Unit 3
Organic Chemistry
Specific Curriculum Outcomes

Suggested Time: 30 Hours

Organic Chemistry

Introduction

Organic chemistry is the study of molecular compounds of carbon. In this unit, the bonding capacity of carbon, hydrogen, oxygen, nitrogen, and the halogens will be reviewed, as will the potential for these atoms to form covalent compounds. The vastness of the number of organic molecules will be explored using isomers and polymers as examples. With so many different organic molecules to consider, students will come to appreciate the need for a systematic naming scheme. Students will be given opportunities to discover how the classification of organic molecules into different family groups depends upon the type of bonding and atoms present. The students will also examine how these factors influence the reactivity of representative molecules from each of the different families.

Focus and Context

Humans and all living organisms are made up of molecules that contain carbon. Carbon provides the backbone for many molecules essential for life. Deoxyribonucleic acids (DNA), proteins, carbohydrates, cellulose, fats, and petroleum products all contain organic molecules. Having students consider the chemistry that exists within their own bodies can make the study of organic molecules more relevant and interesting. By studying the impact of technological applications of organic chemistry on the world around them, students will develop an appreciation for the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology. Using a context such as the problem of ozone depletion provides students with an opportunity for attitudinal growth. Furthermore, students should develop a sense of personal and shared responsibility for maintaining a sustainable environment. Ultimately, students should be aware of the direct and indirect consequences of their actions. Other contexts could work just as well.

Science Curriculum Links

Organic chemistry is a topic that fits in well towards the end of the level 2 course because it provides an opportunity to review outcomes in the "From Structures to Properties" unit. The organic unit will allow students to reinforce their understanding of valence electrons, chemical bonding, and intermolecular and intramolecular forces.

This unit also reinforces and expands upon the study of natural and synthetic compounds containing carbon that was introduced in Science 1206. As well, the grade 9 science program introduced students to the chemistry of petrochemicals. Petrochemicals form the basis of the level 3 thermochemistry unit.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Nature of Science and Technology** **114-4** identify various constraints that result in trade-offs during the development and improvement of technologies **115-1** distinguish between scientific questions and technological problems **115-3** explain how a major scientific milestone revolutionized thinking in the scientific communities **115-6** explain how scientific knowledge evolves as new evidence comes to light **Relationship Between Science and Technology** **116-7** analyze natural and technological systems to interpret and explain their structure and dynamics **Social and Environmental Contexts of Science and Technology** **117-4** debate the merits of funding specific scientific or technological endeavours and not others **117-5** provide examples of how science and technology are an integral part of their lives and their community **118-2** analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology **118-4** evaluate the design of a technology and the way it functions, on the basis of a variety of criteria that they have identified themselves	*Students will be expected to* **Initiating and Planning** **212-2** define and delimit problems to facilitate investigation **212-3** design an experiment identifying and controlling major variables **Performing and Recording** **213-7** select and integrate information from various print and electronic sources or from several parts of the same source **213-8** select and use apparatus and material safely **Analysing and Interpreting** **214-2** identify limitations of a given classification system and identify alternative ways of classifying to accommodate anomalies **214-11** provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion **214-18** identify and evaluate potential applications of findings (e.g., examine findings from research on in-vitro fertilization) **Communication and Teamwork** **215-1** communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others **215-3** synthesize information from multiple sources or from complex and lengthy texts and make inferences based on this information **215-5** develop, present, and defend a position or course of action, based on findings	*Students will be expected to* **319-4** explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom **319-5** write the formula and provide the IUPAC name for a variety of organic compounds **319-6** define isomers and illustrate the structural formulae for a variety of organic isomers **319-7** classify various organic compounds by determining to which families they belong, based on their names or structures **319-8** write and balance chemical equations to predict the reactions of selected organic compounds **319-9** describe processes of polymerization and identify some important natural and synthetic polymers

So Many Compounds

Outcomes

Students will be expected to

- explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom (319-4)
  - compare organic and inorganic compounds in terms of the presence of carbon, variety of compounds formed, and relative molecular size and mass.
  - explain the wide diversity of organic compounds in terms of carbon's bonding capacity, ability to form multiple bonds, and ability to bond in a variety of stable, relatively unreactive structures such as chains and rings.
  - list natural sources of organic compounds.

Elaborations—Strategies for Learning and Teaching

Students could try to explain the diversity of organic compounds. Of the millions of compounds known to humans, the vast majority are molecular compounds of carbon. To develop an appreciation for the scope of organic chemistry, students could brainstorm to compile a list of different molecules they have heard about from biology courses, food sources, pesticides, petroleum products, pharmaceuticals, and other everyday sources. Teachers could begin this topic with a problem relating organic compounds to students' lives. Some examples that might be used are fat-free potato chips or drug research a cure for a disease such as cancer.

Throughout this unit, teachers might refer to a student research project which could be started by each student choosing an organic compound to learn more about. An alternative suggestion to address the outcomes would be for students, in groups of two, to develop an STSE question based on a controversial compound.

Students could be asked to search reference materials, such as a chemistry handbook (example: Merck Index, Handbook of Chemistry and Physics, Chemical Dictionary) and/or the Internet, to try to discover the structural formulae of these different compounds. They could find molecules that contain carbon and look at relative molecular size and mass of the molecules. Once the students compile an array of the molecules they have found, they should be asked to determine which of these come from living organisms and which are artificial or synthesized by humans. From this activity, the students should realize that many organic molecules are derived from living sources and should understand the historical significance of the name "organic chemistry."

So Many Compounds

Tasks for Instruction and/or Assessment

Performance

- Using molecular models, make structures of 10 of the carbon molecules you found. (319-4)
- Draw Lewis structures of five of the carbon molecules you found. (319-4)

Journal

- Carbon bonding is important in organic compounds. Explain why. (319-4)
- Are all carbon compounds organic compounds? Discuss. (319-4)

Paper and Pencil

- Can three-dimensional aspects of structure be communicated easily on paper? If so, how? (319-4)
- Make a chart to list the compounds you found and the elements contained in the compounds according to the following groupings: C and H only; C, H, and O only; C, H, and N only; C, H, and halogens only; and others. (319-4)
- Suggest a reason why graphite is more chemically reactive than diamond. (319-4)

Presentation

- Your teacher will give you a large index card on which to write one compound's formula or structure and its name. Put yours on the bulletin board to be viewed by your classmates. (319-4)
- Develop a class time-line across one wall of the room of the dates various organic compounds were discovered or developed. Add a compound with the following information: the chemical formula, when it was developed, and one or two interesting facts about it, such as its use and if it were ever banned. (319-4)

Resources/Notes

www.gov.nl.ca/edu/science_ref/main.htm

MGH Chemistry, p. 320, pp. 324-325

MGH Chemistry, pp. 324-325

MGH Chemistry, pp. 322-323

Influences of Organic Compounds on Society

Outcomes

Students will be expected to

- explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom (319-4) (**Cont'd**)
  - briefly describe the origin of the term "organic" and how the conception of organic compounds has changed since the first synthesis of an organic compound, urea from an inorganic compound.
- explain how synthesizing organic molecules revolutionized thinking in the scientific community (115-3)
- provide organic examples of how science and technology are an integral part of their lives and their community (117-5)
- analyze natural and technological systems to interpret and explain the influence of organic compounds on society (116-7)

Elaborations—Strategies for Learning and Teaching

The definition of organic compound changed from compounds found only in living creatures to compounds which contain C in 1828 when Frederick Wohler produced urea, a compound previously found only in urine of living creatures, from two inorganic compounds.

