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UNIT 7

Chemical Changes of Organic Compounds

Chapter 15 *Reactions of Organic Compounds*

Answers to Questions for Comprehension, notes on Figures and Web Links appear throughout the chapter.

Teaching Unit 7: Chemical Changes of Organic Compounds

(20% of the course time; approximately 25 hours)

Student Textbook pages 530–623

General Outcomes

- explore organic compounds as a common form of matter
- describe chemical reactions of organic compounds

Contents

Chapter 14 Structure and Physical Properties of Organic Compounds

Chapter 15 Reactions of Organic Compounds

Content Summary

Carbon is a special element, with the unique ability to bond with many other carbon atoms to form chains and rings. It can form an immense variety of compounds, from methane with one carbon atom to natural and synthetic polymers with millions of carbon atoms. The existence of such a large number of stable compounds is due to the strength and stability of carbon-carbon and carbon-hydrogen bonds. Organic chemistry, the study of the properties and reactions of carbon compounds, touches the lives of all of us. Alberta is the largest producer of crude oil, natural gas, and gas products in Canada, and many Albertans earn their living directly, or indirectly, as a result of organic chemistry.

Chapter 14: Structure and Physical Properties of Organic Compounds introduces students to the structure and physical properties of hydrocarbons and some simple hydrocarbon derivatives. Students begin by learning about the special nature of the carbon atom, and, in Investigation 14.A, they experimentally compare the properties of organic to inorganic compounds. In Section 14.2: Hydrocarbons, students learn the IUPAC system for naming aliphatic and aromatic hydrocarbons and how to draw molecules using various structural formats. The next section, Hydrocarbon Derivatives, builds on these skills, so it is essential that students have a good understanding of naming and drawing hydrocarbons before continuing the chapter. Students learn how to predict and compare the physical properties of organic compounds based on the effects of intermolecular forces between molecules. In Section 14.3, students learn about some of the classes of organic compounds that have single-bonded functional groups. They extend their knowledge of the IUPAC system to naming alcohols, alkyl halides, carboxylic acids, and esters. Students apply their understanding of molecular polarity and intermolecular forces to help them understand the relative physical properties of each functional group. The final section in this chapter, Refining and Using Organic Compounds, provides insight into how petroleum is isolated from crude sources, and how a refinery separates petroleum into its various hydrocarbon components. Once separated, the refinery increases the value of some components by cracking and reforming. The substances leaving a refinery become fuels or feedstock chemicals for further reactions to make products such as synthetic polymers.

Chapter 15 is an introduction to some of the main types of organic reactions. Students begin the chapter by comparing the reactivity of alkanes with alkenes. A connection is made to show how chemistry relates to dietary fats. Students learn how to predict the products of reactions and write chemical equations illustrating combustion, addition, elimination, substitution, and esterification (condensation). Organic chemists have made compounds to meet specific needs in society, but students learn that there can be unexpected consequences when a new chemical is used on a large scale. In Thought Lab 15.2: Problem Solving with Organic compounds students assess the risks and benefits of gasoline additives for the automotive industry and CFCs used for refrigeration. Section 15.2: Polymers and the Petrochemical Industry begins by extending students' understanding of addition and condensation reactions to cover addition and condensation polymerization reactions. The cracking of ethane to form ethene and the reactions to form polyvinylchloride (PVC) are used to illustrate industrial reactions of great economic importance in Alberta. Next, students learn about some of the risks to workers in the polymer industry and the effects of synthetic polymers on the environment. The section concludes with a look at biologically significant molecules such as cellulose, starch, and DNA.

Curriculum Fit

This unit builds on:

- *Chemistry 20*, Unit 1: Diversity of Matter and Chemical Bonding. Understanding and making reasonable predictions for the physical properties of organic compounds depends on students' ability to apply what they have learned about intermolecular forces. A brief review of bond polarity and hydrogen bonding may be appropriate. See the Unit Preparation feature on pages 532–535 for such a review.

This unit prepares students for post-secondary studies in related areas. This unit will require approximately 23% of the time allotted to *Chemistry 30*.

