the water trough and quickly cover it with one of the test tubes filled with water. The gas is collected by the displacement of water. Several test tubes of acetylene can be collected by this method. Once the tubes are filled with gas they can be stoppered and removed from the trough for testing. Test the gas for flammability using a burning splint. The reaction for the preparation of acetylene is as follows:

$$CaC_2 + 2H_2O \longrightarrow HC \equiv CH + Ca(OH)_2$$

A more detailed discussion of the three series of alkanes, alkenes, and alkynes will occur in relation to learning outcomes C11-5-05, C11-5-09, and C11-5-12.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

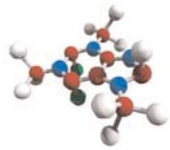
Textbooks will usually have some of the physical properties of at least the first two series of hydrocarbon compounds, the alkanes and alkenes. Some data are provided in the following table.

Physical Properties of Some Normal Saturated Hydrocarbons				
Name	**Formula**	**MP °C**	**BP °C**	**State**
Methane	CH_4	–182.6	–161.4	gas
Ethane	C_2H_6	–172.0	–88.3	gas
Propane	C_3H_8	–187.1	–44.5	gas
n-Butane	C_4H_{10}	–135.0	–0.5	gas
n-Pentane	C_5H_{12}	–129.7	36.2	liquid
n-Hexane	C_6H_{14}	–94.0	69	liquid
n-Heptane	C_7H_{16}	–90.5	98.4	liquid
n-Octadecane	$C_{18}H_{38}$	28	308	solid

Reference: Linstromberg, Walter W., and Henry E. Baumgarten. *Organic Chemistry: A Brief Course.* Lexington, MA: D.C. Heath and Company, 1978. 43.

Properties of Normal Paraffin Hydrocarbons

Have students carefully plot a data chart (by hand, initially) that illustrates the relationships among melting point (MP), boiling point (BP), and the number of carbons in the parent chain (up to 15-C at least). A sample plot is provided for teacher reference.



SPECIFIC LEARNING OUTCOMES

C11-5-03: Describe the structural characteristics of carbon.

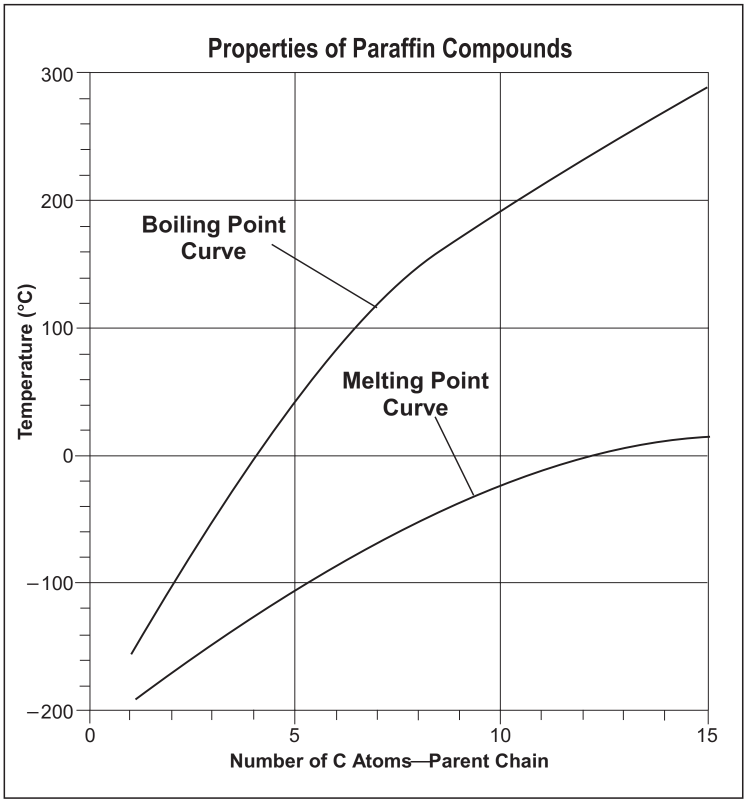
Include: bonding characteristics of the carbon atom in hydrocarbons (single, double, triple bonds)

C11-5-04: Compare and contrast the molecular structures of alkanes, alkenes, and alkynes.

Include: trends in melting points and boiling points of alkanes only

(continued)

Properties of Paraffin Hydrocarbons		
Number of Carbons in Chain	**Melting Point (°C)**	**Boiling Point (°C)**
1	–180	–160
2	–190	–90
3	–175	–40
4	–140	0
5	–140	+40
6	–90	+80
7	–95	+100
8	–50	+140
9	–45	+150
10	–20	+180
11	–20	+195
12	0	+220
13	–5	+250
14	+5	+270
15	+15	+290



Students should intuit that the MP and BP are proportional to the molar mass or length of the hydrocarbon chain. While students are not expected to memorize the data, they should remember the general trends. For instance, there is a dramatic increase in the value of the physical properties for carbon chains from 1-C to 8-C.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Paper-and-Pencil Tasks

Students should be able to compare the difference in structure between the three series of hydrocarbon families. They should also be able to relate the chain length of the alkanes to the MP and BP of the members in that family.

LEARNING RESOURCES LINKS

Chemistry (Chang 980)

Chemistry (Zumdahl and Zumdahl 1044)

Chemistry: The Central Science (Brown, *et al.* 984)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 176)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 608)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 698)

Introductory Chemistry: A Foundation (Zumdahl 576)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 342)

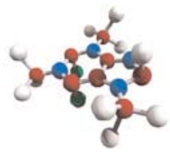
McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 538)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 502)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 11)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 181)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 805)



SPECIFIC LEARNING OUTCOMES

C11-5-05: Name, draw, and construct structural models of the first 10 alkanes.

Include: IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula $C_nHB_{(2n+2)}$

C11-5-06: Name, draw, and construct structural models of branched alkanes.

Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature

(1.5 hours)

SLO: C11-5-05
SLO: C11-5-06

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students are not expected to have any prior knowledge of learning outcomes C11-5-05 and C11-5-06, other than knowing that the carbon atom has four valence electrons and needs to share four other electrons to achieve a stable octet.

TEACHER NOTES

If possible, have students work with atomic models that will allow them to see the structural arrangement of atoms as they build each successive structure in the alkane series. Using other materials, such as marshmallows and toothpicks, to create the alkane series may give students the wrong impression of the actual three-dimensional structure. If not enough model kits are available for students to use, then at least one set should be available for the teacher to illustrate the correct structures.

Activity

The learning activities in this document are written as suggestions only. Teachers are expected to use whatever materials are available to present a concept effectively.

Give student pairs a number of

- black carbon atom representations with four holes in them to bond to other carbon atoms
- white hydrogen atoms with one hole in them to connect with the carbon atoms

General Learning Outcome Connections

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

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After showing students how to connect the atoms carefully, allow them to construct molecules of the alkane series. Many students will know the Latin prefixes for the number of carbon atoms: *meth*, *eth*, *prop*, *but*, *pent*, *hex*, *hept*, *oct*, *non*, and *dec*. Ask students to use the general formula to determine the number of hydrogen atoms for a given number of carbon atoms.

TEACHER NOTES

Students should be able to draw at least the first 10 alkanes. In addition, they should be able to name the compounds, when given either the molecular formula or the structural formula.

Students should also know the general formula for the alkanes and the International Union of Pure and Applied Chemistry (IUPAC) nomenclature, which enables scientists to talk to each other about organic compounds using a common naming system. Teachers will remember that there are other methods of naming organic compounds (e.g., the common name, the derived name).

For information about current nomenclature rules and for additional information and examples about the naming of organic compounds, see the following websites:

The Catalyst: Chemistry Resource for the Secondary Education Teacher on the WWW: <http://catalyst.8media.org/m13organ.html>

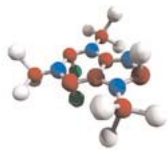
This online resource is intended for teachers interested in a wide-ranging “clearinghouse” website related to organic chemistry topics.

Michigan State University. Nomenclature: Naming Organic Compounds: <http://www.cem.msu.edu/~reusch/VirtualText4/nomen1.htm>

This website provides a detailed, comprehensive treatment of why a systematic naming of organic compounds is necessary to chemists, and thoroughly treats all important groups of compounds and homologous series.

The IUPAC organic naming system enables scientists to name very complex branched molecules. This brief introduction to organic chemistry is not intended to overwhelm students with complex structures. These learning outcomes specify only that methyl and ethyl side chains be used with a maximum six-carbon parent chain:

- methylpropane
- dimethylpropane
- 2-methylbutane
- 2,2,3,4-tetramethylpentane



SPECIFIC LEARNING OUTCOMES

C11-5-05: Name, draw, and construct structural models of the first 10 alkanes.

Include: IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula $C_nHB_{(2n+2)}$

C11-5-06: Name, draw, and construct structural models of branched alkanes.

Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature

(continued)

IUPAC Rules for Nomenclature

The general IUPAC rules for nomenclature are:

1. Find and name the *longest continuous carbon chain*.
2. Identify and name groups attached to this chain.
3. Number the chain consecutively, starting at the end nearest a *substituent* group.
4. Designate the location of each substituent by an appropriate *number* and *name*.
5. An older rule required that the sum of the numbers be as small as possible; however, a relatively new rule requires that the lower first number be used, so 1,1,3– would be used rather than 1,2,2–, and 1,1,3,4– rather than 1,2,2,3–. (This would apply to functional groups and not to branched alkanes, as identifying a branch group with a 1 would make the parent chain longer.)
6. Assemble the name, listing groups in *alphabetical order*. The prefixes (e.g., *di*, *tri*, *tetra*, etc.) used to designate several groups of the same kind are not considered when alphabetizing (e.g., 3–ethyl-2,2–dimethylpentane).

Reference: Linstromberg, Walter W., and Henry E. Baumgarten. *Organic Chemistry: A Brief Course*. Lexington, MA: D.C. Heath and Company, 1978. 37–38.

SUGGESTIONS FOR ASSESSMENT

Paper-and-Pencil Tasks

Students should be able to write the correct formulas when given the name of a branched alkane with a parent chain up to six-carbon atoms. They should also be able to produce the name when given either the structural or molecular formula.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

LEARNING RESOURCES LINKS

Chemistry (Chang 982)

Chemistry (Zumdahl and Zumdahl 1044)

Chemistry: The Central Science (Brown, *et al.* 987)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 623)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 614)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 699)

Introductory Chemistry: A Foundation (Zumdahl 577)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 333)

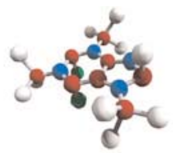
McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 547)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 509)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 12)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 182)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 816)



SPECIFIC LEARNING OUTCOME

C11-5-07: Name, draw, and construct structural models of isomers for alkanes up to six-carbon atoms.