$AgOCN + NH_4Cl + heat \rightarrow (NH_2)_2C{=}O$

Students might consider what makes carbon compounds different from other compounds. Because students have studied some bonding, organic chemistry offers an opportunity for students to explore the spatial characteristics of simple organic compounds. Students could use model kits to investigate the symmetry of simple organic compounds. For example, the nature of methane's tetrahedron or the ends of ethane rotating could be examined with the models. Students might compare properties of C_4H_{10} with Si_4H_{10} or CCl_4 with $SiCl_4$. Students might look at the structures of graphite and diamond to demonstrate the layering of hexagons and the strength of a tetrahedron.

Students should consider the significance of being able to synthesize organic molecules. The fact that this was not always possible could be explored with students. On the one hand, students have probably heard that it is now possible to synthesize the molecule insulin, which is needed in the treatment of diabetes. Since insulin had previously been isolated from the pancreas of cows and pigs, the discovery of a method to produce it artificially was a welcome innovation. On the other hand, the ability to manufacture molecules has caused problems. For example, the production of CFCs, are currently destroying the ozone layer.

Students could explain how Kekulé's concept of the ring structure of benzene revolutionized thinking in chemistry. Students could debate the advantages and disadvantages of synthesizing molecules.

Students should be exposed to today's world of rapid technological development in which the concepts of organic chemistry are being applied to everything. Students could analyze the numerous steps involved in the refining of petroleum to obtain gasoline and a variety of other products. Students might look at technologies that allow us to produce organic chemicals and the societal implications of the science and technology.

Influences of Organic Compounds on Society

Tasks for Instruction and/or Assessment

Informal Observation

- Create an observation criteria with your teacher to consider the synthesizing of organic molecules from a number of different perspectives and to weigh conflicting information. Think about and articulate the kinds of knowledge, skills, and attitudes needed to analyze and critique this major scientific issue. (115-3, 115-6)

Journal

- What are the societal implications of the use of organic chemicals to control pests in agricultural chemistry? (114-4, 117-5)
- If you were using a product that you found was harmful to the environment, would you continue to use it? (116-7, 117-5)

Paper and Pencil

- Investigate the technology of designing new synthetic schemes to prepare important organic compounds. Report your findings in a brochure, newspaper article, or memo. (114-4, 115-3, 117-5)
- CFCs are unique in that they have no natural source. Discuss the history of CFC production, useful qualities, absorption in the atmosphere, and questions that need to be addressed to draw conclusions. (116-7, 115-3, 115-6, 114-4, 117-5)
- Address the problem of ozone depletion. This is not a problem with a single correct solution, but once evidence is assessed, decisions must be made and measures taken. With evidence, describe a possible solution. (116-7)
- Research and report on Canadian Raymond Lemieux and the synthesis of sucrose. (116-7)

Presentation

- Debate the advantages and disadvantages of synthesizing molecules. (115-3, 115-6)
- Debate the power of synthetic chemistry versus the use of naturally occurring, limited resources. (115-3, 114-4, 117-5)

Performance

- Debate the pros and cons of being able to manufacture organic molecules. Debate or assume roles that scientists play in changing the directions of chemical research. One scientist students could refer to is Friedrich Wöhler. (116-7)

Resources/Notes

MGH Chemistry, pp. 321-322

Classifying Organic Compounds

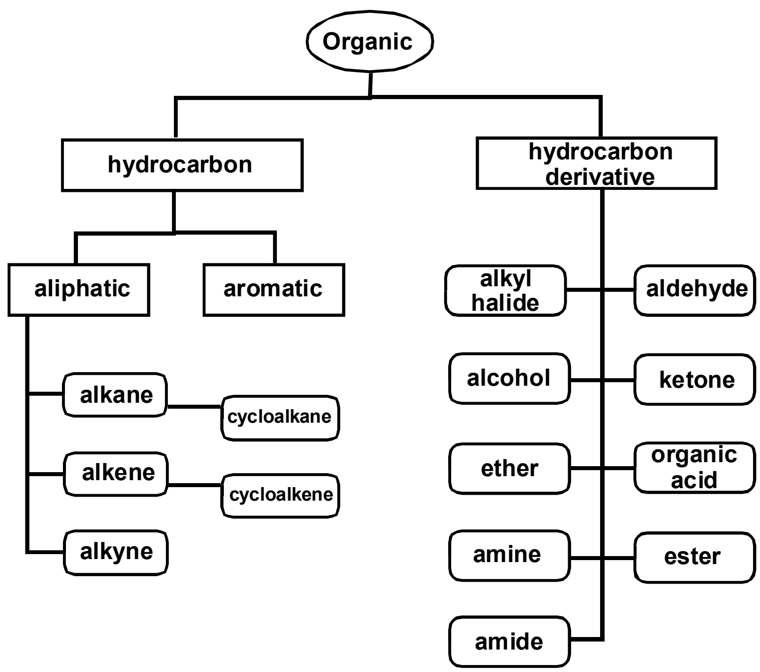
Outcomes

Students will be expected to

- classify organic compounds into hydrocarbons and hydrocarbon derivatives based on their names or structures (319-7)
  – differentiate between pure hydrocarbons and hydrocarbon derivatives on the basis of composition.

Elaborations—Strategies for Learning and Teaching

The millions of known organic compounds are often organized based on their chemical and physical properties. No classification system will neatly fit all possible organic compounds, hence, there are many attempts at classifying organic compounds. This section of Chemistry 2202 is guided by the following classification structure:



For the rest of this section students will investigate the chemical and physical properties of each type of compound. Physical properties that should be covered are: melting point/boiling point, solubility and bonding/structure (e.g., functional group). The chemical properties investigated will be selected reactions that are highlighted by the unique chemistry of each group. For example alkenes undergo addition, alcohols undergo elimination, and so on. (More specifics will be delineated with each individual outcome.) The classification scheme itself is not important; however, it helps to organize students' knowledge about organic chemistry.