Core Concepts

Concept	Outcome	Text Reference
Organic chemistry plays a vital role in most of the substances that we encounter and use every day.	30–C1.2k 30–C1.2sts	Unit 7 opener, pp. 530-531 Chapter 14 opener, p. 536 Section 14.2: Hydrocarbons, pp. 544, 551, 556 Section 14.3: Hydrocarbon Derivatives, pp. 566, 567, 569 Chapter 15 opener, pp. 586 Section 15.1: Types of Organic Reactions, p. 592
An organic compound is any compound that contains carbon, with the exception of a carbonate, hydrogen carbonate, cyanide, cyanate, or gaseous oxide.	30–C1.1k	Section 14.1: Introducing Organic Compounds, pp. 538-539
Carbon atoms can form strong single, double, and triple bonds with itself to form a variety of geometric structures.	30–C1.5k	Section 14.1: Introducing Organic Compounds, pp. 539, 542 Thought Lab 14.1, Section 14.1: Introducing Organic Compounds, p. 539
Aliphatic compounds contain no benzene rings; aromatic compounds contain benzene rings.	30–C1.2k	Section 14.2: Hydrocarbons, p. 544
Alkanes are saturated hydrocarbons with general formula $C_nH_{2n+2.}$	30–C1.2k	Section 14.2: Hydrocarbons, pp. 544-548
A homologous series is a series of compounds that differ by one specific unit such as $–CH_2$.	30–C1.3k 30–C1.4k	Section 14.2: Hydrocarbons, p. 545
The physical properties of alkanes, alkenes and alkynes (including cyclic compounds) can be explained based on London (dispersion) forces between molecules.	30–C1.6k	Section 14.2: Hydrocarbons, p. 551, 555, 557, 558
Alkenes are unsaturated hydrocarbons containing a double bond with general formula C_nH_{2n}.	30–C1.3k 30–C1.4k	Section 14.2: Hydrocarbons, p. 552
Alkynes are unsaturated hydrocarbons containing a triple bond with general formula C_nH_{2n-2}.	30–C1.3k 30–C1.4k	Section 14.2: Hydrocarbons, pp. 556
Cyclic hydrocarbons are aliphatic hydrocarbon chains that form rings. They can be alkanes, alkenes, or alkynes.		Section 14.2: Hydrocarbons, pp. 557-558
Benzene (C_6H_6) is a six-membered ring of carbon atoms, with an electronic structure best represented as a resonance hybrid.	30–C1.2k	Section 14.2: Hydrocarbons, pp. 560-561
The functional group of an organic molecule is the reactive portion that undergoes a characteristic reaction, for example: ■ R–OH alcohol ■ R–X alkyl halide ■ R–COOH carboxylic acid ■ RCOOR′ ester	30–C1.3k 30–C1.4k	Section 14.3: Hydrocarbon Derivatives, p. 565
The physical properties of alcohols can be explained by the polar nature of the hydroxyl group and hydrogen bonding between molecules.	30–C1.6k	Section 14.3: Hydrocarbon Derivatives, p. 567
Carboxylic acids are more polar than alcohols, and thus form stronger hydrogen bonds with one another and with water.	30–C1.6k	Section 14.3: Hydrocarbon Derivatives, p. 571

Concept	Outcome	Text Reference
Esters are somewhat polar, but cannot form hydrogen bonds between their molecules.	30–C1.6k	Section 14.3: Hydrocarbon Derivatives, p. 573
Structural isomers have the same molecular formula but different structural formulas; they have different physical and chemical properties.	30–C1.5k 30–C1.3s	Section 14.3: Hydrocarbon Derivatives, p. 573
In Alberta, the extraction of petroleum and the manufacture of petrochemicals is a major contributor to the economy.	30–C2.1sts	Section 14.4: Refining and Using Organic Compounds, pp. 575-577, 580 Section 15.2: Polymers and the Petrochemical Industry, pp. 604-605, 609

Related Skills

Skills	Outcome	Text Reference
Students will describe procedures for safe handling, storage and disposal of materials used in the laboratory, with reference to WHMIS and consumer product labelling information.	30–C2.1s	Chapter 14 Launch Lab, p. 537 Investigation 14.A, Section 14.1: Introducing Organic Compounds, pp. 540-541 Investigation 14.C, Section 14.4: Refining and Using Organic Compounds, p. 581 Chapter 15 Launch Lab, p. 587 Investigation 15.A, Section 15.1: Types of Organic Reactions, pp. 597-599 Investigation 15.B, Section 15.2: Polymers and the Petrochemical Industry, pp. 607-608
Students will perform experiments to investigate the reactions of organic compounds.	30–C2.2s	Chapter 14 Launch Lab, p. 537
Students will perform experiments to compare the properties of organic to inorganic compounds.	30–C1.2s	Investigation 14.A, Section 14.1: Introducing Organic Compounds, pp. 540-541
Students will state the IUPAC name and draw structural and condensed structural formulas for the following hydrocarbon and hydrocarbon derivatives containing up to 10 carbon atoms in the parent chain or cyclical structure: alkane, alkene, alkyne, alcohol, alkyl halide, carboxylic acid and ester.	30–C1.3k 30–C1.3s	Section 14.2: Hydrocarbons, pp. 546-551; 553-555; 556-557; 558-560 Section 14.3: Hydrocarbon Derivatives, pp. 566-567; 568-569; 570; 571-572
Students will state the IUPAC name and draw structural and condensed structural formulas for simple aromatic compounds.	30–C1.3k	Section 14.2: Hydrocarbons, pp. 561-562
Students will build molecular models depicting the structure of selected organic compounds, including polymers.	30–C1.2s 30–C2.3s	Investigation 14.B, Section 14.2: Hydrocarbons, p. 563 Investigation 15.B, Section 15.2: Polymers and the Petrochemical Industry, pp. 607-608
Students will name and draw structural and condensed structural formulas for structural isomers.	30–C1.5k	Section 14.3: Hydrocarbon Derivatives, p. 573
Given the structural formula of an organic compound, students will make predictions for the physical properties of the compound.		Section 14.3: Hydrocarbon Derivatives, p. 573