Include: condensed structural formulas

(0.5 hour)

SLO: C11-5-07

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students are not expected to have any entry-level knowledge other than their current knowledge of organic IUPAC nomenclature.

TEACHER NOTES

Students should build these molecular models using techniques similar to those used for the previous learning outcome (C11-5-06).

Structural isomers are compounds having the same molecular formula, C_5H_{12}, but a different structural formula.

Example:

n–pentane $CH_3CH_2CH_2CH_2CH_3$

2–methylbutane

$$\begin{array}{l} CH_3\underset{\substack{|\\ CH_3}}{C}HCH_2CH_3 \end{array}$$

2,2–dimethylpropane

$$CH_3\overset{\substack{CH_3\\|}}{\underset{\substack{|\\ CH_3}}{C}}CH_3$$

General Learning Outcome Connections

GLO B1: Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

GLO B2: Recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time.

GLO D1: Understand essential life structures and processes pertaining to a wide variety of organisms, including humans.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO E1: Describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world.

SKILLS AND ATTITUDES OUTCOME

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

Structural isomers will have the same molar mass but differing physical and chemical properties. The number of isomers that are possible for a given molecular formula increases rapidly with the number of carbon atoms.

Number of Carbon Atoms	Number of Isomers
4	2
5	3
6	5
10	75
40	62,491,178,805,831

Activity

Have students try to draw all the possible structures for heptane, C_7H_{16}. That should keep them busy for a while!

While other kinds of isomerism (beyond structural) could be addressed, they are not discussed in Grade 11 Chemistry (they are reserved for advanced-level study).

SUGGESTION FOR ASSESSMENT

Paper-and-Pencil Task

Students should be able to use an example to illustrate and explain isomers.

LEARNING RESOURCES LINKS

Chemistry (Chang 981)

Chemistry (Zumdahl and Zumdahl 1045)

Chemistry: The Central Science (Brown, *et al.* 988)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 628)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 623)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 717)

Introductory Chemistry: A Foundation (Zumdahl 579)

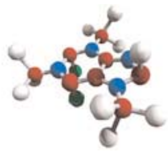
McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 326)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 539)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 529)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 13, 814)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 820)



SPECIFIC LEARNING OUTCOME

C11-5-08: Outline the transformation of alkanes to alkenes and vice versa.

Include: dehydrogenation/hydrogenation, molecular models

(0.5 hour)

SLO: C11-5-08

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

The formation of fossil fuels was discussed in detail in Grade 7 Science:

- 7-4-06: Identify geological resources that are used by humans as sources of energy, and describe their method of formation.
  Include: fossil fuels, geothermal energy.

Students may not have been taught much about the *cracking process*, but they may be aware of its purpose in the refining of petroleum products.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

The chemical processes involving organic compounds are not simple. This is true for the transformation of alkanes to alkenes and the reverse. However, this is a logical way to introduce the next homologous family of alkenes or olefins. Short-chain alkanes are found in crude oil before it is introduced to the cracking process, sometimes called *fractional distillation* or *pyrolysis*. The word *pyrolysis* is taken from the Greek word *pyr*, meaning fire, and *lysis*, a loosening. To chemists, it means a cleavage by heat. During the pyrolysis of crude oil, smaller-chain alkenes are produced.

At this point, teachers can show students how a multiple bond forms by the removal of hydrogen. Each C atom still maintains an octet.

$$-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}- \longrightarrow -\overset{|}{C}=\overset{|}{C}- +H_2$$

General Learning Outcome Connections

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO D4: Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts.

GLO E3: Recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

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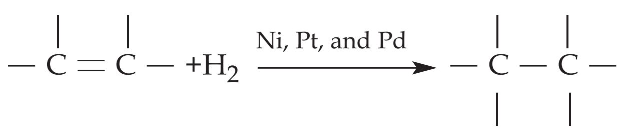
The pyrolysis of alkanes, when petroleum is concerned, is known as *cracking*. In the thermal cracking process, alkanes are simply passed through a high temperature reaction chamber. Large alkane chains are converted into smaller alkane molecules, alkenes, and some hydrogen. This process produces mainly ethylene. Because hydrogen is released or removed during the reaction, the process is also called *dehydrogenation*. Steam cracking is a process whereby the hydrocarbons are diluted with steam and instantly heated to 700°C to 900°C. This process produces ethylene, propylene, and a number of important *dienes*.

It is interesting to note that *n*-butane will dehydrogenate with high temperature and a catalyst to form a mixture of 1-butene and 2-butene.

Students should understand that the conversion of alkanes to alkenes requires a complex process that produces a number of different products.

In contrast, alkenes are converted to alkanes by a less complex reaction. Hydrogen can be added to an alkene in the presence of a nickel, platinum, or palladium catalyst. For obvious reasons, this process is called an *addition reaction* and is a common reaction in organic chemistry. Not surprisingly, this reaction is also called *catalytic hydrogenation*.



SUGGESTIONS FOR ASSESSMENT

Toward the end of any course, time becomes critical. Unfortunately, it is not uncommon for teachers to be rushed in addressing Topic 5: Organic Chemistry at the end of Grade 11 Chemistry. It is hoped that organic chemistry will occasionally be moved to another place in the course so that it could be treated with the same enthusiasm and detail as the other topics. With this in mind, if time is available, teachers could ask students to research the pyrolysis of crude oil and become involved with STSE issues. The assessment suggestions that follow reflect a detailed treatment of this topic.

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Specific Learning Outcome

C11-5-08: Outline the transformation of alkanes to alkenes and vice versa.

Include: dehydrogenation/hydrogenation, molecular models

(continued)

Research Reports

Have students conduct research and report their findings either individually or in small groups. The information collected can be presented as

- written reports
- oral presentations
- bulletin board displays
- multimedia presentations

Visual Displays

Students could present the material they have collected using

- posters
- pamphlets
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students before the assignment was begun. Samples of presentation rubrics are provided in Appendix 10 of this document.

STSE Decision-Making Issues

Global concern over the depletion of renewable resources and the Kyoto Accord are always in the news. Another environmental concern is the transportation of petroleum products by any means, whether by rail, sea, or pipeline. Any of these issues would be exceptional discussion topics for environmental concerns.

Journal Writing

If students are exposed to the refining of crude oil and its subsequent transport around the world, they may wish to address related STSE issues in their journals.

Paper-and-Pencil Tasks

Students should be able provide a brief explanation of pyrolysis of crude oil in the formation of alkanes and in the transformation of alkanes to alkenes. They should also be able to write the hydrogenation reaction for the formation of alkanes from alkenes.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

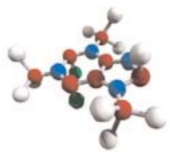
LEARNING RESOURCES LINKS

Chemistry (Chang 989)

Chemistry (Zumdahl and Zumdahl 1055)

Chemistry: The Central Science (Brown, *et al.* 997)

Introductory Chemistry: A Foundation (Zumdahl 592)



SPECIFIC LEARNING OUTCOME

C11-5-09: Name, draw, and construct molecular models of alkenes and branched alkenes.

Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula C_nH_{2n}

(1.5 hours)

SLO: C11-5-09

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students were introduced to alkenes in learning outcome C11-5-04 where a brief comparison was made to identify differences in structure and relative physical properties. Students have also drawn members of the homologous series of alkanes, as well as branched alkanes and isomers. They should now also understand the differences among molecular formulas, structural formulas, and condensed structural formulas.

TEACHER NOTES

Point out to students that the first member of the alkene series must be a two-carbon molecule, namely ethene. With a general formula of C_nH_{2n}, students should realize that the number of hydrogen atoms is double that of the number of carbon atoms. In addition, every member of this series will contain a double bond. Students should first draw structural formulas so they can more easily see the octet for each atom of carbon. The double bond also reduces the number of hydrogen atoms associated with the carbon atoms connected to the double bond. Students should use the atomic model kits again to create examples of molecules for this learning outcome. As students draw and construct ethene, propene, and so on, they will appreciate the structure of the compounds and the position of the hydrogen atoms around the molecule. When students get to butene, they should be shown the two possible isomers:

$CH_2 = CHCH_2\,CH_3$ 1–butene

$CH_3CH = CHCH_3$ 2–butene

If students have understood the concept of numbering for branched alkane compounds, they will understand the necessity of naming the position of the double bond and correctly propose the names of the two isomers. Remind students that the numbering can begin from either end of the molecule, so the following structure is still 1–butene:

$CH_3CH_2CH = CH_2$ 1–butene

General Learning Outcome Connections

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

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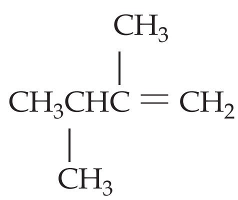
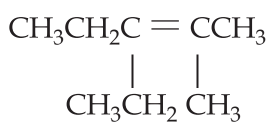
Again, the learning outcome specifies using a maximum of six-carbon parent chains. The molecules will become complex enough once students begin to add branching side chains. The learning outcome also limits the side chains to methyl and ethyl groups. In Grade 11 Chemistry, there is no point in loading students down with complex side chains such as isopropyl. As students have already mastered branching side chains for the alkanes, the alkenes should be more straightforward. Inform students that the double bond is always numbered first, so as to be the smallest number.



Remind students that the general formula must always work. In this case: C_6H_{12}.

The IUPAC standard naming is 2,3–dimethyl–1–butene.

The numbering of the parent chains is from right to left so that the multiple bond is on the first carbon rather than on the third carbon.



(C_8H_{16})

The IUPAC standard naming is 3–ethyl–2–methyl–2–pentene.

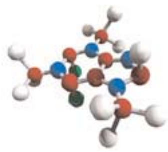
Note: All bonds are shown attached to the carbon atoms.

SUGGESTIONS FOR ASSESSMENT

Paper-and-Pencil Tasks

Students should be able to write the correct formula when given the name of the alkene and, conversely, they should be able to draw the correct condensed structural formula when given the name. Students should also be able to draw and name branched alkenes with a parent chain up to six-carbon atoms.

Keep in mind that it is easy to make up names for which the structure is impossible. Always write out the structure for a given name before giving examples or test questions to students.



SPECIFIC LEARNING OUTCOME

C11-5-09: Name, draw, and construct molecular models of alkenes and branched alkenes.

Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula C_nH_{2n}

(continued)

LEARNING RESOURCES LINKS

Chemistry (Chang 988)

Chemistry (Zumdahl and Zumdahl 1054)

Chemistry: The Central Science (Brown, *et al.* 994)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 324)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 618)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 711)

Introductory Chemistry: A Foundation (Zumdahl 590)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 345)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 557)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 543)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 16)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 184)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 825)

SKILLS AND ATTITUDES OUTCOMES

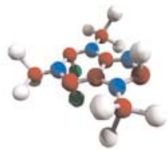
C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

NOTES



SPECIFIC LEARNING OUTCOME

C11-5-10: Differentiate between saturated and unsaturated hydrocarbons.