Classifying Organic Compounds

Tasks for Instruction and/or Assessment

Journal

- Explain why triple bonds are more difficult to break than single bonds. (319-7)
- Explain why the reaction takes place at the site of the triple bonds in alkynes. (319-7)

Paper and Pencil

- Draw electron dot diagrams for seven compounds that you randomly draw from the deck of cards on alkanes, alkenes, alkynes, cycloalkanes, aromatics, and organic halides. (319-7)
- How are organic compounds classified? (319-7)
- List elements that can bond to carbon in organic compounds. (319-7)

Presentation

- Design and make models for a number of hydrocarbon molecules using different materials. (319-7)

Resources/Notes

MGH Chemistry, p. 320, p. 331

Classifying Organic Compounds *(continued)*

Outcomes

Students will be expected to

- classify organic compounds into hydrocarbons and hydrocarbon derivatives based on their names or structures (319-7) (**Cont'd**)

Elaborations—Strategies for Learning and Teaching

There are several ways teachers could approach this organic unit. Typically, students should progress through the organic unit in a vertical fashion (from top to bottom in the diagram, Page 80). However, as they progress, they should concentrate on one classification of organic compounds at a time and only be introduced to the counterpart. For example: students could begin by distinguishing between types of organic compounds; it is only necessary to initially be introduced to the major categories. Next, students should distinguish between hydrocarbons and hydrocarbon derivatives by covering details about hydrocarbons while simply being introduced to derivatives (greater detail concerning derivatives will follow). Students should then distinguish between aliphatics and aromatics by exploring the details about aliphatics, again by simply being introduced to aromatics. Next students would investigate alkanes in depth (covering naming, physical properties, chemical reactions and the concepts of formula, isomerism, homologous series and saturation). Teachers should note that it may take a considerable amount of time for students to master these concepts concerning alkanes. Yet, once alkanes have been completed, the time necessary for an anagolous treatment of all other organic compounds is very much reduced. Finally, students would return to study aromatics and hydrocarbon derivatives.

- classify hydrocarbon compounds into aliphatics and aromatics based on their names or structures (319-7)
  - defining aromatics as compounds that contain one (or more) benzene ring
- classify aliphatic compounds into alkanes, alkenes and alkynes based on their names or structures (319-7)
  - describe and explain the trend in boiling points of hydrocarbons as the number of C's increase.
  - describe the solubility of these compounds in polar and non-polar solvents.
  - define and be able to give examples of saturated and unsaturated hydrocarbons.

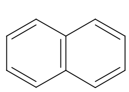
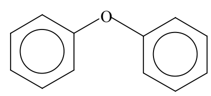
Aliphatics (alkanes, alkenes and alkynes) are the simplest organic compounds and should be studied first. They provide a good context in which fundamental organic topics can be studied. Teachers may wish to avoid aromatics until all of the aliphatic compounds and related concepts are completed. If teachers prefer to distinguish aliphatics from aromatics first, it is sufficient for the students to define aromatic compounds as containing at least one benzene ring. The presence of this structure often has a profound effect on the chemical and physical properties of the compound which distinguishes them from aliphatics. A more detailed investigation of aromatic compounds will follow.

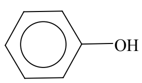
Classifying Organic Compounds *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Draw the different representations of benzene. (319-7)
- Classify the following structures as aromatic or aliphatic:

(i)  (ii) $CH_3{-}CH{=}CH_2$ (iii) 

(iv)  (v) C_2H_6 (vi) $HC{\equiv}CH$ (319-7)

- Which of butane, hexane and octane has the highest boiling point? (319-7)
- Do aromatic compounds dissolve in water? Explain. (319-7)

Journal

- What are the advantages of classifying between hycrocarbon types? (319-7)
- What are the advantages of classifying hydrocarbons from hycrocarbon derivatives? (319-7)
- Look up the boiling point of methane, chloromethane and dichloromethane and explain the difference in boiling points between the hydrocarbon and the hydrocarbon derivatives. (319-7)

Presentation

- Make a collage of "hydrocarbons around us," including structure, name and use or interesting fact(s) regarding each compound. Some compounds to consider are propane, 2,2,4-trimethylpentane (the isomer of octane most apparent in gasoline), benzene, napthalene or pyrobenzene. (319-7)
- Research the boiling points of the various simple hydrocarbons, in order to identify any trends within each group. (319-7)
- At lab benches, test the solubility of liquid hydrocarbons in water and liquid (polar) hydrocarbon derivatives in water. (319-7)

Resources/Notes

MGH Chemistry, p. 331, p. 360

MGH Chemistry, p. 339

MGH Chemistry, p. 331, p. 348

Classifying Organic Compounds *(continued)*

Outcomes

Students will be expected to

- classify aliphatic compounds into alkanes, alkenes and alkynes based on their names or structures (319-7) (**Cont'd**)
  - draw Lewis dot diagrams to show the bonding in ethane, ethene, and ethyne.
  - describe the bonding shapes around each of the carbon atoms involved in a single, double or triple bond.
  - write the general formulae for alkanes, alkenes (1 double bond), alkynes (1 triple bond), cycloalkanes and cycloalkenes and make predictions based on these formulae.

Elaborations—Strategies for Learning and Teaching

Students should have the necessary skills to draw Lewis diagrams based on their work on bonding. Teachers are not limited to ethane, ethene or ethyne; the intent is for students to be able to draw Lewis dot diagrams for $C{-}C$, $C{=}C$, $C{\equiv}C$ bonds.

The general formula of each compound group is listed below:

Alkanes:	C_nH_{2n+2}
Alkenes:	C_nH_{2n}
Alkynes:	C_nH_{2n-2}
Cycloalkanes:	C_nH_{2n}
Cycloalkenes:	C_nH_{2n-2}

Note that these general formulae indicate that alkenes and cycloalkanes have the same chemical formula (i.e., are isomers) and alkynes and cycloalkenes are isomers.

The students should be able to predict:

- the chemical formula given the compound type and number of C atoms or H atoms.
- the possible compound type(s) given the complete chemical formula.
- cyclic isomers of alkenes or alkynes given a chemical formula or vice versa. (This could be covered now or later in the unit with cyclo-hydrocarbons.)