Activities and Target Skills

Activity	Target Skills
Chapter 14: Structure and Physical Properties of Organic Compounds	
Launch Lab: Familiar Organic Compounds	■ Preparing methyl salicylate from salicylic acid ■ Identifying the common chemical name for methyl salicylate from its characteristic aroma
Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes	■ Comparing the physical properties of fullerenes with those of diamond and graphite
Investigation 14.A: Comparing Organic and Inorganic Compounds	■ Performing an experiment to compare the properties of organic to inorganic components
Investigation 14.B: Modelling Organic Compounds	■ Building molecular models depicting the structures of selected organic compounds ■ Analyzing the structure of molecular models
Investigation 14.C: Separate an Organic Mixture	■ Designing a procedure for separating a mixture of organic compounds based on boiling point differences
Chapter 15: Reactions of Organic Compounds	
Launch Lab: Comparing the Reactivity of Alkanes and Alkenes	■ Using an organic reaction to identify the difference between saturated fats and unsaturated fats
Thought Lab 15.1: Fossil Fuels and Climate Change	■ Understanding that science and technology have both intended and unintended consequences ■ Assessing the effects of burning fossil fuels on climate change
Investigation 15.A: Preparing Esters	■ Performing an investigation of esterification reactions by producing an ester ■ Describing procedures for safe handling, storage, and disposal of materials used in the laboratory with reference to WHMIS labelling
Thought Lab 15.2: Problem Solving with Organic Compounds	■ Assessing the impact of CFCs on the ozone layer ■ Describing the processes involved in producing gasoline and adjusting the octane rating
Investigation 15.B: Modelling and Making Polymers	■ Building models depicting the structures of organic compounds ■ Performing an experiment to synthesize a polymer ■ Analyzing a process for producing polymers

Conceptual Challenges

Section 14.2

- Many students will initially find naming aliphatic hydrocarbons difficult. The two most common difficulties (which often carry over to naming compounds that contain a functional group) are identifying the longest chain of carbon atoms, and the correct numbering of carbon atoms in the chain. Point out, with examples, that "1-methyl" and 2-ethyl" must be incorrect because the longest chain of carbon atoms was not identified. Students will often begin numbering atoms at the end most convenient to them, which is usually on the left. Organic molecules are modelled in Investigation 14.B (Section 14.2: Hydrocarbons, pp. 563), and this is an important activity to help see how the correct numbering scheme is essential for an unambiguous name. The text has many worked examples and sample problems for students to work on, and students who continue to have problems correctly naming compounds should be encouraged to build models for these problems.
- Many students think of benzene as having three double bonds and three single bonds, and, unfortunately, some textbooks show that structure. The term "resonance" must be carefully explained, otherwise students will have a completely incorrect idea of the structure of benzene and other resonance molecules. As discussed in the student text, the electrons involved in the double bonds in benzene are actually "shared" over the entire molecule. Explain delocalized bonding in benzene, and point out that this bonding model predicts each carbon-carbon bond is chemically identical. Benzene would be expected to combine with reactants in addition reactions if there were double bonds present, but this does not happen.

Section 14.3

- When studying hydrogen bonding between organic molecules, students sometimes think that any molecule containing an O, N, or F atom can undergo hydrogen bonding. In fact, the O, N, or F atom must be *directly bonded* to a hydrogen atom in order for hydrogen bonding to occur between molecules. In addition, students can become confused between different appearances of the –OH group. Take time to explain how the –OH group in hydroxides, alcohols, and carboxylic acids is different.
- Students may find it difficult to differentiate between the reaction conditions for the *elimination* of an alcohol and the reaction conditions for the substitution of an alcohol. Both reactions involve an alcohol and an acid. The elimination reaction, however, involves sulfuric acid, H_2SO_4. If a halogen acid such as HCl or HBr is present, the reaction will be a substitution.

Section 14.4

- Many people, not just students, regard synthetic chemicals with suspicion. Compounds found in nature are identical to those made by chemists when the structures are the same. We want our students to be able to assess the benefits and disadvantages of chemicals or any other technology we use, and the text illustrates this with several fair and balanced examples.

Using the Unit 7 Preparation Feature

The unit opener and the Focussing Questions introduce organic compounds, asking students to begin to consider the uses of the reactions of organic compounds and their technical applications. The Unit Preparation feature will help students recall previous studies about intermolecular forces, including a brief review of bond polarity and hydrogen bonding. Encourage students to take the Unit Prequiz (found at **www.albertachemistry.ca,** Online Learning Centre, Student Edition) to gauge their recall of these concepts and methods, noting that if they are familiar with the background science, their experience with this unit will be much easier.