(0.5 hour)

SLO: C11-5-10

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students may have heard the term *polyunsaturated* in reference to nutrition, diet, or health issues. Many students would, by now, also have heard of a family of partially hydrogenated fats known as *trans fats*. Ingestion of trans fats remains a nutritional issue of interest today.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

It is not necessary for students to understand all the complexities of *cis* vs. *trans* structures of alkenes. Suffice it to say that *trans fats* or *trans fatty acids* are formed when manufacturers hydrogenate unsaturated compounds with hydrogen to form saturated structures. Manufacturers have found that hydrogenating vegetable oils has many economic benefits. The process produces a solid product, extends its shelf life, increases its flavour stability, and reduces the risk of rancidity, to name a few benefits.

To use a non-scientific analogy, anything that is saturated cannot hold any more and so an alkane is unable to hold any more carbon atoms, whereas an alkene is able to add hydrogen to the double bond. Students should be able to draw the difference between an unsaturated alkene and a saturated alkane. In learning outcome C11-5-08, students were shown how alkanes could be transformed to alkenes and vice versa.

General Learning Outcome Connections

GLO A4: Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

GLO B3: Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

GLO C8: Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

C11-0-D4: Recommend an alternative or identify a position and provide justification.

C11-0-D5: Propose a course of action related to an STSE issue.

Much information is available on the topic of trans fats. If time is available and if students are interested in exploring the topic in more detail, they could find information on websites such as the following:

Maclean's: <http://www.macleans.ca>

University of Guelph. Bruce J. Holub. Trans Watch:
<http://www.uoguelph.ca/~bholub/trans.html>

U.S. Food and Drug Administration. Revealing *Trans* Fats:
<http://www.fda.gov/fdac/features/2003/503_fats.html>

WebMD. Trans Fats: The Science and the Risks:
<http://my.webmd.com/content/article/71/81217.htm>

SUGGESTIONS FOR ASSESSMENT

Research Reports

Have students conduct research and report their findings either individually or in small groups. The information collected could be presented as

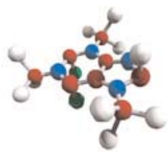
- written reports
- oral presentations
- bulletin board displays
- multimedia presentations

Visual Displays

Students could present the material they have collected using

- posters
- pamphlets
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students prior to the assignment. Samples of presentation rubrics are provided in Appendix 10 of this document.



SPECIFIC LEARNING OUTCOME

C11-5-10: Differentiate between saturated and unsaturated hydrocarbons.

(continued)

Journal Writing

A few suggestions for discussion regarding obesity, trans fats, and the health of Canadians are provided below:

- How does the manufacturing industry use trans fats to sell products?
- How serious is the consumption of these fats today?
- Do we have a problem with obesity?
- Is there a solution to obesity?
- What effect will obesity have on future generations?

Ask students to reflect on or present opinions about these questions in their journals. If students are especially interested in this topic, give them an opportunity to use a decision-making process to decide what might be done to reduce the impact of obesity on future generations.

Paper-and-Pencil Tasks

Students should be able to show how the conversion of an alkane to an alkene produces an unsaturated compound.

Any assessment that results from the discussion of trans fats and related topics will depend on the teacher and the amount of time taken with the discussion.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

C11-0-D4: Recommend an alternative or identify a position and provide justification.

C11-0-D5: Propose a course of action related to an STSE issue.

LEARNING RESOURCES LINKS

Chemistry (Chang 980)

Chemistry (Zumdahl and Zumdahl 1044)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 623)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 613)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 710)

Introductory Chemistry: A Foundation (Zumdahl 577)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 331)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 544)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 538)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 11)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 188)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 817)

SPECIFIC LEARNING OUTCOME

C11-5-11: Outline the transformation of alkenes to alkynes and vice versa.

Include: dehydrogenation/hydrogenation, molecular models

(0.5 hour)

SLO: C11-5-11

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students are now familiar with the structure of alkanes and alkenes, as well as the transformation processes of dehydrogenation and hydrogenation. They should also be familiar with the arrangement of electrons around the carbon atom in single and double bonds.

Students may remember nitrogen from Grade 10 Science, where they encountered the sharing of electrons within the nitrogen diatomic molecule to establish a stable octet of electrons for each nitrogen atom.

$$:N:::N:$$

It should not be much of a surprise that triple bonds also occur in organic compounds.

TEACHER NOTES

The following information is meant as background for teachers; however, teachers may wish to provide students with some of this historical information.

The manufacture of the first member of this new homologous series of hydrocarbons, *acetylene*, is very important to manufacturing and construction due to the use of this gas in the process of oxy-acetylene welding. Enormous quantities of this gas are consumed each year.

Acetylene gas is derived from pressurized tanks of acetone. It is sold as a fuel for welding. It is also the organic starting material for the large-scale synthesis of a number of important organic compounds, including acetic acid, and a number of unsaturated compounds that are used in the manufacture of plastics and synthetic rubber.

General Learning Outcome Connections

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

GLO E3: Recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

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Although acetylene was discovered by Edmund Davy in 1836, and much of the research was accomplished by Marcelin Berthelot, it was not until the French chemist Ferdinand Frederick Henri Moissan invented the electric furnace and was able to produce calcium carbide on a large scale that acetylene could become an important industrial chemical. Many of the synthetic uses of acetylene resulted from the work done in Germany before, during, and after the Second World War by W. Reppe. Research with this compound was accelerated by the lack of crude petroleum resources in Germany. The hope was that this compound might replace petroleum as a fuel. Much of the research that was done revolutionized the industrial chemistry of acetylene.

Demonstration

Perform an "underwater fireworks" demonstration. In this demonstration, chlorine gas is bubbled into a graduated cylinder in which acetylene gas is also being generated. When the bubbles interact, the gases ignite, with sparkling results. For the complete procedure, see Appendix 5.1: Underwater Fireworks.

TEACHER NOTES

The manufacture of acetylene can be accomplished by the reaction of water on calcium carbide, CaC_2. This compound is manufactured by the simple reaction of calcium oxide and coal under high temperatures. An alternative synthesis is based on the high temperature partial oxidation of methane.

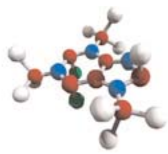
$$6CH_4 + O_2 \xrightarrow{1500°C} 2HC \equiv CH + 2CO + 4H_2$$

Teachers will remember that, similar to the preparation of higher alkenes, higher alkynes are manufactured by the dehydrohalogenation of alkyl halides.

The reverse process is much less complex. An alkyne can readily be transformed into an alkane.

$$-C \equiv C- \xrightarrow[\text{Ni, Pt, or Pd}]{2H_2} \begin{array}{c} H \quad H \\ | \quad\;\; | \\ -C-C- \\ | \quad\;\; | \\ H \quad H \end{array}$$

Hydrogenation under different conditions produces an alkene; however, two forms of the alkene are produced, the *cis* and the *trans* forms.



SPECIFIC LEARNING OUTCOME

C11-5-11: Outline the transformation of alkenes to alkynes and vice versa.

Include: dehydrogenation/hydrogenation, molecular models

(continued)

SUGGESTIONS FOR ASSESSMENT

Students should gain an appreciation for the complexity of organic compounds and their reactions, but are not expected to memorize the transformations.

Any assessment that results from the discussion of the historical development of the alkynes and related topics will depend on the teacher and the amount of time taken with the discussion.

LEARNING RESOURCES LINKS

Chemistry (Chang 989)

Chemistry (Zumdahl and Zumdahl 1055)

Chemistry: The Central Science (Brown, *et al.* 997)

Introductory Chemistry: A Foundation (Zumdahl 592)

SKILLS AND ATTITUDES OUTCOMES

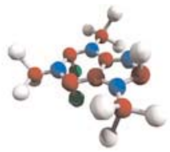
C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

NOTES



SPECIFIC LEARNING OUTCOME

C11-5-12: Name, draw, and construct structural models of alkynes and branched alkynes.

Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula C_nH_{2n-2}

(1.5 hours)

SLO: C11-5-12

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students were introduced to alkynes in learning outcome C11-5-04 where a brief comparison was made to identify differences in structure and relative physical properties. Students have also drawn members of the homologous series of both alkanes and alkenes, as well as branched structures and isomers. They should also understand the differences among molecular formulas, structural formulas, and condensed structural formulas.

TEACHER NOTES

Point out to students that the first member of the *alkyne* series must be a two-carbon molecule, namely ethyne, commonly known as acetylene.

With a general formula of C_nH_{2n-2}, students should realize that the number of hydrogen atoms will be two *less* than that observed for an alkene. In addition, every member of this series will contain a triple bond. Students should first draw structural formulas so they can more easily see an octet for each atom of carbon. The triple bond also reduces the number of hydrogen atoms associated with the carbon atoms connected to the double bond. Students should use the atomic model kits again to create examples of molecules for this learning outcome.

As students draw and construct ethyne, propyne, and so on, they will appreciate the structure of the compounds and the position of the hydrogen atoms around the molecule. When students progress in the series to butyne, they will realize that butane has two different isomers, having different names.

Students should be able to name alkynes up to and including six-carbon parent chains: ethyne, propyne, butyne, pentyne, and hexyne.

Students have already had experience with branching alkanes and alkenes and so the replacement of a triple bond for the double bond should not present difficulty, provided they have carefully learned the system of naming up to this point.

General Learning Outcome Connections

GLO D1: Understand essential life structures and processes pertaining to a wide variety of organisms, including humans.

GLO E2: Describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

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Note that mixed double- and triple-bond compounds should not be introduced, nor should the concepts of dienes, trienes, diynes, and triynes.

Examples:

The following examples illustrate the naming of branched alkynes.

$$\begin{array}{lll} & CH_3 & \\ & | & \\ CH_3 & C-C \equiv CH & \qquad (C_6H_{10}) \\ & | & \\ & CH_3 & \qquad \text{3,3–dimethyl–1–butyne} \end{array}$$

$$\begin{array}{lll} CH_3CHC \equiv CCHCH_3 & & \\ \quad | \qquad\qquad | & & \\ CH_3CH_2 \quad\; CH_3 & & \qquad (C_9H_{16}) \end{array}$$

This example is using a clever technique, as the longest parent chain is 7, making the correct name:

2,5–dimethyl–3–heptyne

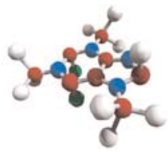
Remind students that in 3-D space, molecules look quite different. This presents a further argument for having students use molecular models to appreciate the 3-D configuration of branched organic molecules.