Classifying Organic Compounds *(continued)*

Tasks for Instruction and/or Assessment

Journal

- Given the type of hydrocarbon and with the number of carbons or hydrogens, determine the chemical formula of the compound. Perform this for each hydrocarbon type. (319-7)
- What is the first member of each of the following families: (i) alkanes; (ii) alkenes; (iii) alkynes; (iv) cycloalkanes; (v) cycloalkenes (319-7)

Paper and Pencil

- Draw electron dot diagrams for seven compounds that you randomly choose from the alkane, alkene, alkyne and cycloalkane families. (319-7)
- Identify the families to which each of the following compounds may belong to: (i) C_4H_{10}; (ii) C_5H_8; (iii) $C_{10}H_{20}$ (319-7)
- Draw 3-D structures for: (i) CH_4; (ii) C_2H_4; (iii) C_2H_2 (319-7)

Presentation

- Make molecular models for various alkanes, alkenes, alkynes. Place name tags on the models and suspend them from the class ceiling. (319-7)
- Make and present a chart with the following headings: hydrocarbon type, general formula, and then examples with the following headings underneath: name and formula, structure and common name and/or common use. (319-7)

Resources/Notes

MGH Chemistry, p. 324, p. 345

MGH Chemistry, p. 329

MGH Chemistry, p. 331, p. 345, p. 354, p. 357

Naming and Writing Organic Compounds

Outcomes

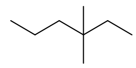
Students will be expected to

- write the formula and provide the IUPAC name for a variety of organic compounds (319-5)
  - name all the prefixes for 1 to 10 carbons in a compound or alkyl group
  - write names and molecular formulae, and draw structural formulae, complete structural diagrams, condensed structural diagrams, skeletal structural diagrams, and line diagrams using the IUPAC rules for the alkanes, cycloalkanes, alkenes, cycloalkenes, and, alkynes.

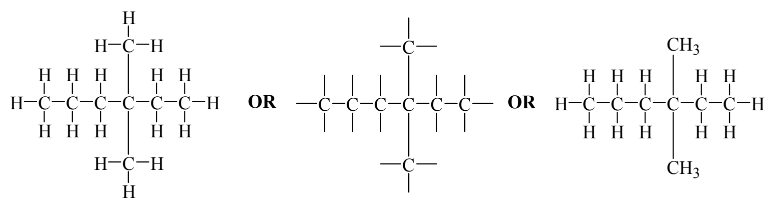
Elaborations—Strategies for Learning and Teaching

Students should be able to draw structures according to the acceptable formats, not to name the acceptable formats. The following examples illustrate the acceptable structure formats for 3,3-dimethylhexane and 1-ethylcyclopentane.

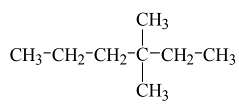
3,3-dimethylhexane



Line Structural

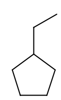


Complete Structural

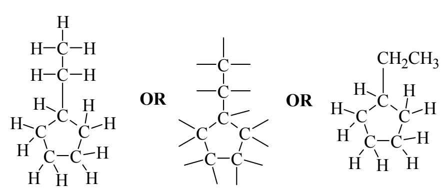


Condensed Structural

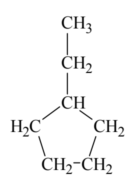
1-ethylcyclopentane



Line Structural

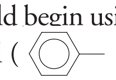


Complete Structural



Condensed Structural

Students should be able to name hydrocarbons with multiple alkyl branches. Possible compound types include: alkanes, alkenes (one double bond), alkynes (one triple bond) with one or several branches; and cycloalkanes or cycloalkenes (one double bond) with one or several branches.

Teachers should, at first, limit substituent groups to alkyl chains; however, students may begin naming other types of organic compounds at this point. Teachers could begin using other substituent groups such as; halogens (F, Cl, Br, I), phenyl (), and nitro groups (NO_2).

Naming and Writing Organic Compounds

Tasks for Instruction and/or Assessment

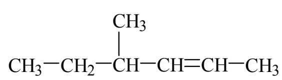
Performance

- Design and present a flow chart, poem, story or song to summarize the IUPAC rules for naming and writing organic compounds. (319-5)

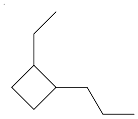
Paper and Pencil

- Name the following straight-chain alkanes such as: $C_{10}H_{22}$, C_3H_8, C_8H_{18}, C_4H_{10}. (319-5)
- Name several organic compounds such as:

(i)



(ii)



- Draw the structure of C_5H_{10}. Classify it. Explain your choice. (319-5)
- Compare structural formulae with chemical formulae. Are there any advantages for either? (319-5)
- List the rules for assigning numbers to carbon atoms. (319-5)

Presentation

- Make a game where a spinner determines the number of carbon atoms, number of branches, location of branch on main chain, and size/type of branch on the main chain. Play the game, recording the structure and IUPAC name for all compounds developed. (319-5)

Resources/Notes

MGH Chemistry, p. 333

MGH Chemistry, pp. 325-328 and throughout Chapter 9

Isomers in Organic Chemistry

Outcomes

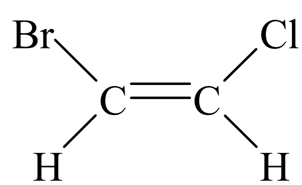
Students will be expected to

- define isomers and illustrate the structural formulae for a variety of organic isomers (319-6)
  – define and give examples of structural isomerism.
  – compare the properties of a pair of organic isomers.
  – define geometric isomers (cis and trans)
  – draw and/or name geometric isomers (cis and trans) for ethene derivatives.
  – draw and name all structural isomers of alkanes (up to 6 carbons).
  – draw and name all structural isomers (including all cyclic) of hydrocarbons with general formula C_nH_{2n} (up to 5 carbons).
  – draw and name all structural isomers (including all cyclic) of hydrocarbons with general formula C_nH_{2n-2} (up to 4 carbons).
- define and delimit problems to facilitate investigation (212-2)
- perform an experiment identifying and controlling major variables (212-3)
- select and use apparatus and material safely (213-8)

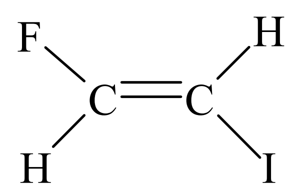
Elaborations—Strategies for Learning and Teaching

Students could gather data about physical properties of two isomers in Core Lab #6 and compare the differences. Based on their bonding studies, students should offer explanations about why their physical properties are similar or different.

Any halide can be used to illustrate cis and trans substituted ethene molecules.



cis-bromochloroethene



trans-fluoroiodoethene

The Laboratory outcomes 212-2, 212-3, 213-8 and 319-6 are addressed by completing *Structures and Properties of Aliphatic Compounds* CORE LAB #6.