UNIT 7: COURSE MATERIALS

Chapter, Section	Item Description	Suggested Quantity (assume 40 in class)	Text Activity
Chapters 14, 15	safety goggles	40 pairs	Chapter 14 Launch Lab; Chapter 15 Launch Lab; Investigations: 14.A, 14.C, 15.A, 15.B
Chapters 14, 15	nonlatex disposable gloves	40 pairs $\times$ 6 investigations	Chapter 14 Launch Lab; Chapter 15 Launch Lab; Investigations: 14.A, 14.C, 15.A, 15.B
Chapters 14, 15	aprons	40	Chapter 14 Launch Lab; Chapter 15 Launch Lab; Investigations: 14.A, 14.C, 15.A, 15.B
Chapter 14, Chapter Opener	water salicylic acid methanol [*Note: flammable and poisonous*] 3.0 mol/L sulfuric acid, H_2SO_4(aq) [*Note: corrosive and poisonous*] 1.0 mol/L sodium carbonate, Na_2CO_3(aq) 100 mL graduated cylinder 250 mL beaker hot plate or electric kettle small test tube rubber stopper to fit test tube test tube rack beaker tongs test tube clamp	4 L 1 drop per group [*Note: If using powdered Aspirin™, use amount about the size of a match head per group*] 3 drops per group 1 drop per group 4 drops per group 1 per group 1 per group 1 per group 1 per group 1 per group 1 per group 1 per group 1 per group	Launch Lab: Familiar Organic Compounds, p. 537
Chapter 14, Section 14.1	deionized (or distilled) water, H_2O (ℓ) ethanoic acid, $C_2H_4O_2$ (ℓ) (acetic acid or vinegar) [Note: corrosive] propanol, C_3H_8O (ℓ) [*Note: flammable and poisonous*] pentane, C_5H_{12} (ℓ) [*Note: flammable*] sodium chloride crystals, NaCl(s) (table salt) sodium hydrogen carbonate, $NaHCO_3$(s) (baking soda) calcium carbonate, $CaCO_3$(s) salicylic acid crystals, $C_7H_6O_3$(s) sucrose crystals, $C_{12}H_{22}O_{11}$(s) (table sugar) naphthalene, $C_{10}H_8$ (s) (mothball crystals) [*Note: oxidizing and poisonous*] food colouring (red, green, or blue) hexane, C_6H_{14} (ℓ), or cyclohexane, C_6H_{12} (ℓ) [*Note: flammable and poisonous*] propylene glycol, $C_3H_8O_2$ ([el]) (propane-1,2-diol) [*Note: poisonous*] glycerol, $C_3H_8O_3$ (ℓ)) (propane-1,2,3-triol) 1 mL pipette or medicine dropper well plate (12 or 24 wells are preferable) conductivity tester microspatula or wood splint test tubes	12 mL per group 7 mL per group for Part 1 & 2; 25 mL per station for Part 3 7 mL per group for Part 1 & 2; 25 mL per station for Part 3 7 mL per group 1 box 1.25 mL per group 1.25 mL per group 1.25 mL per group 1.25 mL per group 1.25 mL per group 45 drops 1 mL per group 25 mL per station for Part 3 25 mL per station for Part 3 1 per group 1 per group 1 per group 5 per group 5 per group	Investigation 14.A: Comparing Organic and Inorganic Compounds, pp. 540–541

Chapter, Section	Item Description	Suggested Quantity (assume 40 in class)	Text Activity
Chapter 14, Section 14.1 (continued)	grease pen or marker plastic wrap or Parafilm' test tube rack 50 mL burettes double burette clamps 2-ring stands 250 mL Erlenmeyer flasks stopwatch funnel	10 1 roll 1 per group 4 per station for Part 3 2 per station for Part 3 2 per station for Part 3 4 per station for Part 3 1 per station for Part 3 4 per station for Part 3	
Chapter 14, Section 14.2	paper and pencil molecular modelling kit	1 per student 1 per student	Investigation 14.B: Modelling Organic Compounds, p. 563
Chapter 14, Section 14.4	corn oil ethanoic acid (vinegar) [*Note: corrosive and flammable*] commercial grade cyclohexane [*Note: flammable and poisonous*] iodine crystals, $I_2(s)$ [*Note: skin irritant*] distillation apparatus (varies) [see note] boiling chips cobalt chloride paper litmus paper wood splint or microspatula test tubes or 50 mL beakers test tube rack reference tables and access to library resources or the Internet	500 mL 500 mL 500 mL 500 mL 1 per group 1 box or bag 1 box 1 box 1 per group 5 per group 1 per group 10	Investigation 14.C: Separate an Organic Mixture, p. 581 [*Note: 2 basic setups are available: (1) using traditional distillation apparatus, which may be in short supply; (2) using a simpler test tube setup.*]
Chapter 15, Chapter Opener	samples of vegetable oils, such as margarine, corn oil, and coconut oil samples of animal fats, such as butter and lard 5.0 mmol/L $KMnO_4(aq)$ (potassium permanganate) [*Note: Class C Oxidizing Material and E Corrosive Material*] warm-water bath hot plate medicine droppers [*Note: have a container of soapy water ready to clean used droppers and test tubes.*] test tubes test tube rack stoppers sodium bisulfite (to remove stains in case of spillage)	~500 mL of each sample ~500 mL of each sample ~700 mL 4-10 2-5 1 for each sample per group 2 per group 1 per group 2 per group	Launch Lab: Comparing the Reactivity of Alkanes and Alkenes , p. 587