SUGGESTIONS FOR ASSESSMENT

Teachers who have taken organic chemistry understand how complex the naming of organic compounds can easily become. Try to make the learning experiences related to this brief introduction to organic chemistry as positive as possible. Students who demonstrate a particular interest in organic chemistry may wish to increase the scope of the challenge by naming and/or drawing more complex structures. However, these extensions should be clearly identified as being optional, for enriched learning, and perhaps useful for those planning advanced study options.

Paper-and-Pencil Tasks

Students should be able to provide the correct names for various alkynes and branched alkynes when given the condensed structural formulas. Conversely, they should be able to draw a molecule from its name.



SPECIFIC LEARNING OUTCOME

C11-5-12: Name, draw, and construct structural models of alkynes and branched alkynes.

Include: six-carbon parent chain, methyl and ethyl substituent groups, IUPAC nomenclature, structural formulas, condensed structural formulas, molecular formulas, general formula C_nH_{2n-2}

(continued)

Laboratory Test

If atomic model sets are available, have students review the homologous series of hydrocarbons that have been studied so far by giving them a lab test. Arrange various molecules around the lab and give students a short period of time to identify the structure and write the correct name for a molecule before moving to the next molecule.

Journal Writing

Have students write journal entries about their impressions of organic chemistry. They may also want to comment on the number of compounds.

LEARNING RESOURCES LINKS

Chemistry (Chang 991)

Chemistry (Zumdahl and Zumdahl 1054)

Chemistry: The Central Science (Brown, *et al.* 996)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 325)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 621)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 711)

Introductory Chemistry: A Foundation (Zumdahl 590)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 354)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 560)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 543)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 16)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 184)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 825)

SKILLS AND ATTITUDES OUTCOMES

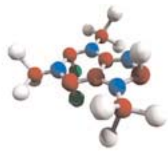
C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

NOTES



SPECIFIC LEARNING OUTCOME

C11-5-13: Compare and contrast the structure of aromatic and aliphatic hydrocarbons.

Include: molecular models, condensed structural formulas

(0.5 hour)

SLO: C11-5-13

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Other than knowing the non-organic meaning of aromatic, students will have no prior knowledge of aromatic hydrocarbons. Some students will know that an aromatic substance produces a strong odour. In fact, it was this description that originally set aromatics apart from their aliphatic relatives.

TEACHER NOTES

The name *aromatic* originated from the pleasant odour of many naturally occurring compounds. Benzene and its derivatives were produced from a number of odorous aromatic balsams and resins. The name *aliphatic* originally applied to substances derived from fatty acid sources, hence the name (Greek *aleiphatos*, fat). These names provide the basis for nomenclature of the two branches of organic chemistry: *aliphatic* and *aromatic*. Aromatics are associated with benzene and its derivatives, whereas aliphatics are essentially straight-chain compounds, with the exception of some cyclic-aliphatics, such as cyclopropane and cyclopentane.

Aliphatic and aromatic compounds are similar in that they are hydrocarbon compounds containing hydrogen atoms attached to carbon atoms and maintain the stable octet electronic structure for carbon. Both groups of compounds are generally flammable, having relatively low boiling points.

However, the unsaturated benzene compounds, besides having a different structure, do not react the same as aliphatic olefin compounds.

There are a multitude of references to the fascinating "story" of how the cyclic structure of compounds such as benzene was determined. Pursue this historical vignette with students.

General Learning Outcome Connections

GLO A2: Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

GLO A4: Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

GLO B1: Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

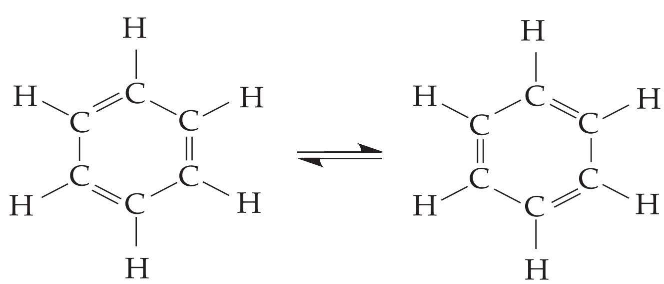
Include: print and electronic sources, specialists, other resource people

Historical Background

The discovery of benzene and its structure was both an interesting and a significant milestone in organic chemistry. Michael Faraday first isolated this remarkable substance in 1825. He discovered the compound in the oily condensate that collected in the illuminating gas lines of London, England. Faraday established its empirical formula as CH and called it *carburetted hydrogen*. The actual molecular formula of C_6H_6 was determined by Eilhard Mitscherlich in 1834 by heating gum benzoin with lime. The structural formula of this compound presented a much greater challenge than that of other organic compounds. Its molecular formula suggested it was unsaturated; however, it did not react like other unsaturated hydrocarbons. In fact, it was remarkably stable.

It was not until 1865 that the German chemist Friedrich August Kekulé von Stradonitz (usually known to us simply as Kekulé) proposed a structure for benzene that explained its chemical behaviour. He proposed a cyclic hexagonal structure of six-carbon atoms with alternate double and single bonds. Each carbon atom was bonded to only one hydrogen atom.

After further experimentation by other scientists, Kekulé modified his structure to reflect the additional information. In the diagrams below, the double bond is between carbons 2 and 3. Kekulé proposed that the double bonds oscillate or resonate between carbon atoms 2 and 1. Similarly, the other double bonds would resonate between the other carbon atoms, as illustrated.



Kekulé Structure

These two energetically equal structures are called *resonance hybrids*. The actual structure is believed to be somewhere between these two structures.

SPECIFIC LEARNING OUTCOME

C11-5-13: Compare and contrast the structure of aromatic and aliphatic hydrocarbons.

Include: molecular models, condensed structural formulas

(continued)

For additional information, see the following websites:

Doc Brown’s Chemistry Clinic:
<http://www.wpbschoolhouse.btinternet.co.uk/page06/FunctionalGroups.htm>

Rod Beavon. F A Kekulé von Stradonitz:
<http://www.rod.beavon.clara.net/kekule.htm>

SUGGESTIONS FOR ASSESSMENT

Research Reports

If sufficient time is available, have students research and report on the work done by Kekulé and others to determine the structure of benzene. The information collected could be presented as

- written reports
- oral presentations
- bulletin board displays

Visual Displays

Students could present the material they have collected using

- posters
- pamphlets
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students prior to the assignment. Samples of presentation rubrics are provided in Appendix 10 of this document.

Journal Writing

Have students comment on the structure of benzene that Kekulé proposed.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

LEARNING RESOURCES LINKS

Chemistry (Chang 993)

Chemistry (Zumdahl and Zumdahl 1055)

Chemistry: The Central Science (Brown, *et al.* 1000)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 636)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 622)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 722)

Introductory Chemistry: A Foundation (Zumdahl 592)

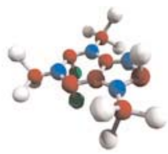
McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 357)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 561)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 508)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 19)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 824)



SPECIFIC LEARNING OUTCOME

C11-5-14: Describe uses of aromatic hydrocarbons.

Examples: polychlorinated biphenyls, caffeine, steroids, organic solvents (toluene, xylene)…

(1.0 hour)

SLO: C11-5-14

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students would likely have no previous knowledge of the uses of benzene.

TEACHER NOTES

The discovery of benzene and its unique structure and properties spawned a new industry solely focused on the manufacture of benzene and its derivatives. As students research this topic using the Internet, or print resources provided by the teacher, they will quickly appreciate the toxicity of most aromatic derivatives of benzene. Even though such compounds have high toxicity, they are essential to the manufacture of nylon and plastic products upon which we rely so much.

It is of interest that Michael Faraday—more widely known for his contributions to electromagnetism—first isolated benzene in 1825 by compressing oil gas, the lightest fraction of hydrocarbons produced by the distillation of coal tar. This was well ahead of any attempts to understand the molecular characteristics of benzene.

STSE Issues

Many STSE issues could be included in class discussion of benzene and its derivatives. Questions such as the following could be used to initiate discussion regarding the use and disposal of aromatic hydrocarbons:

- How toxic are benzene and its derivatives?
- How important are plastics and synthetic rubber products in our lives?
- How necessary are these products?
- How necessary are these toxic solvents to the manufacture of plastics and synthetic rubber products?
- Where are the majority of these products manufactured?

General Learning Outcome Connections

GLO A5: Recognize that science and technology interact with and advance one another.

GLO B3: Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

GLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

GLO E2: Describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

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- What is the primary workforce that is employed in the manufacture of plastic products?
- What safety precautions are necessary for the safety of the workers in this industry?
- How are anabolic steroids used by society?
- What adverse effects are known for caffeine?
- Is caffeine addictive?
- How are polychlorinated biphenyls (PCBs) used today?
- What safety precautions are in place to dispose of PCBs?
- Where are toxic wastes stored in Canada?
- Where are toxic wastes stored in Manitoba?

Online Research

The actual physical structures for the aromatic hydrocarbon compounds suggested in this learning outcome (e.g., caffeine) are not given here, as they are readily available from most texts and from online sources.

What follows are some suggested starting points for online research.

Connecticut Department of Environmental Protection. PCBs:
<http://dep.state.ct.us/wst/pcb/pcbindex.htm>

This website provides information on the history of the uses of polychlorinated biphenyls.

eMedicine (from WebMD). Toxicity, Toluene:
<http://www.emedicine.com/emerg/topic594.htm>

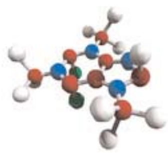
Toluene is a widely used solvent, but poses significant risks to human health, upon exposure. This website provides an abundance of detail, and includes information related to health chemistry or human biology contexts.

Greener Industry: <http://www.greener-industry.org/>

This UK website highlights many of the current industrial uses of benzene, including world production statistics. “Mouse over” the links to “benzene” for many detailed web pages.

Iowa Health System (HIS). Drug: Anabolic Steroids:
<http://www.ihs.org/body.cfm?id=580>

This is a brief fact sheet on the uses (and street terminologies) associated with teen use of anabolic steroids.



SPECIFIC LEARNING OUTCOME

C11-5-14: Describe uses of aromatic hydrocarbons.

Examples: polychlorinated biphenyls, caffeine, steroids, organic solvents (toluene, xylene)…

(continued)

Material Safety Data Sheet (MSDS). Toluene:
<http://www.jtbaker.com/msds/englishhtml/t3913.htm>

Teachers may wish to bookmark this website for further reference to other MSDS information.

U.S. Environmental Protection Agency. Software for Environmental Awareness:
<http://www.epa.gov/seahome/hwaste.html>

This website offers teachers and students the opportunity to run simulations using free-use software provided by EPA. It can be used to simulate how to control hazardous wastes around the home.