Isomers in Organic Chemistry

Tasks for Instruction and/or Assessment

Paper and Pencil

- Draw and name two structural formulae for an alcohol with the molecular formula C_4H_9O. (319-6)
- Draw and name structural isomers for butane and for butene. (319-6)
- Draw and name cis and trans isomers for chlorofluroethane. (319-6)
- Draw and name all structural isomers for: (i) C_3H_6; (ii) C_4H_6; (iii) C_6H_{14} (319-6)

Journal

- You have two structural formulae, but each has the same chemical formula. What differences in the properties of each are a result of the structure? Explain why? (319-6)
- Isomers of butyne include structural isomers. Draw structures and name two cyclic isomers of butyne which have different ring sizes. (319-6)

Presentation

- The physical properties and potential uses of cis and trans 2-butene are quite different. Research and record these properties and, where possible, explain why these differences are found. (319-6)
- Research the use and effects of thalidamide. Include its chemical formula (319-6)

Resources/Notes

MGH Chemistry, pp. 326-327

Core Lab #6: *"Structures and Properties of Aliphatic Compounds"*, p. 359

MGH Chemistry, p. 348

MGH Chemistry, pp. 332-339

MGH Chemistry, pp. 344-347

MGH Chemistry, pp. 354-355

Core Lab #6: *"Structures and Properties of Aliphatic Compounds"*, p. 359

Writing and Balancing Chemical Equations

Outcomes

Students will be expected to

- write and balance chemical equations to predict the reactions of alkanes (and cycloalkanes), alkenes (and cycloalkenes) and alkynes (319-8)
  - – define thermal and catalytic cracking.
  - – compare hydrocarbon cracking and reforming.
  - – draw structural diagrams of all organic reactants for:
    - (i) addition
    - (ii) substitution
    - (iii) cracking
    - (iv) reforming
    - (v) complete combustion
    - (vi) incomplete combustion
  - – given the reactants in an organic reaction, determine which type of reaction will proceed and predict the products, including the formation of any isomers.
  - – determine the name and structure of a missing compound, given an organic reaction with one reactant or product missing

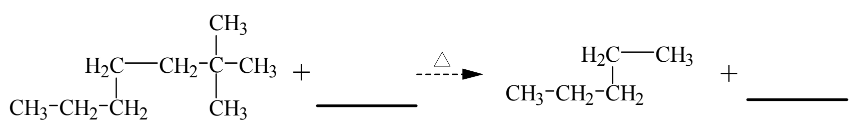
Elaborations—Strategies for Learning and Teaching

Teachers should strongly emphasize that structures need to be drawn only for organic reactants and products. For example, it is not necessary to draw structural diagrams for O_2, CO_2 or H_2O for complete combustion or for O_2, CO or H_2O for incomplete combustion, or, it is not necessary to draw diagrams for water or hydrogen halides.

The major difference between these two methods of hydrocarbon cracking is the involvement of a catalyst (although still requiring a large amount of heat). Students, at this point in the course, are not required to explain how a catalyst works. Instead, a catalyst can be presented as a "special" reactant that speeds up the reaction and doesn't get consumed.

Students may have difficulty completing cracking and reforming chemical equations because it is very difficult to predict the products of these reactions. To overcome this, students could solve problems such as:

1. Write a balanced chemical equation for the thermal cracking of octane into pentane and propane.
2. Write a balanced chemical equation for the catalytic reforming of methane into hexane.
3. Complete the following:



Alkanes undergo substitution reactions with halogens (in the presence of light). Alkenes and alkynes undergo addition reactions with (i) halogens, (ii) hydrogen, (iii) hydrogen halides, and (iv) water. Students should be able to write the addition of two moles of reactant to an alkyne to illustrate that two bonds of the triple bond may be broken (i.e., they should be able to indicate the two steps of this reaction).

Organic reactions may have more than two structural isomers; if more are possible, students should have to indicate that more isomeric products are possible and be able to draw no more than two of them. This will apply to subsequent reactions studied.

Writing and Balancing Chemical Equations

Tasks for Instruction and/or Assessment

Paper and Pencil

- Write a balanced chemical equation for the addition reaction involving hydrogen bromide and ethene. (319-8)
- Write a balanced chemical equation for the complete combustion of C_4H_{10}. (319-8)
- Write a balanced chemical equation for the substitution reaction involving one molecule of methane and one molecule of chlorine. (319-8)
- Write a balanced chemical equation for the addition reaction involving two molecules of hydrogen bromide and one molecule of propyne. (319-8)
- Write a balanced chemical reaction for the cracking of nonane into hexane and one other organic product. (319-8)
- Complete the following:

(i) $CH_3{-}CH_2{-}CH_3 + \_\_\_\_\_\_ \longrightarrow CH_3{-}\underset{}{\overset{\displaystyle Br}{\overset{|}{C}H}}{-}CH_3 + HBr$

(ii) $H_2C{=}CH_2 + HOH \longrightarrow$

(319-8)

- 2,2,4-trimethylpentane may be reformed when propane and 2,2-dimethylpropane react. Given that the only by product is not organic, write the balanced equation. (319-8)

Presentation

- Interview a person, in person or via e-mail, whose occupation involves organic chemistry. Determine the organic chemical reaction(s) involved in their occupation and talk about the equation. (319-8)
- Contact North Atlantic Refinery at Come By Chance and determine compounds which are cracked and/or reformed during their refining processes. Present your results, including balanced equations. (319-8)

Resources/Notes

MGH Chemistry, p. 367

MGH Chemistry, p. 368

MGH Chemistry, pp. 340-344

Industrial Processes: Hydrocarbons

Outcomes

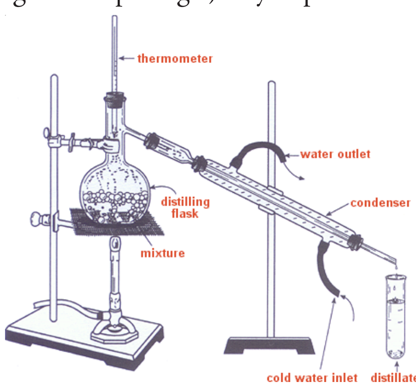
Students will be expected to

- evaluate the design of a technology and the way it functions, on the basis of a variety of criteria that they have identified themselves (118-4)
  - explain the chemical and physical processes involved in oil refining (fractional distillation, cracking/ reforming).
- identify various constraints that result in trade-offs during the development and improvement of technologies (114-4)
  - describe how modern oil refineries apply a fractional distillation process, and cracking/reforming reactions to produce petroleum products
- distinguish between scientific questions and technological problems (115-1)
  - compare fractional distillation, cracking/ reforming done in a laboratory setting with the same processes carried out in oil refining.

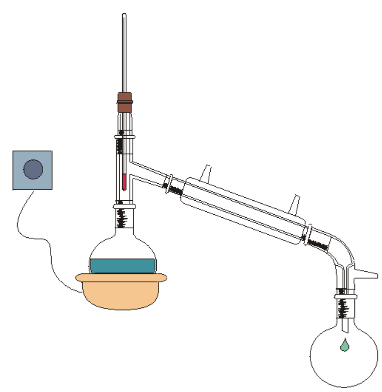
Elaborations—Strategies for Learning and Teaching

The fact that oil refining involves both chemical and physical processes should be reinforced. Some students mistakenly assume it is only fractional distillation. Most crude oil consists of a wide range of organic compounds. The very small or very large compound may not be commercially viable. For example, products such as gasoline (mostly C_8) or kerosene (C_{12} to C_{16}) are only a small fraction of crude oil and may be separated by the physical process of fractional distillation. The smaller compounds are then reformed and/or the larger compounds are cracked to produce more commercially viable products.