Chapter, Section	Item Description	Suggested Quantity (assume 40 in class)	Text Activity
Chapter 15, Section 15.1	ice (to use as chips) tap water distilled water ethanoic acid [*Note: corrosive and flammable*] ethanol [*Note: flammable, poisonous and toxic immediate, poisonous toxic*] propan-1-ol [*Note: flammable and poisonous*] butanoic acid [*Note: flammable and corrosive*] 6 mol/L sulfuric acid [*Note: corrosive and poisonous*] 250 mL beakers 50 mL beakers 100 mL beaker 10 mL graduated pipettes watch glass hot plate thermometer (alcohol or digital) retort stand clamps plastic micropipettes medicine dropper rubber stopper or paper towel (to hold thermometer)	2 bags approx. 200 mL per group 5 mL per group 2 mL per group 2 mL per group 1 mL per group 1 mL per group 12 drops per group 2 per group 2 per group 1 per group 3 per group 3 per group 2-5 1 per group 1 per group 2 per group 4 per group 1 1 stopper per group or 1 roll per class	Investigation 15.A: Preparing Esters, p. 597–599
Chapter 15 Section 15.2	Part 1: molecular model kit Part 2: pieces of polyvinyl alcohol bags (totalling about 20 cm^2) very hot water food colouring 4% borax solution kettle or hot plate 10 mL graduated cylinder 50 mL beaker stirring rod	 1 per group 20 10 mL per group 2 drops per group 5 mL per group 3–5 1 per group 1 per group 1 per group	Investigation 15.B: Modelling and Making Polymers, pp. 607–608

CHAPTER 14 STRUCTURE AND PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS

Curriculum Correlation

(Note: This correlation includes Chapters 14 and 15. Chapter 14 references are in bold.)

General Outcome 1: Students will explore organic compounds as a common form of matter.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–C1.1k define organic compounds as compounds containing carbon, recognizing inorganic exceptions such as carbonates, cyanides and carbides	**Defining Organic Compounds, Section 14.1, pp. 538-539**	**Section 14.1 Review: 1-7, p. 543** **Chapter 14 Review: 1-4, pp. 584-585** **Chapter 14 Test** Unit 7 Review: 1-4, pp. 620-623
30–C1.2k identify and describe significant organic compounds in daily life, demonstrating generalized knowledge of their origins and applications; e.g., *methane, methanol, ethane, ethanol, ethanoic acid, propane, benzene, octane, glucose, polyethylene*	**Throughout Chapters 14** and 15	**Section 14.1 Review: 1-7, p. 543** **Section 14.4 Review: 1-8, p. 582** **Chapter 14 Review: 1-4, 23-25, pp. 584-585** **Chapter 14 Test** Unit 7 Review: 32-36, pp. 620-623
30–C1.3k name and draw structural, condensed structural, and line diagrams and formulas for saturated and unsaturated aliphatic (including cyclic) and aromatic carbon compounds [bullet] containing up to 10 carbon atoms in the parent chain/cyclical structure ■ containing only one type of a functional group (including only alcohols, carboxylic acids, esters, or multiple bond ■ using International Union of Pure and Applied Chemistry (IUPAC) nomenclature guidelines	**Modelling Alkanes, Section 14.2, p. 545** **Naming Alkanes, Section 14.2, pp. 546-548** **Sample Problem: Naming Alkanes, Section 14.2, p. 548** **Drawing Alkanes, Section 14.2, pp. 549-550** **Sample Problem: Drawing an Alkane, Section 14.2, p. 550** **Modelling Alkenes, Section 14.2, pp. 552-553** **Naming Alkenes, Section 14.2, p. 553** **Sample Problem: Naming Alkenes, Section 14.2, p. 553** **Sample Problem: Drawing Alkenes, Section 14.2, p. 555** **Naming and Drawing Alkynes, Section 14.2, p. 556** **Naming Cyclic Hydrocarbons, Section 14.2, p. 558** **Sample Problem: Naming Cyclic Hydrocarbons, Section 14.2, p. 559** **Naming Aromatic Hydrocarbons, Section 14.2, p. 561** **Sample Problem: Naming and Drawing Aromatic Hydrocarbons, Section 14.2, p. 562** **Naming and Drawing Alcohols, Section 14.3, p. 566** **Sample Problem: Naming Alcohols, Section 14.3, pp. 566-567** **Naming and Drawing Alkyl Halides, Section 14.3, p. 568** **Naming and Drawing Carboxylic Acids, Section 14.3, p. 570** **Sample Problem: Naming Carboxylic Acids, Section 14.3, p. 570** **Naming and Drawing Esters, Section 14.3, pp. 571-572**	**Practice Problems: 1-3, Section 14.2, p. 549** **Practice Problems: 4-9, Section 14.2, pp. 550-551** **Practice Problems: 10-13, Section 14.2, p. 554** **Practice Problems: 14, 15, Section 14.2, p. 555** **Practice Problems: 16, 17, Section 14.2, pp. 556-557** **Practice Problems: 18-23, Section 14.2, pp. 559-560** **Practice Problems: 24-27, Section 14.2, pp. 562** **Section 14.2 Review: 1-8, p. 564** **Practice Problems: 28-30, Section 14.3, p. 567** **Practice Problems: 31-32, Section 14.3, p. 569** **Practice Problems: 33-36, Section 14.3, p. 570**