Virginia Commonwealth University. Steroids—Introduction:
<http://www.people.vcu.edu/~urdesai/intro.htm#Structure>

This website addresses, in a rather sophisticated manner, the structural chemistry of various steroid molecules (e.g., progesterone, testosterone, cholesterol).

Webshells.com. Oil, Chemical and Atomic Workers Union (OCAW). Benzene:
<http://www.webshells.com/ocaw/txts/doc999994.htm>

This website addresses the human health risks associated with the use of benzene. It contains a short essay on benzene—what it is, its uses, and its associated hazards.

The WELL. Web of Addictions. Steroids:
<http://www.well.com/user/woa/fsroids.htm>

This is a fact sheet on the treatment of steroids by the Missouri Department of Mental Health, Division of Alcohol and Drug Abuse.

York University. The Chemistry Hall of Fame. Benzene: The Parent Aromatic Compound:
<http://www.chem.yorku.ca/hall_of_fame/essays97/benzene/benzene.htm>

This essay is a contribution to an award-winning secondary-level student essay contest.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

SUGGESTIONS FOR ASSESSMENT

Research Reports

Have students conduct research and report their findings either individually or in small groups. The information collected could be presented as

- written reports
- oral presentations
- bulletin boards
- multimedia

Visual Displays

Students could present the material they have collected using

- posters
- pamphlets
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students prior to the assignment. Samples of presentation rubrics are provided in Appendix 10 of this document.

Discussion Formats

Several optional formats could be used to discuss issues related to the use and disposal of aromatic hydrocarbons:

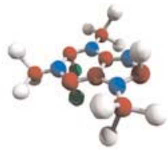
- town hall meeting
- courtroom arguments over a lawsuit
- public inquiry into pollution issues caused by a local industry

Journal Writing

Many controversial issues are related to this learning outcome, so it should not be difficult to encourage students to write a journal entry.

Paper-and-Pencil Tasks

This learning outcome serves as a focus for student concern for the environment and the issues regarding the use and disposal of toxic materials. Ask students for opinions, suggestions, and decisions. The structure of these compounds should not be emphasized.



SPECIFIC LEARNING OUTCOME

C11-5-14: Describe uses of aromatic hydrocarbons.

Examples: polychlorinated biphenyls, caffeine, steroids, organic solvents (toluene, xylene)…

(continued)

Did You Know?

In the storyline of *Sahara*, an action/adventure movie based on a novel by Clive Cussler, toxic waste has begun to pollute the waters of the Niger River in Africa, and the heroes in the film are the antagonists of the polluters.

LEARNING RESOURCES LINKS

Chemistry (Chang 502—toluene)

Chemistry: The Central Science (Brown, *et al.* 437—toluene, 519—caffeine)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 686—steroids)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 566, 591—PCBs, 622—toluene)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 787)

Introductory Chemistry: A Foundation (Zumdahl 642—steroids)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 356—steroids)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 561—steroids)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 19—toluene, 32—PCBs, 54—steroids, 80—caffeine)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 214)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 880)

SKILLS AND ATTITUDES OUTCOMES

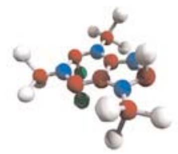
C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

NOTES



SPECIFIC LEARNING OUTCOMES

C11-5-15: Write condensed structural formulas for and name common alcohols.
Include: maximum of six-carbon parent chain, IUPAC nomenclature

C11-5-16: Describe uses of methyl, ethyl, and isopropyl alcohols.

(0.5 hour)

SLO: C11-5-15
SLO: C11-5-16

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students should, by this point, know the names of methanol, ethanol, and isopropyl alcohols. They may also know other names for these alcohols and some information about the fermentation process for the production of ethyl alcohol.

Students are already aware of the uses of numerical and Greek prefixes for chain length when naming organic compounds.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

Students should know the common, the derived, and the IUPAC names for methanol, ethanol, and isopropyl alcohol.

R — OH	general case, where R is any parent chain
CH_3OH	methanol, methyl alcohol, wood alcohol
CH_3CH_2OH	ethanol, ethyl alcohol, grain alcohol
$\begin{array}{l} CH_3CHOH \\ \quad\quad \vert \\ \quad\ CH_3 \end{array}$	2–propanol, isopropyl alcohol, rubbing alcohol

General Learning Outcome Connections

GLO B1: Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

GLO B3: Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

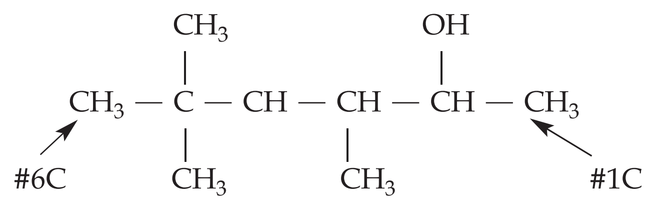
C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.
Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

C11-0-C1: Collaborate with others to achieve group goals and responsibilities.

Inform students of the uses of these alcohols as well. Students should gain familiarity with other alcohol compounds up to and including hexanol. At this level of study, it is preferred that teachers limit the number of side chains and give examples of single alcohol units only (i.e., no diols).

Several examples are provided below for information. Tell students that the alcohol or hydroxyl radical –OH takes precedence over numbering. The following molecule is numbered to make the carbon atom to which the –OH is attached the smallest.



3, 5, 5–trimethyl–2–hexanol

Students will need use this knowledge in the study and preparation of esters (learning outcomes C11-5-19 to C11-5-21). Rather than placing the emphasis on drawing structural diagrams of alcohol compounds, concentrate primarily on nomenclature, characteristics, and applications of certain alcohols.

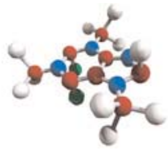
SUGGESTIONS FOR ASSESSMENT

Research Reports

Teachers may wish to have students research information about the various common alcohols or the production of alcohols. Students have not yet encountered the fermentation process in the production of ethanol. Have students research and report their findings individually or in small groups.

The information collected could be presented as

- written reports
- oral presentations
- bulletin board displays
- multimedia presentations



SPECIFIC LEARNING OUTCOMES

C11-5-15: Write condensed structural formulas for and name common alcohols.

Include: maximum of six-carbon parent chain, IUPAC nomenclature

C11-5-16: Describe uses of methyl, ethyl, and isopropyl alcohols.

(continued)

Visual Displays

Students could present the material they have collected using

- posters
- pamphlets
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students prior to the assignment. Samples of presentation rubrics are provided in Appendix 10 of this document.

Laboratory Reports

The lab activities for this learning outcome could be assessed as formal lab reports using the Laboratory Report Outline or the Laboratory Report Format (see *SYSTH* 11.38, 14.12) or by using questions and answers from the data collected from the activities.

Journal Writing

Teachers may want students to write journal entries regarding alcohols.

Paper-and-Pencil Tasks

Students should write names for and draw condensed structural formulas for six-carbon parent chain alcohols.

LEARNING RESOURCES LINKS

Chemistry (Chang 996)

Chemistry (Zumdahl and Zumdahl 1058)

Chemistry: The Central Science (Brown, *et al.* 1003)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 628)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 743)

Introductory Chemistry: A Foundation (Zumdahl 598)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 38)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 204)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 841)

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

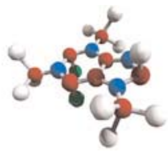
Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

C11-0-C1: Collaborate with others to achieve group goals and responsibilities.

NOTES



SPECIFIC LEARNING OUTCOMES

C11-5-17: Write condensed structural formulas for and name organic acids.
Include: maximum of six-carbon parent chain, IUPAC nomenclature

C11-5-18: Describe uses or functions of common organic acids.
Examples: acetic, ascorbic, citric, formic, acetylsalicylic (ASA), lactic…

(0.5 hour)

SLO: C11-5-17
SLO: C11-5-18

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students will not know the formula of organic acids but they will certainly recognize vinegar or acetic acid if they have ever eaten fish and chips.

TEACHER NOTES

Provide students with the general formula for organic acids. This will help them understand the reaction between organic acids and alcohols to form esters, which will be addressed in the next series of learning outcomes.

Organic acids can be represented by a general formula:

$$\begin{array}{c} \text{O} \\ \| \\ \text{R} — \text{C} — \text{OH} \end{array}$$

In biology this would most likely be written as RCOOH where R represents any hydrocarbon, not unlike algebra where *x* can represent any integer.

The functional group $\begin{array}{c} \text{O} \\ \| \\ — \text{C} — \text{OH} \end{array}$ or — COOH is known as the carboxyl group.

The simplest organic acid or carboxylic acid contains 1C:

methanoic acid	$HCOOH$	formic acid
ethanoic acid	CH_3COOH	acetic acid
propanoic acid	CH_3CH_2COOH	
butanoic acid	$CH_3CH_2CH_2COOH$	

General Learning Outcome Connections

GLO B3: Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

Students can easily see that the root word has not changed but the suffix has become *oic* once the "e" has been dropped from methane, ethane, propane, and butane.

Compounds for which the functional group is located in positions other than in the "n" (or normal) position are not included in Grade 11 Chemistry.

Teachers have the option of giving students the condensed structural formulas for the carboxylic acid derivatives suggested in the examples (ascorbic, lactic, etc.) for learning outcome C11-5-18, but should not expect students to memorize these formulas.

Formic acid is found in the nervous system of most species of ants (hence the name *antacid*). Teachers have the choice of providing students with the uses or functions of these acids or having students find the information themselves, using their chemistry text or some other resource. The examples specified in the learning outcome are only suggestions and so other examples could be used.

Model-Building Activity

Atomic models could be used to help students gain an appreciation for the 3-D structure of the carboxylic acids, as well as for the other families of organic compounds.

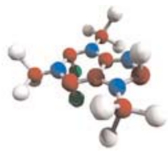
SUGGESTIONS FOR ASSESSMENT

Because both alcohols and carboxylic acids are the reactants for the production of esters, it is important that students understand these compounds so they can more clearly understand the ester lab activity suggested for learning outcomes C11-5-19 to C11-5-21.

Paper-and-Pencil Tasks

Remind students that the carbon atom (C) in COOH is counted as *one of the parent chain C atoms*. When providing student learning activities, combine both acids and alcohols, and reverse the lettering direction of the alcohol and/or the carboxylic acid as follows:

$HOCH_2CH_2CH_3$ as 1–propanol or n–propanol



SPECIFIC LEARNING OUTCOMES

C11-5-17: Write condensed structural formulas for and name organic acids.

Include: maximum of six-carbon parent chain, IUPAC nomenclature

C11-5-18: Describe uses or functions of common organic acids.