Students could perform a Fractional Distillation. When choosing an apparatus for this lab, a teacher may choose between several potential apparatus set ups. One acceptable set-up requires very basic lab equipment, while a complete fractional distillation apparatus (chem kits: organic ground glassware packages) may be purchased commercially.



basic lab equipment


chem kit

Note: never heat organic compounds with a bunsen burner. Water baths or heating mantles are much safer alternatives.

Industrial Processes: Hydrocarbons

Tasks for Instruction and/or Assessment

Paper and Pencil

- Undertake an independent research project on the environmental impact of an organic chemical and write a research paper. (118-4, 118-2, 215-5)
- When chemical engineers are doing a cost-benefit analysis on a chemical they have just synthesized, what questions might they ask? Include the cost (both environmental and monetary) associated with using up our natural resources. (118-4, 118-2, 215-5)
- Generate your own example of a scientific question or technological problem on an application of organic chemistry. Trade with another student and suggest an answer to his/her question or problem. (115-1)
- Evaluate the environmental impact of an oil refinery on a local ecosystem. Identify and evaluate the criteria that you select. (118-4)

Presentation

- Ask a researcher from the chemistry discipline to visit the classroom and talk about how chemists conduct research or design synthetic routes to chemicals. (118-4)
- Discuss, in small groups, the following problems that face a research or industrial chemist:
- – How are products recognized and isolated?
- – How are yields optimized?
- – What is the potential for isomeric products and is it possible to increase the yield of one isomer over the other?
- – What commercial uses are there for the products made?
- – What conclusions can be drawn about the presence of a particular functional group and its potential for reaction? (319-8)
- Develop and defend your position on the development and use of CFCs. (215-5, 118-4)

Resources/Notes

MGH Chemistry, pp. 365-368

MGH Chemistry, pp. 366-367

MGH Chemistry, p. 369

Aromatic Compounds

Outcomes

Students will be expected to

- classify various organic compounds as aromatic, based on their names or structures (319-7)
  - define aromatics as compounds that contain at least one benzene ring structure.
  - describe the bonding in benzene using the term "delocalized electrons," and explain how its unreactive nature and the equal C-C bond lengths in benzene are evidence that it does not have alternating single and double bonds.
  - draw structures for simple monosubstituted benzenes given the name, and vice-versa.
  - draw structures for simple polysubstituted benzene given their names (IUPAC and ortho, meta or para when disubstituted) and vice-versa.
- explain how organic chemistry evolved as new evidence comes to light (115-6)
  - explain how Kekulé's invention of the concept of the ring structure of benzene revolutionized thinking in organic chemistry

Elaborations—Strategies for Learning and Teaching

This course limits the treatment of aromatics to compounds containing the benzene ring. Students should realize that the unique bonding which occurs in the benzene ring is what characterizes aromatics.

A historical approach to the development of the structure for benzene may help students understand the different theories that attempted to explain the bonding within benzene. It may increase student interest as well! (Read up on Kekule's story.) Benzene's chemical formula, C_6H_6, was inconsistent with its chemical properties (unreactive). Further research indicated that the properties of the C-C in benzene were intermediate between single and double bond character. The theory of delocalized electrons adequately explains the characteristics.

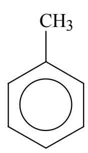
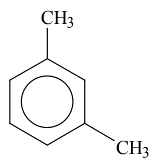
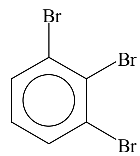
For disustituted aromatics, teachers should use various examples which include not only the same alkyl substituent (i.e., 1,2-dimethylbenzene) but also different alkyl substituents (i.e., 1-ethyl-2-methylbenzene). Note that this study of polysubstituted benzene is not limited to disubstituted benzene.

Aromatic Compounds

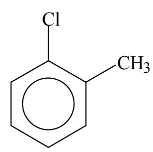
Tasks for Instruction and/or Assessment

Paper and Pencil

- Draw the structure of methylbenzene. (319-7)
- Give the IUPAC name for the following:

(i)  (ii)  (iii) 

(319-7)

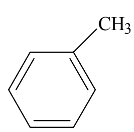
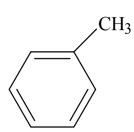
- Give the IUPAC and traditional name for  (319-7)

- Give the correct structures for:

(i) 1-bromo-3-chloro-4-methylbenzene (ii) o-diethylbenzene
(iii) p-dimethylbenzene (iv) 1,3,4-trichlorobenzene
(319-7)

Journal

- Research the C to C bond lengths in benzene and compare them to the C to C single and C to C double bond in cyclohexane. Comment on the variation in the bond lengths. (319-7)
- Are these two compounds equivalent?

(319-7)

Presentation

- Research the reactions of benzene compared to cyclohexane and account for any differences in the degree of reactivity between the two compounds. (319-7)

Resources/Notes

MGH Chemistry, p. 331, p. 360

MGH Chemistry, p. 360

MGH Chemistry, p. 361

MGH Chemistry, p. 360

Aromatic Compounds (continued)

Outcomes

Students will be expected to

- write and balance chemical equations to predict the reactions of benzene (319-8)
  - draw structural diagrams of all organic reactants and products in substitution and complete combustion reactions
  - given the reactants in an aromatic reaction, determine which type of reaction will proceed, and predict what the products will be, including the formation of any isomers.
  - determine the name and structure of a missing reactant or product in a reaction of an aromatic

Elaborations—Strategies for Learning and Teaching

The chemical properties of aromatics are often indicated by the strength of the benzene ring. It rarely breaks apart and usually only undergoes substitution.

Reactions of aromatics, like other organic compounds, may have more than two structural isomers; if more are possible, students should indicate that more isomeric products are possible and be able to draw no more than two of them.