	Student Textbook	Assessment Options
30–C1.3k (continued)	**Sample Problem: Naming Esters, Section 14.3, pp. 572**	**Practice Problems: 37, 38, Section 14.3, p. 572** **Section 14.3 Review: 1, 2, 7, p. 574** **Chapter 14 Review: 7, 9-13, 22, pp. 584-585** **Chapter 14 Test** Unit 7 Review: 5-7, 10-13, 18, 21, 22, 24, 27, pp. 620-623
30–C1.4k identify types of compounds from the functional groups (carboxyl, hydroxyl, ester linkage, and halogen), given the structural formula	**Hydrocarbon Derivatives, Section 14.3, pp. 565-566**	**Section 14.3 Review: 6, p. 574** **Chapter 14 Review: 8, 9, 12, pp. 584-585** **Chapter 14 Test** Unit 7 Review: 7, 8, 11, 27, pp. 620-623
30–C1.5k define structural isomerism as compounds having the same empirical formulas but different structural formulas and relate to variations in properties of structural isomers	**Structural Isomerism, Section 14.3, p. 573**	**Questions for Comprehension: 1, 2, Section 14.3, p. 573** **Section 14.3 Review: 3, 4, p. 574** **Chapter 14 Review: s13, 14, pp. 584-585** **Chapter 14 Test** Unit 7 Review: 9, 13, 25, pp. 620-623
30–C1.6k compare, both within a homologous series and between compounds with different functional groups, the boiling points and solubility of examples of aliphatics, aromatics, alcohols and carboxylic acids	**Physical Properties of Alkanes, Section 14.1, p. 551** **Physical Properties of Alkenes, Section 14.1, p. 555** **Physical Properties of Alkynes, Section 14.1, p. 557** **Physical Properties of Aromatic Compounds, Section 14.1, p. 561** **Physical Properties of Alcohols, Section 14.2, p. 567** **Physical Properties of Carboxylic Acids, Section 14.2, p. 571** **Physical Properties of Esters, Section 14.2, p. 573**	**Section 14.3 Review: 2, 5, 8, p. 574** **Section 14.4 Review: 3, p. 582** **Chapter 14 Review: 14-19, 21, 22, pp. 584-585** **Chapter 14 Test** Unit 7 Review: 23, 26, 32-36, pp. 620-623
30–C1.7k describe, in general terms, the physical, chemical and technological processes used to separate organic compounds from natural mixtures or solutions by fractional distillation and solvent extraction; e.g., *petroleum refining, bitumen recovery.*	**Refining and Using Organic Compounds, Section 14.4, pp. 575-582**	**Section 14.4 Review: 1-8, p. 582** **Chapter 14 Review: 15, 16, 19, 21, 23-25, pp. 584-585** **Chapter 14 Test** Unit 7 Review: 14, 23, 26, 30-36, pp. 620-623
Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)		
30–C1.1sts demonstrate an understanding that science and technology are developed to meet societal needs and expand human capability by ■ *describing where organic compounds are used in processes and common products; e.g., hydrogenation to produce margarine, esters used as flavouring agents*	**Chapter 14 Launch Lab: Familiar Organic Compounds, p. 537** **Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes, Section 14.1, p. 539** **Investigation 14.B: Modelling Organic Compounds, Section 14.2, p. 563** **Connections: Tar Sands and Bitumen, Section 14.4, pp. 576-577**	**Chapter 14 Launch Lab: Familiar Organic Compounds: 1, 2, p. 537** **Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes: 1-3, Section 14.1, p. 539** **Investigation 14.B: Modelling Organic Compounds: 5, 6, Section 14.2, p. 563** **Connections: Tar Sands and Bitumen: 1-3, Section 14.4, pp. 576-577** Unit 7 Review: 32-36, pp. 620-623
30–C1.2sts explain how science and technology are influenced and supported by society and have influenced, and been influenced by, historical development and societal needs by	**Chapter 14 Launch Lab: Familiar Organic Compounds, p. 537** **Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes, Section 14.1, p. 539**	**Chapter 14 Launch Lab: Familiar Organic Compounds: 1, 2, p. 537** **Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes: 1-3, Section 14.1, p. 539**