Examples: acetic, ascorbic, citric, formic, acetylsalicylic (ASA), lactic…

(continued)

LEARNING RESOURCES LINKS

Chemistry (Chang 999)

Chemistry (Zumdahl and Zumdahl 1061)

Chemistry: The Central Science (Brown, *et al.* 1005)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 642)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 636)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 749)

Introductory Chemistry: A Foundation (Zumdahl 605)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 405)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 58)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 218)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 852)

SKILLS AND ATTITUDES OUTCOMES

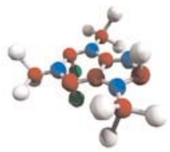
C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

NOTES



SPECIFIC LEARNING OUTCOMES

C11-5-19: Perform a lab involving the formation of esters, and examine the process of esterification.

C11-5-20: Write condensed structural formulas for and name esters.
Include: up to 6-C alcohols and 6-C organic acids, IUPAC nomenclature

C11-5-21: Describe uses of common esters.
Examples: pheromones, artificial flavourings…

(2.0 hours)

SLO: C11-5-19
SLO: C11-5-20
SLO: C11-5-21

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students will have no previous knowledge of or experience with the preparation of esters.

TEACHER NOTES

A lab procedure for the preparation of esters can be found in Appendix 5.2: Preparation of Esters. The odour from this lab can be irritating; however, the Material Safety Data Sheets for the esters produced do not indicate any adverse effects from the vapours of the resulting ester compounds. Nevertheless, if the lab has a poor circulation system, the lab activity should be performed in a fume hood. Alternatively, the activity could be done on warm days when classroom windows can be opened to ensure adequate ventilation.

The reaction, even with the catalyst concentrated sulphuric acid, is still slow. The addition of an excess amount of alcohol will usually force the equilibrium in the direction of the *products*, resulting in a slightly better yield for the ester. Instruct students to "waft" the odour toward them in the classical way to dilute the substance with air. Teachers who have done this lab activity know that the odours are not very distinct. Esters that can usually be identified include wintergreen and methyl salicylate. As the esters are oily and their densities are less than the density of water, they can be carefully poured into cold water in an evaporating dish to appreciate the odour better.

General Learning Outcome Connections

GLO C2: Demonstrate appropriate scientific inquiry skills when seeking answers to questions.
GLO C3: Demonstrate appropriate problem-solving skills when seeking solutions to technological challenges.
GLO C7: Work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities.
GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.
GLO D6: Understand the composition of the universe, the interactions within it, and the implications of humankind's continued attempts to understand and explore it.
GLO E1: Describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

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Teachers will not want to use all the reactions, as the lab room would become so filled with the various odours that it would be very difficult, if not impossible, to identify any clear differences in the odours. Students generally say that the esters produced all smell the same. Teachers may wish to use different compounds each year until the results are satisfactory. Since only small amounts of each substance are used in the lab procedure, the acids and alcohols could be shared among schools, with obvious economic merit.

Laboratory Activities

1. The lab procedure described in Appendix 5.2: Preparation of Esters provides some of the more complex structures. Ensure that students complete the formulas contained in this activity prior to the lab. Encourage students to read the lab procedure very carefully, and consider any safety precautions. The hot water bath required to compete the reaction must be prepared before students begin to use flammable alcohols. Very hot water from the tap will often be satisfactory as a temperature bath.

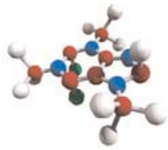
2. A classroom-based organic molecule model-building activity can be used for review and reinforcement. For a sample procedure, see Appendix 5.3: Organic Model-Building Presentation.

TEACHER NOTES

The acidified reaction of an alcohol with a carboxylic acid to produce an ester is generally known as *Fischer esterification*. The reactions are reversible. At equilibrium, an appreciable amount of unreacted acid and alcohol may be present, producing a relatively large K_{eq}. Considering Le Châtelier's Principle, the equilibrium should be shifted to the right to produce more esters. In the Senior Years lab this can be accomplished by adding an excess of organic acid.

Investigations using primary alcohols containing isotopic oxygen–18 (O^{18}) in the hydroxyl group have shown that the radioactive oxygen from the alcohols becomes part of the ester and not the water in the products. This is an interesting use of a radioactive tracer to follow the course of a reaction.

$$\underset{\text{methyl alcohol}}{CH_3O^{18}}\boxed{H + HO}\underset{\text{ethanoic acid / acetic acid}}{\overset{\overset{O}{||}}{C}CH_3} \xrightleftharpoons{\quad H \quad} \underset{\text{methyl ethanoate / methyl acetate}}{CH_3O^{18}\overset{\overset{O}{||}}{C}CH_3} + \boxed{H_2O}$$



SPECIFIC LEARNING OUTCOMES

C11-5-19: Perform a lab involving the formation of esters, and examine the process of esterification.

C11-5-20: Write condensed structural formulas for and name esters.
Include: up to 6-C alcohols and 6-C organic acids, IUPAC nomenclature

C11-5-21: Describe uses of common esters.
Examples: pheromones, artificial flavourings…

(continued)

Formula of Esters

The reactions for the lab experiment have already exposed students to the formula of esters. The esterification reactions also illustrate to students how the pieces are put together to form an ester. Provide students with the general formula for esters:

$$\begin{array}{c} \mathrm{O} \\ || \\ \mathrm{R^1OCR} \end{array} \qquad \text{where R and } R^1 \text{ can be any alkyl or aryl group}$$

Uses of Esters

In addition to having flavour-enhancing properties, many esters are pheromones. A *pheromone* is a chemical substance that transmits information from one member of a species to another. In the case of insects, a virtual language exits between family members. Specific pheromones have been detected and analyzed. These pheromones may be used for diverse purposes such as marking a trail, warning of danger, attracting the opposite sex, or calling an assembly. The ester isopentyl acetate happens to be the alarm pheromone for the honeybee. Students will remember its characteristic odour resembling bananas when prepared in the lab. A more complete discussion can be found in Appendix 5.4: Esters: Flavours and Fragrances.

TEACHER NOTES

Inform students that, although the IUPAC naming system has been stressed, the conventions for naming esters often involve the common *names of both the alcohol and the carboxylic acid*. Alternate names are provided in the Sample Esters chart that follows.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

Sample Esters

Alcohol	Carboxylic Acid	Ester	Odour
ethyl $CH_3CH_2\boxed{OH \qquad HO}-\overset{O}{\overset{\|}{C}}CH_2CH_2CH_3$	butanoic butyric	ethyl butanoate ethyl butyrate $CH_3CH_2O\overset{O}{\overset{\|}{C}}CH_2CH_2CH_3$	pineapple
Note that if the alcohol and acid are removed together and the water is removed as shown, the structure becomes the ester of the alcohol and acid. The oxygen in the ester comes from the alcohol.			
isopentyl (isoamyl) 3–methyl–1–butanol $CH_3\overset{CH_3}{\overset{\|}{C}}HCH_2CH_2\boxed{OH \qquad HO}\overset{O}{\overset{\|}{C}}CH_3$	acetic ethanoic	isopentyl acetate $CH_3\overset{CH_3}{\overset{\|}{C}}HCH_2CH_2O\overset{O}{\overset{\|}{C}}CH_3$	banana
isobytyl 2–methyl–1–propanol $CH_3\overset{CH_3}{\overset{\|}{C}}HCH_2\boxed{OH \qquad HO}\overset{O}{\overset{\|}{C}}CH_2CH_3$	propionic propanoic	isobutyl propionate isobutyl propanoate $CH_3\overset{CH_3}{\overset{\|}{C}}HCH_2O\overset{O}{\overset{\|}{C}}CH_2CH_3$	rum
n–octyl 1–octanol $CH_3(CH_2)_6CH_2\boxed{OH \qquad HO}\overset{O}{\overset{\|}{C}}CH_3$	acetic ethanoic	octyl acetate $CH_3(CH_2)_6CH_2O\overset{O}{\overset{\|}{C}}CH_3$	orange
methyl methanol $CH_3\boxed{OH \qquad HO}\overset{O}{\overset{\|}{C}}CH_2CH_2CH_3$	butanoic butyric	methyl butanoate methyl butyrate $CH_3O\overset{O}{\overset{\|}{C}}CH_2CH_2CH_3$	apple

SPECIFIC LEARNING OUTCOMES

C11-5-19: Perform a lab involving the formation of esters, and examine the process of esterification.

C11-5-20: Write condensed structural formulas for and name esters.
Include: up to 6-C alcohols and 6-C organic acids, IUPAC nomenclature

C11-5-21: Describe uses of common esters
Examples: pheromones, artificial flavourings…

(continued)

SUGGESTIONS FOR ASSESSMENT

By the end of learning outcomes C11-5-19 to C11-5-21, students should know that an ester can be prepared by the acidified reaction of an alcohol with a carboxylic acid in a process called esterification. They should be able to write the reaction for the formation of an ester, when given the names of the alcohol and the carboxylic acid, and they should be able to write the correct condensed structural formula for the ester and provide its correct name.

Paper-and-Pencil Tasks

The material presented in these learning outcomes could be assessed using an activity that begins with a question, complete with reactants, products, and all correct names and formulas. As the activity progresses, omit more and more information from the questions. By the last few questions, provide only the names of the reactants. A progressive exercise such as this enables students to develop their skill and knowledge of the material gradually.

Laboratory Reports

The lab activities for these learning outcomes could be assessed as formal lab reports using the Laboratory Report Outline or the Laboratory Report Format (see *SYSTH* 11.38, 14.12) or by using questions and answers from the data collected from the activities.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.

Include: print and electronic sources, specialists, other resource people

LEARNING RESOURCES LINKS

Chemistry (Chang 1000)

Chemistry (Zumdahl and Zumdahl 1061)

Chemistry: The Central Science (Brown, *et al.* 1007)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 643, plus ester lab)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 637)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 750)

Introductory Chemistry: A Foundation (Zumdahl 605)

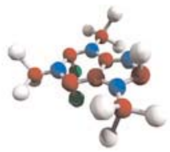
McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 410, plus ester lab)

Microscale Chemistry Laboratory Manual (Slater and Rayner-Canham 82—ester lab)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 65)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 223, plus ester lab)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 855, plus ester lab)



SPECIFIC LEARNING OUTCOMES

C11-5-22: Describe the process of polymerization and identify important natural and synthetic polymers.

Examples: polyethylene, polypropylene, polystyrene, polytetrafluoroethylene (Teflon®)…

C11-5-23: Describe how the products of organic chemistry have influenced quality of life.