Aromatic Compounds (continued)

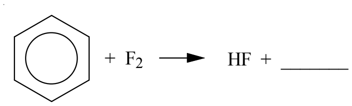
Tasks for Instruction and/or Assessment

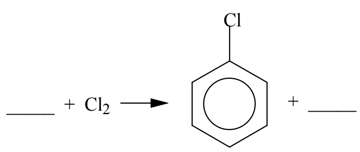
Paper and Pencil

- Complete the balanced chemical reaction between:

  (i) benzene and bromine

  (ii) methylbenzene and oxygen

  (iii) 

  (iv) 

  (319-8)

Journal

- Research the pros and cons of various benzene compounds. List the compound name, structure and use. Students should note the benefit and/or problems associated with the compound. (319-8)
- Research the work of Alfred Nobel, or any other chemist, with aromatic compounds. (319-8)

Presentation

- Construct a poster of a common benzene compound such as TNT, napthalene, PABA (para-aminobenzoic acid), ASA (acetylsalicyclic acid). Include in your poster such points as: chemical name, commom name, chemical formula, structure, use, benefits/problems. (319-8)

Resources/Notes

MGH Chemistry, p. 343, p. 341, p. 362

Hydrocarbon Derivatives

Outcomes

Students will be expected to

- classify hydrocarbon derivative compounds into alcohols, ethers, aldehydes, ketones, organic acids, organic halides, esters, amines and amides based on their names or structures (319-7)
  - define functional group
  - define "alkyl group"
  - identify alcohols, ethers, aldehydes, ketones, organic acids, organic halides, esters, amines and amides from their names and the functional groups in their structural formulae.
  - name and draw structures for derivatives of hydrocarbons (listed above) with only 1 functional group
- identify limitations of the IUPAC naming system and identify reasons for alternative ways of naming (214-2)

Elaborations—Strategies for Learning and Teaching

Teachers could develop a series of learning centres such as; a) composition of hydrocarbons and derivatives, b) bonding and electron dot diagrams, c) molecular model activities, d) benzene and relatives, e) paper and pencil activities, f) defining and identifying functional groups, and g) computer activities. Teachers could develop each centre so that it could be checked by the student and verified by the teacher to ensure that there is a plan to follow. Separate folders of information on the tasks work well and help students' organization.

Students could do an activity that looks at organic compounds and bonding and then draw electron dot diagrams. These diagrams could show the bonding in alkanes, alkenes, alkynes, aromatics, cycloalkanes, and organic halides. Students could use molecular models for the same groups as the bonding activity. Students could draw bonds and use molecular models for hydrocarbons and their derivatives.

Nomenclature of organic compounds can become a complex, time-consuming activity. There is no intent for students to master all possible naming situations. The following are restrictions to limit naming, yet allow students to appreciate its complexity.

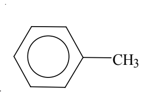
For alcohols, aldehydes, ketones, organic acids and organic halides, structures may contain:

- one functional group only;
- only single C-C bonds on the main chain;
- up to and including two branches off of the main carbon chain;
- alkyl and/or halide branches;
- no branching within an alkyl branch (i.e. only straight chain alkyl branches are allowed.);
- alkyl branches no longer than three carbons

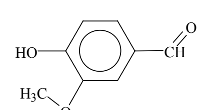
For ethers, esters, amines and amides, structures may contain:

- one functional group only;
- only single C-C bonds on the main chain;
- no branching of any kind, off of the main carbon chain;
- for amines and amides, no alkyl groups off of the N atom. (i.e. "NH_2" group only for amines and amides).

Due to either the complexity and/or the familiarity of certain organic compounds, IUPAC naming can become cumbersome and not practical. For example; 1. Toluene was named so because it was first obtained by distilling tolu balsam. It is a well-known and widely used solvent.
2. Vanillin has a structure that produces a complex name using IUPAC naming rules: 4-hydroxy-3-methoxybenzaldehyde. It is much more convenient to use the trivial name Vanillin.



toluene



Vanillin

Hydrocarbon Derivatives

Tasks for Instruction and/or Assessment

Paper and Pencil

- Identify the compound and define the functional group from compound models made from a model kit. (319-7, 319-5)
- Draw complete structural diagrams that show the difference between 1-propanol and dimethyl ether. (319-7, 319-5)
- Draw structural formulae and give the molecular formulae for 2-pentanone, a solvent; butanoic acid, a component of butter; and chloroethene, used in plastics. (319-7, 319-5)
- Why do the names of aldehydes or organic acids not always contain numbers indicating the position of the aldehyde and acid groups? (319-7, 319-5)

Journal

- Why do dieticians tell us unsaturated fatty acids are a better choice than saturated fatty acids? (319-7)
- For each hydrocarbon derivative, research and find a compound with a common or "real-life" use. Note the name, structure, chemical formula and use of the compound. (319-7)
- Esters are very fragile compounds. Research ester compounds to determine the various fragrances possible for different esters. (319-7)
- Methane gas is sometimes referred to as marsh gas. Discuss this. (214-2)

Presentation

- Design a game for naming examples of all hydrocarbons derivatives. The game could be designed such that the main chain, alkyl and/or halide branches and functional group are randonly chosen, the resulting compound is classified and then correctly named. (319-7)

Resources/Notes

MGH Chemistry, p. 377

MGH Chemistry, p. 334

MGH Chemistry, p. 378, pp. 386-388, p. 390, pp. 394-398, pp. 402-403, p. 405, pp. 410-411, pp. 413-414 and throughout Chapter 10

Hydrocarbon Derivatives (continued)

Outcomes

Students will be expected to

- describe the relationship between intermolecular forces for organic structures investigated (214-11)
  - distinguish between the melting and boiling points of hydrocarbon derivatives and hydrocarbons (of the same size)
- write and balance chemical equations to predict the reactions of hydrocarbon derivatives (319-8)
  - define and give examples of elimination, esterification, and combustion reactions
  - given reactants, determine the type of reaction that proceeds, and the products, including the formation of any isomers.
  - determine the name and structure of a missing reactant or product in a reaction of a hydrocarbon derivative
- design an experiment identifying and controlling major variables (212-3)
- select and use apparatus and material safely (213-8)
- identify and evaluate potential applications of findings (214-18)
  - synthesize a carboxylic acid

Elaborations—Strategies for Learning and Teaching

Hydrocarbon derivatives are generally polar compared to hydrocarbons of the same size. For this reason, hydrocarbon derivatives generally have higher melting points and boiling points compared to their hydrocarbon analogs.

Students should be able to complete alkyl halide eliminations by reaction with a strong base (base elimination) and alcohol eliminations in the present of concentrated strong acid (acid elimination). In both cses, a double bond organic product forms.

When covering combustion reactions students should be able to complete combustion of hydrocarbons and hydrocarbon derivatives that only contain oxygen. In both these scenarios the products would be CO_2 and H_2O. The combustion of nitrogen and halogen containing hydrocarbon derivative could be an excellent extension activity.

The laboratory coutcomes (212-3, 213-8, 214-18) as well as 319-8 are addressed by completing *Preparing a Carboxylic Acid Derivative*, CORE LAB #7.