	Student Textbook	Assessment Options
30–C1.2sts (continued) ■ *explaining how, as a result of chemistry and chemical technology, synthetic compounds of great benefit to society have been produced, e.g., plastics, medicines, hydrocarbon fuels and pesticides.*	**Investigation 14.A: Comparing Organic and Inorganic Compounds, Section 14.1, pp. 540-541** **Connections: Tar Sands and Bitumen, Section 14.4, p. 576**	**Investigation 14.A: Comparing Organic and Inorganic Compounds: 7, Section 14.1, pp. 540-541** **Connections: Tar Sands and Bitumen: 1-3, Section 14.4, p. 576** Unit 7 Review: 32-36, pp. 620-623
Skill Outcomes (Focus on problem solving)		
Initiating and Planning		
30–C1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ designing a procedure to identify types of organic compounds	**Investigation 14.C: Separate an Organic Mixture, Section 14.4, p. 581**	**Investigation 14.C: Separate an Organic Mixture: 1-5, Section 14.4, p. 581** Unit 7 Review: 14, 23, 26, 30-36, pp. 620-623
■ describing procedures for safe handling, storage and disposal of materials used in the laboratory, with reference to WHMIS and consumer product labelling information		
■ designing a procedure for separating a mixture of organic compounds based on boiling point differences.		
Performing and Recording		
30–C1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by ■ building molecular models depicting the structures of selected organic and inorganic compounds	**Investigation 14.B: Modelling Organic Compounds, Section 14.2, p. 563**	**Investigation 14.B: Modelling Organic Compounds: 1-6, Section 14.2, p. 563**
■ performing an experiment to compare the properties of organic to inorganic compounds, e.g., solubility, viscosity, density, conductivity, reactivity.	**Investigation 14.A: Comparing Organic and Inorganic Compounds, Section 14.1, pp. 540-541**	**Investigation 14.A: Comparing Organic and Inorganic Compounds: 1-7, Section 14.1, pp. 540-541**
Analyzing and Interpreting		
30–C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ following appropriate IUPAC guidelines in writing the names and formulas of organic compounds	**Investigation 14.B: Modelling Organic Compounds, Section 14.2, p. 563**	**Investigation 14.B: Modelling Organic Compounds: 1-6, Section 14.2, p. 563**
■ compiling and organizing data to compare the properties of structural isomers; e.g., *pairs of hydrocarbon isomers, primary, secondary and tertiary alcohols*	**Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes, Section 14.1, p. 539**	**Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes: 1-3, Section 14.1, p. 539**
■ interpreting the results of a test to distinguish between a saturated and an unsaturated aliphatic using aqueous bromine or potassium permanganate solutions	Chapter 15 Launch Lab: Comparing the Reactivity of Alkanes and Alkenes, p. 587	Chapter 15 Launch Lab: Comparing the Reactivity of Alkanes and Alkenes: 1-4, p. 587
■ *analyzing the contributions and limitations of scientific and technological knowledge to societal decision making in relation to the costs and benefits of society's use of petrochemicals, pharmaceuticals and pesticides.*	**Connections: Tar Sands and Bitumen, Section 14.4, p. 576**	**Connections: Tar Sands and Bitumen: 1-3, Section 14.4, p. 576**
Communication and Teamwork		
30–C1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *using advanced menu features within a word processor to accomplish a task and to insert tables, graphs, text and graphics.*	**Investigation 14.A: Comparing Organic and Inorganic Compounds, Section 14.1, pp. 540-541** **Connections: Tar Sands and Bitumen, Section 14.4, p. 576**	**Investigation 14.A: Comparing Organic and Inorganic Compounds: 1-7, Section 14.1, pp. 540-541** **Connections: Tar Sands and Bitumen: 1, 2, Section 14.4, p. 576**

Chapter 14

Structure and Physical Properties of Organic Compounds

Student Textbook pages 536–585

Chapter Concepts

Section 14.1 Introducing Organic Compounds

- The study of traditional sources of medicines has led to important discoveries of organic compounds that can be used to treat illness and disease.
- Organic compounds contain carbon atoms, which bond to one another in chains, rings, and two- and three-dimensional networks to form a variety of structures.

Section 14.2 Hydrocarbons

- The International Union of Pure and Applied Chemistry (IUPAC) system lists rules for naming organic compounds based on structural features.
- Structural models are useful tools to use in predicting the chemical and physical properties of organic compounds.

Section 14.3 Hydrocarbon Derivatives

- Functional groups are responsible for characteristic physical and chemical properties of organic compounds.
- Isomers of compounds contain the same number and type of atoms but are structurally different and have different properties.