Examples: synthetic rubber, nylon, medicines, polytetrafluoroethylene (Teflon®)…

(2.0 hours)

SLO: C11-5-22
SLO: C11-5-23

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Most students will have some understanding of polymers. An assessment of students' prior knowledge is a necessary preamble to the discussion of these learning outcomes.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

One of the most important reactions of the alkenes and branched dienes is *polymerization*. When oxygen, heat, and pressure are applied to ethylene, a compound with a molecular weight of 20,000 is produced. This super-molecule is essentially a very long chain alkane. The molecule that starts the addition process is called the *monomer*, in this case, ethylene.

Polymerization usually requires the presence of a small amount of initiator. Among the most common of these initiators are the peroxides. Chemists now know that the function of the peroxide is to produce a free radical. A *free radical* is an atom or group of atoms possessing an odd (unpaired) electron (e.g., CH_4 •). These very

General Learning Outcome Connections

GLO A4: Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

GLO A5: Recognize that science and technology interact with and advance one another.

GLO D4: Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts.

GLO E1: Describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world.

GLO E2: Describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems.

Skills and Attitudes Outcomes

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

C11-0-C1: Collaborate with others to achieve group goals and responsibilities.

C11-0-C3: Evaluate individual and group processes.

C11-0-D1: Identify and explore a current STSE issue.

Examples: clarify what the issue is, identify different viewpoints and/or stakeholders, research existing data/information…

C11-0-D2: Evaluate implications of possible alternatives or positions related to an STSE issue.

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position…

C11-0-D3: Recognize that decisions reflect values and consider their own values and those of others when making a decision.

Examples: being in balance with nature, generating wealth, respecting personal freedom…

C11-0-D4: Recommend an alternative or identify a position and provide justification.

C11-0-D5: Propose a course of action related to an STSE issue.

C11-0-D6: Reflect on the process used by self or others to arrive at an STSE decision.

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reactive, unstable free radicals add to alkenes to form larger alkane free radicals. This chain propagation occurs, forming the polymer. Eventually, two radicals combine and the process terminates.

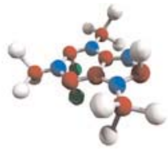
Note that even the smallest impurity in the reaction vessel will initiate chain termination. As a result, the monomers that are used in polymerization are among the purest organic compounds produced. Many polymeric products are tough, flexible, and unreactive to most chemical reagents. Some have a waxy feel and are insoluble in most solvents. Others, with excellent thermal and electric properties, are useful insulating materials.

Chemists divide polymers into several main categories, depending on how they are prepared.

Addition Polymers

Addition polymers are formed by a reaction in which a monomer unit is made to be additive—that is, forming a long-chain polymer. The monomer usually contains a carbon-carbon double bond (e.g., ethylene). Polyethylene, polypropylene, polytetrafluoroethylene (Teflon®), acrylic fibre (Orlon®), and synthetic rubbers are examples of polymeric products formed in this way.

The following sequence of steps demonstrates how these polymers are formed. The sequence presented here is intended for teacher background only.



Specific Learning Outcomes

C11-5-22: Describe the process of polymerization and identify important natural and synthetic polymers.

Examples: polyethylene, polypropylene, polystyrene, polytetrafluoroethylene (Teflon®)…

C11-5-23: Describe how the products of organic chemistry have influenced quality of life.

Examples: synthetic rubber, nylon, medicines, polytetrafluoroethylene (Teflon®)…

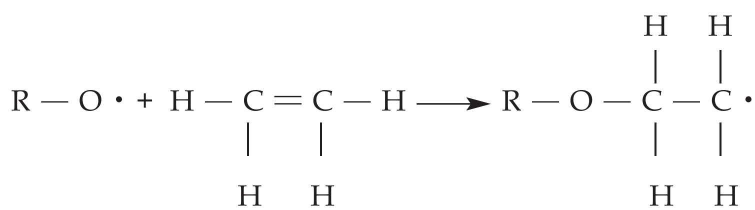
(continued)

A free radical often produced from peroxide, ROOR, combines with an olefin monomer to produce a larger free radical, as shown in the sequence of steps that follow.

Initiation: Free radicals are produced by an initiator.

$$R — O : O — H \longrightarrow 2R — O\cdot$$

These reactive, unstable radicals react with an ethylene molecule to form another larger radical.



ethylene

Propagation: Continued addition of alkene molecules produces still larger radicals.

$$R — O — CH — CH\cdot + n(H_2C = CH_2) \longrightarrow$$
$$R — O — (CH — CH)_n — CH_2 — C\cdot$$

Termination: Two free radicals finally couple up or *disproportionate*.

$$RO(CH — CH)_nCH_2CH_2\cdot + \cdot CH_2CH_2(CH — CH)_mOR^1$$

Option 1: Couple

$$RO(CH_2 — CH_2)_{n+m+2}OR^1$$

Option 2: Disproportionate

$$RO(CH_2 — CH_2)_m — CH = CH + RO(CH_2 — CH_2)_n — CH_2CH_3$$

polyethylene

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

C11-0-C1: Collaborate with others to achieve group goals and responsibilities.

C11-0-C3: Evaluate individual and group processes.

C11-0-D1: Identify and explore a current STSE issue.

Examples: clarify what the issue is, identify different viewpoints and/or stakeholders, research existing data/information…

C11-0-D2: Evaluate implications of possible alternatives or positions related to an STSE issue.

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position…

C11-0-D3: Recognize that decisions reflect values and consider their own values and those of others when making a decision.

Examples: being in balance with nature, generating wealth, respecting personal freedom…

C11-0-D4: Recommend an alternative or identify a position and provide justification.

C11-0-D5: Propose a course of action related to an STSE issue.

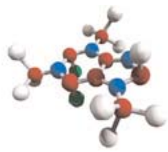
C11-0-D6: Reflect on the process used by self or others to arrive at an STSE decision.

TEACHER NOTES

The following table illustrates various polymers that are produced when the R group is substituted for the specified groups.

Common Addition Polymers

Structure of R	Name of Monomer	Name of Polymer	Use
–H	ethylene	polyethylene	film, conduit piping, rubber-like articles, squeeze bottles
$–CH_3$	propylene	polypropylene	moulded and extruded plastics, film, fibres for garments and carpeting
–Cl	vinyl chloride	polyvinyl chloride	electrical insulation, film, rubber-like articles, synthetic leather, floor covering, raincoats, shower curtains
$–CF_2CF_2$	fluoroethylene	polyfluoroethylene (Teflon®)	heat- and stick-resistant coating that is resistant to high temperatures and inert to almost all solvents and other chemicals
$–O—C(=O)—CH_3$	vinyl acetate	polyvinyl acetate	film, fibres, moulded articles



SPECIFIC LEARNING OUTCOMES

C11-5-22: Describe the process of polymerization and identify important natural and synthetic polymers.

Examples: polyethylene, polypropylene, polystyrene, polytetrafluoroethylene (Teflon®)…

C11-5-23: Describe how the products of organic chemistry have influenced quality of life.

Examples: synthetic rubber, nylon, medicines, polytetrafluoroethylene (Teflon®)…

(continued)

Condensation Polymers

Condensation polymers are formed by reactions of bi- or poly-functional (many-functional) groups, with the elimination of some small molecules such as water, ammonia, or hydrogen chloride. Familiar examples of condensation polymers are nylon, synthetic polyester fibre (Dacron®) and its synthetic film analogue (Mylar®), and polyurethane.

Cross-Linked Polymers

Cross-linked polymers are formed by the linking together of long chains into gigantic 3-D structures with great rigidity. Addition and condensation polymers can exist with cross-linking. Familiar examples of such compounds are phenol formaldehyde resin (Bakelite™), rubber, and fibreglass resins.

Industrialists and technologists often divide polymers into *thermoplastics* and *thermoset plastics*.

Demonstration

A rather unusual polymer can be found in disposable baby diapers. This granular polymer is sodium polyacrylate (Waterloc®). This solid will absorb approximately 100 times its own weight of water.

A number of "magic" tricks can be performed with the sodium polyacrylate substance and a few cardboard cups that are white on the inside.

- Place about 0.25 g of sodium polyacrylate in the bottom of one cup.
- Add a few drops of water to adhere the powder to the bottom of the cup.
- Take a glass of water and play the "shell game" with students, being careful to pour the water into each of the cups except the one with the powder.
- Shuffle the cups, and then have students guess where the water is.
- After several shuffles, pour the water into the cup with the powder in it.
- Wait a few moments and then invert the cup.

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

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Examples: clarify what the issue is, identify different viewpoints and/or stakeholders, research existing data/information…

C11-0-D2: Evaluate implications of possible alternatives or positions related to an STSE issue.

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Examples: being in balance with nature, generating wealth, respecting personal freedom…

C11-0-D4: Recommend an alternative or identify a position and provide justification.

C11-0-D5: Propose a course of action related to an STSE issue.

C11-0-D6: Reflect on the process used by self or others to arrive at an STSE decision.

The sodium polyacrylate will soak up all the water and the cup will appear to be empty. (Teachers will need to practise a few times to get the appropriate amount of water and powder so that all the water is absorbed.)

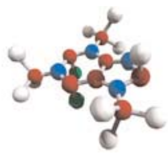
TEACHER NOTES

Learning outcome C11-5-23 asks students to describe how the products of organic chemistry have influenced their lives. This learning outcome is best achieved by drawing on student knowledge of organic substances. After suitable class discussion and class research, ask students to write journal entries. Additional examples from medicine could be addressed, as there are plenty of examples of how organic compounds have advanced this field.

This topic was introduced by asking students how their lives would change if organic materials vanished from the classroom, the home, the hospital, the recreational world around them, and so on. Their responses could now be revisited, with the addition of further information gained from their study of the topic. Students know that organic materials have resulted in remarkable improvements to human progress. But at what expense to the environment? The discussion of this issue should lead students to the next learning outcome, which focuses specifically on STSE issues.

For additional information, see the following article:

Coggan, Jenn. "Organic Molecules of Everyday Life: 1. Citronellal." *CHEM 13 NEWS* 324 (Nov. 2004): 1–2.



SPECIFIC LEARNING OUTCOMES

C11-5-22: Describe the process of polymerization and identify important natural and synthetic polymers.

Examples: polyethylene, polypropylene, polystyrene, polytetrafluoroethylene (Teflon®)…

C11-5-23: Describe how the products of organic chemistry have influenced quality of life.

Examples: synthetic rubber, nylon, medicines, polytetrafluoroethylene (Teflon®)…

(continued)

SUGGESTIONS FOR ASSESSMENT

Assessment of learning outcomes C11-5-22 and C11-5-23 could be accomplished by a number of authentic methods, some of which are described below.

The material addressed in these learning outcomes is relevant to students' lives. Students will have had some experience with almost all the polymers that have been described, whether at home, in school, or in recreational activities.