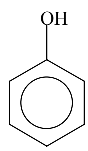
Hydrocarbon Derivatives (continued)

Tasks for Instruction and/or Assessment

Paper and pencil

- Design a checklist of safety procedures for the ester lab. This list should check for your knowledge and application of the procedures. (319-8)
- Complete the following reactions. Indicate that several isomeric products are possible when necessary.

a) $CH_3CH_2CH(OH)CH_2CH_3 \xrightarrow{HNO_3}$

b) $CH_3CH_2CH_2COOH$ +  $\xrightarrow{H^+}$

c) $C(CH_3)Br + KOH \longrightarrow$

d) _______ + NaOH $\longrightarrow$ $CH_3CH{=}CHCH_3 + HOH + NaI$

e) _______ + _______ $\xrightarrow{H_2SO_4}$ $CF_3COOCH_2CH_3 + H_2O$

f) bromobutane + lithium hydroxide $\longrightarrow$ _______ + _______

(319-8)

Journal

- Research the importance of elimination reactions in alcohols and alkyl halides in chemical research and industry. (214-18)

Presentation

- Create and present a poster or collage of organic compounds which have common uses and common names (other than IUPAC names). Include names (traditional/common and IUPAC, if possible) and structures. Sources to use in your research include food labels and pharmaceuticals. (214-18)

Resources/Notes

MGH Chemistry, pp. 381-382, pp. 390-392, p. 410, pp. 416-417

Core Lab #7: *"Preparing a Carboxylic Acid Derivative"*, p. 408

Polymer Chemistry

Outcomes

Students will be expected to

- describe processes of polymerization and identify some important natural and synthetic polymers (319-9)
  - define and outline the structures of monomers, polymers, and polymerization
  - identify addition and condensation polymerization reactions
  - build models depicting polymerization
  - provide examples of polymerization in living and/or non-living systems
- solve problems for writing complete balanced chemical polymerization reactions (319-8)
- define problems to facilitate investigation of polymers (212-2)
  - given a polymer, draw the monomer reactant(s)
  - describe environmental/ health problems associated with the use of polymers

Elaborations—Strategies for Learning and Teaching

The CORE STSE component of this unit incorporates a broad range of Chemistry 2202 outcomes. More specifically, it targets 319-9, 319-8, 118-2, 215-3, 218-7, 117-4, 215-1, and 215-5. The STSE component, *Polymers*, can be found in Appendix A.

Teachers could introduce the topic of polymers by gathering a list of everyday items containing polymers. This list should include items containing plastics, rubbers, teflon, vinyl, films, nylon and so on. Teachers could challenge students to describe a day in a world without polymers.

Students could integrate their understanding of functional groups and reactivity and extend this to the production of polymers.

Students should decide on a polymer problem to investigate. Students could do research to design an experiment to prepare soap or to prepare acetylsalicylic acid. This could be an organizational activity to plan, not to do, the lab.

Teachers could approach this topic by following the historical development of polymer chemistry from the first discoveries/uses of natural rubber, efforts to decrease its durability (vulcanization), to the production of synthetic rubbers and finally the proliferation of modern synthetic polymers.

Students should find a polymer, define the substances needed to make it, and list problems associated with its formation, structure, and/or use. Teachers might introduce various experiments that use monomers, polymers, and polymerization. Connections could be made to the features of reactants that make them potential monomers. Students might experiment with the production of a polymer such as nylon or rayon in the laboratory.

Polymer Chemistry

Tasks for Instruction and/or Assessment

Paper and Pencil

- A simple polyester can be made from the reaction of a dicarboxylic acid with a diol. What type of polymerization is this? Write a structural formula for a portion of the polymer chain. (319-9)
- Write the repeating unit of the polymer when "n" molecules of chloroethene undergoes addition polymerization. (319-9)
- Write the monomers which would yield the following polymers:

  a) $-(O-CH_2-CH_2-O-CO-CH_2-CO-O-)_n$

  b) $-(CCH_3-C-)_n$

(212-2)

Journal

- List some examples where polymers have replaced metals. What properties are polymers capable of having that makes them so useful? (319-9)
- Write an account of the items that you use or come in contact with in a single day that include polymers. Are polymers important to you? (319-9)
- Research the efforts of the chemical industry to produce durable yet environmentally friendly polymers. (212-2)

Presentation

- From molecular model kits, students are to individually create the same monomer for an addition polymerization reaction. The students could then complete the polymerization process by connecting their models throughout the classroom. (319-9)

Resources/Notes

MGH Chemistry, p. 427

MGH Chemistry, pp. 428-430

MGH Chemistry, p. 427

MGH Chemistry, pp. 426-427, p. 429, p. 437 and throughout Chapter 11

MGH Chemistry, pp. 427-429

MGH Chemistry, pp. 434-435

Polymer Chemistry (continued)

Outcomes

Students will be expected to

- select, evaluate and integrate information concerning recyclable polymers from experimental, print and media sources, and to present an understanding of this information in a variety of formats such as lab reports, web pages, or posters (213-7, 215-3)
- apply organic polymer knowledge to a particular problem, recycling, and analyze the benefits to society by using organic polymers as the basis for recyclable materials (118-2)
- debate the merits of funding specific scientific endeavours and not others (117-4)
- communicate questions, ideas, and intentions regarding recycling (215-1)
- receive, interpret, understand and respond to the ideas of others regarding recycling (215-1)
- develop, present and defend your position regarding recycling (215-5)

Elaborations—Strategies for Learning and Teaching

The CORE STSE component of this unit incorporates a broad range of Chemistry 2202 outcomes. More specifically, it targets 319-9, 319-8, 118-2, 215-3, 218-7, 117-4, 215-1, and 215-5. The STSE component, *Polymers*, can be found in Appendix A.

Teachers should note that students are not expected to know the structures of the specific polymers and monomers presented in the STSE modules. The depth of treatment of the STSE modules *Polymers* is for the students to be able to identify the type of polymer and reactant monomers from a given polymer structure (and vice versa).

It is interesting that the ability to synthesize organic molecules artificially was considered impossible until about 170 years ago. It was thought that organic compounds could come only from living sources. In 1828, German chemist Freidrich Wöhler synthesized a common organic compound, urea, from the inorganic compound ammonium cyanate.

Thomas Midgley synthesized the first chlorofluorocarbon (CFC) years later. Many people consider the subsequent attack on Earth's atmosphere to have many ramifications in science and technology. Human history and the study of chemistry were changed by these experiments.

Polymer Chemistry (continued)

Tasks for Instruction and/or Assessment

Journal

- Is all the negative concern about synthesized organic compounds justified? Support your answer. (213-7, 215-3, 117-4, 215-1)

Presentation

- As a team, choose an organic chemistry-related issue and discuss how it is related to your life. Describe the impact of technology and express your opinion on the impact of your issue on society. Some suggestions are poisons, chemical warfare, starch and proteins, or fat content in milk. Present this as a laboratory activity, a debate, or a talk accompanied with visuals. (213-7, 215-3, 117-4, 215-1)
- Debate the positive and negative effects of an organic compound or a group of organic compounds. (117-4, 215-1)

Paper and Pencil

- Discuss the information regarding the positive and negative effects of an organic compound with reference to the:
  - risks and benefits to society and the environment
  - technological solutions involved
  - scientific principles involved. (118-2, 215-5)

Resources/Notes

Core STSE #3: *"Polymers"*, **Appendix A**