The products of organic chemistry are remarkable materials that have improved our lifestyle. But at what cost to the environment? These learning outcomes provide students with another opportunity to examine lifestyle vs. STSE issues. Students could consider questions such as the following:

- Do plastic and rubber products decay?
- What is the primary source of garbage on most seashores and lakeshores?
- What percentage of Canadians participate in recycling?
- Should there be a penalty for not recycling?
- Should there be a fee for garbage collection?

The technical information in these learning outcomes could be considered secondary to the discussion of STSE issues and decision making.

Research Reports

Have students conduct research and report their findings either individually or in small groups. The information collected could be presented as

- written reports
- oral presentations
- bulletin board displays
- multimedia presentations

SKILLS AND ATTITUDES OUTCOMES

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

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C11-0-C1: Collaborate with others to achieve group goals and responsibilities.

C11-0-C3: Evaluate individual and group processes.

C11-0-D1: Identify and explore a current STSE issue.

Examples: clarify what the issue is, identify different viewpoints and/or stakeholders, research existing data/information…

C11-0-D2: Evaluate implications of possible alternatives or positions related to an STSE issue.

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position…

C11-0-D3: Recognize that decisions reflect values and consider their own values and those of others when making a decision.

Examples: being in balance with nature, generating wealth, respecting personal freedom…

C11-0-D4: Recommend an alternative or identify a position and provide justification.

C11-0-D5: Propose a course of action related to an STSE issue.

C11-0-D6: Reflect on the process used by self or others to arrive at an STSE decision.

Visual Displays

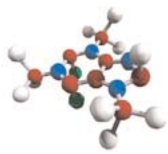
Students could present the material they have collected using

- posters
- pamphlets
- bulletin boards
- models

Each of these presentation styles could be assessed using an appropriate rubric created with students prior to the assignment. Samples of presentation rubrics are provided in Appendix 10 of this document.

Journal Writing

Encourage students to reflect on how polymers have influenced their lives.



SPECIFIC LEARNING OUTCOMES

C11-5-22: Describe the process of polymerization and identify important natural and synthetic polymers.
Examples: polyethylene, polypropylene, polystyrene, polytetrafluoroethylene (Teflon®)…

C11-5-23: Describe how the products of organic chemistry have influenced quality of life.
Examples: synthetic rubber, nylon, medicines, polytetrafluoroethylene (Teflon®)…

(continued)

LEARNING RESOURCES LINKS

Chemistry (Chang 1016)

Chemistry (Zumdahl and Zumdahl 1064)

Chemistry: The Central Science (Brown, *et al.* 456)

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 649)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 465)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 761)

Introductory Chemistry: A Foundation (Zumdahl 607)

McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition (Mustoe, *et al.* 427)

McGraw-Hill Ryerson Chemistry 11, Ontario Edition (Mustoe, *et al.* 535—silly putty, 559)

Nelson Chemistry 11, Ontario Edition (Jenkins, *et al.* 555)

Nelson Chemistry 12, Ontario Edition (van Kessel, *et al.* 98)

Nelson Chemistry 12, College Preparation, Ontario Edition (Davies, *et al.* 179—Waterloc®, 237)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 827)

Skills and Attitudes Outcomes

C11-0-S1: Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), emergency equipment

C11-0-S9: Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, supporting or rejecting a hypothesis or prediction

C11-0-C1: Collaborate with others to achieve group goals and responsibilities.

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Examples: clarify what the issue is, identify different viewpoints and/or stakeholders, research existing data/information…

C11-0-D2: Evaluate implications of possible alternatives or positions related to an STSE issue.

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position…

C11-0-D3: Recognize that decisions reflect values and consider their own values and those of others when making a decision.

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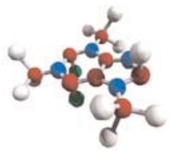
C11-0-D6: Reflect on the process used by self or others to arrive at an STSE decision.

Notes



SPECIFIC LEARNING OUTCOME

C11-5-24: Use the decision-making process to investigate an issue related to organic chemistry.

Examples: gasohol production, alternative energy sources, recycling of plastics…

(1.5 hours)

SLO: C11-5-24

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

A decision-making process model was introduced to the skills component of student learning outcomes in Grade 9 Science. That series of Grade 9 learning outcomes, carried forward into Grade 10 Science, has required students to investigate STSE issues using such a decision-making process model. Students should be familiar with the process; however, a review would be prudent before beginning to address this learning outcome.

Assessing Prior Knowledge

Check for student understanding of prior knowledge and review as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share—see *SYSTH*, Chapter 9).

TEACHER NOTES

Obviously, students cannot make decisions without the necessary background information. This learning outcome is intended to encourage students to become more aware of the STSE issues in their local community. Teachers are encouraged to have students investigate a local or provincial issue that could have an impact on their community.

Previous learning outcomes in Topic 5 will have given students much of the information they require to begin the decision-making process; however, gasohol production and the recycling of plastics will require additional research. Other issues might include the production of methane and other materials from hog barns, industrial organic waste from a local industry by groundwater saturation or air contamination, and so on.

General Learning Outcome Connections

GLO B1: Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

GLO B2: Recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time.

GLO B3: Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

GLO B4: Demonstrate knowledge of and personal consideration for a range of possible science- and technology-related interests, hobbies, and careers.

GLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.
Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

STSE Decision-Making Issues

Teachers will decide whether to discuss one issue as a whole class or whether to have students discuss a number of different issues. Students will have differing opinions based, in part, on the source of information.

Students could present these various opinions on issues using

- debates
- posters
- courtroom arguments
- role-plays
- multimedia formats

Before students are able to use the decision-making model, they will need to organize the information collected. To make their task easier, they can use organizational forms (e.g., Knowledge Chart, 9.13, 9.25; Chain Concept Map, 11.14; Research Notes, 14.7) found in *SYSTH*.

Once students have presented their arguments, they use the decision-making process to come to a consensus. A class or grade vote could also be conducted.

For additional reference material, see the following article:

Barton, Leslie. "Plastic: Chemistry, Commerce and Culture in Canada, 1945–Present." *CHEM 13 NEWS* 324 (Nov. 2004): 15.

Websites for Student Research

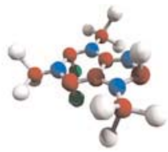
For online information related to *alternative energy sources*, see the following websites:

Alternate Energy Resource Network: <http://www.alternate-energy.net/>

This website provides for a wide variety of energy alternatives as updates in industry.

Alternative Energy, Renewable Energy—Hydrogen, Solar, Biofuel, Geothermal, Hydro, and More: <http://curtrosengren.typepad.com/alternative_energy/>

Developed by Curt Rosengren, this website surveys more than 20 different alternative fuel and energy sources. The site is constantly update, is very easy to navigate, and has a familiar tone.



SPECIFIC LEARNING OUTCOME

C11-5-24: Use the decision-making process to investigate an issue related to organic chemistry.

Examples: gasohol production, alternative energy sources, recycling of plastics…

(continued)

Andy Darvill's Science Site. Energy Resources: <http://www.darvill.clara.net/altenerg/>

Darvill is a science educator in the UK. His website offers editable blackline masters and templates that are curriculum matched to the General Curriculum for Science Education (GCSE) in the UK.

Energy Alternatives Ltd.: <http://www.energyalternatives.ca/conservation.asp>

This website is devoted to programs underway in Canada.

The Environment Directory: <http://www.webdirectory.com/Science/Energy/Alternative_Energy/>

A primarily American-based source of information about energy alternatives, this website can provide a useful contrast to the previous Canadian link.

Topix.net. Alternative Energy News: <http://www.topix.net/tech/alt-energy>

This "clearinghouse" type of website provides many links to other, more specific, sources of information from the field of alternative energy research and development.

For information on *ethanol-blended fuels*, see the following websites:

Manitoba Energy, Science and Technology. Energy Development Initiative. Gasohol Incentives: <http://www.gov.mb.ca/est/energy/ethanol/ethincentives.html>

---. ---. Ethanol-Blended Fuels: <http://www.gov.mb.ca/est/energy/initiatives/ethanolfuels.html>

Renewable Fuels Association: <http://www.ethanolrfa.org/>

For information on *recycling*, particularly plastics, see the following websites:

The American Plastics Council. Plastic Recycling Resources: <http://www.plasticsresource.com/s_plasticsresource/doc.asp?TRACKID=&CID=40&DID=420>

Canadian Plastics Industry Association. Environment and Plastics Industry Council (EPIC): <http://www.cpia.ca/epic/media/news.php?ID=1332>

---. ---. Teacher Resource Site: <http://www.plastics.ca/teachers/>

SKILLS AND ATTITUDES OUTCOMES

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Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles…

C11-0-R1: Synthesize information obtained from a variety of sources.
Include: print and electronic sources, specialists, other resource people

New York State Department of Environmental Conservation. Recycling Plastics Is as Easy as…: <http://www.dec.state.ny.us/website/dshm/redrecy/plastic.htm>

Obvious Implementations Corporation/Obviously Enterprises. The Internet Consumer Recycling Guide: <http://www.obviously.com/recycle/>

Ohio Department of Natural Resources. Division of Recycling and Litter Prevention. Recycling Plastic: <http://www.dnr.state.oh.us/recycling/plastics/>

U.S. Environmental Protection Agency. Recycle City: <http://www.epa.gov/recyclecity/>

Waste Online. Plastic Recycling Information Sheet: <http://www.wasteonline.org.uk/resources/InformationSheets/Plastics.htm>

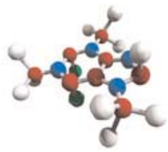
SUGGESTIONS FOR ASSESSMENT

Rubrics/Checklists

See Appendix 10 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Journal Writing

Ask students to write a journal entry summarizing their opinion of the decision of the majority vs. the minority regarding the STSE issues discussed. What, if any, compromises were necessary to resolve the issues?



SPECIFIC LEARNING OUTCOME

C11-5-24: Use the decision-making process to investigate an issue related to organic chemistry.

Examples: gasohol production, alternative energy sources, recycling of plastics…

(continued)

LEARNING RESOURCES LINKS

Gasohol

Chemistry (Zumdahl and Zumdahl 277, 1059)

Chemistry: The Molecular Nature of Matter and Change (Silberberg 243)

Introductory Chemistry: A Foundation (Zumdahl 601)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 296, 843)

Alternative Energy Sources and Climate

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 730, 860)

Recycling and Plasatics

Chemistry: Concepts and Applications (Phillips, Strozak, and Wistrom 659, 661)

Glencoe Chemistry: Matter and Change (Dingrando, *et al.* 764)

Prentice Hall Chemistry: Connections to Our Changing World (LeMay, *et al.* 33, 55, 829)

SKILLS AND ATTITUDES OUTCOMES

C11-0-U1: Use appropriate strategies and skills to develop an understanding of chemical concepts.

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C11-0-R1: Synthesize information obtained from a variety of sources.

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NOTES