Section 14.4 Refining and Using Organic Compounds

- Organic compounds can be separated from natural mixtures, such as petroleum or coal, by physical and chemical processes.
- The enhanced recovery techniques that must be used to extract crude oil from Alberta's bitumen deposits present technological and environmental challenges.

Common Misconceptions

- Students often use a too simplistic definition of organic chemistry and assume that any carbon-containing compound is organic. Reinforce the fact that, even though they contain carbon, carbonates, cyanides, and carbides are classified as inorganic.
- When forming IUPAC names for compounds, students often begin numbering carbons from the left side of the molecules. Emphasize that numbering of the longest chain of carbons most often begins at the end closest to the location of a multiple bond or functional group.
- Students have a tendency to mistake the hydroxyl (–OH) functional group as being the same as the hydroxide ion (OH^-). Be sure to make students aware of the difference between the two.

Helpful Resources

Journal Articles

- White, R. "The great climate debate," *Scientific American.* July 1990.
- Byrd, S., and Hildreth, D.P. "Learning the Functional Groups: Keys to Success," *Journal of Chemical Education.* Vol. 10, 2001, p. 1355.

Web Sites

Web links to the materials related to this chapter can be found at **www.albertachemistry.ca**. Go to the Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web Links.

List of BLMs

Blackline masters (BLMs) have been prepared to support the material in this chapter. The BLMs are either for assessment (AST); use as overheads (OH); use as handouts (HAND), in particular to support activities. Most handouts and all assessment tools are supported by a BLM with the answers (ANS). The BLMs are in digital form, stored on the CD-ROM that accompanies this Teacher's Resource or on the web site at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs. They can be modified to suit the needs of your students.

Number (Type) Title

14.0.1 (OH) Molecular Shapes
14.0.2 (OH) Molecular Shapes and Polarity
14.0.3 (HAND) Launch Lab: Familiar Organic Compounds
14.0.3A (ANS) Launch Lab: Familiar Organic Compounds Answer Key

14.1.1 (HAND) Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes
14.1.1A (ANS) Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes Answer Key
14.1.2 (HAND) Investigation 14.A: Comparing Organic and Inorganic Compounds
14.1.2A (ANS) Investigation 14.A: Comparing Organic and Inorganic Compounds Answer Key

14.2.1 (OH) Steps in Naming Alkanes
14.2.2 (OH) Drawing Alkanes
14.2.3 (OH) Naming Alkenes
14.2.4 (OH) Drawing Alkenes
14.2.5 (OH) Naming Cyclic Hydrocarbons
14.2.6 (AST) Alphatic Hydrocarbons Quiz
14.2.6A (ANS) Alphatic Hydrocarbons Quiz Answer Key
14.2.7 (AST) Naming and Drawing of Hydrocarbons Quiz
14.2.7A (ANS) Naming and Drawing of Hydrocarbons Quiz Answer Key
14.2.8 (HAND) Investigation 14.B: Modelling Organic Compounds
14.2.8A (ANS) Investigation 14.B: Modelling Organic Compounds Answer Key

14.3.1 (OH) Naming and Drawing Alkyl Halides
14.3.2 (OH) Naming and Drawing Carboxylic Acids

14.3.3 (OH) Naming and Drawing Esters
14.3.4 (OH) Common Chemical Families and Their Functional Groups
14.4.1 (OH) Fractional Distillation Towers
14.4.2 (OH) Petroleum Fractionation Products
14.4.3 (AST) Fractional Distillation of Crude Oil Quiz
14.4.3A (ANS) Fractional Distillation of Crude Oil Quiz Answer Key
14.4.4 (HAND) Investigation 14.C: Separate an Organic Mixture
14.4.4A (ANS) Investigation 14.C: Separate an Organic Mixture Answer Key
14.5.1 (AST) Chapter 14 Test
14.5.1A (ANS) Chapter 14 Test Answer Key

Using the Chapter 14 Opener

Student Textbook pages 536–537

Teaching Strategies

- Read the Chapter Opener with your students. Ask students to brainstorm what they know about organic compounds. Have them list organic compounds they are familiar with. Ask them what these compounds are used for.
- Students may need to review the concepts of bonding pairs and lone pairs of electrons.

Launch Lab Familiar Organic Compounds

Student Textbook page 537

Purpose

Students will prepare methyl salicylate from salicylic acid and identify the common chemical name for this compound based on its aroma.

Outcome

- 30-C1.1sts

Advance Preparation

When to Begin	What to Do
2 –3 days before	■ Gather required materials.
1 day before	■ Set out materials for each group. ■ Photocopy **BLM 14.0.3 (HAND) Launch Lab: Familiar Organic Compounds**
1 hour before	■ Set up communal hot water baths, as needed. ■ Place the sulfuric acid and salicylic acid in a fume hood for ventilation of vapours.

Materials
■ water ■ salicylic acid ■ methanol ■ 3.0 mol/L sulfuric acid, $H_2SO_4(aq)$ ■ 1.0 mol/L sodium carbonate, $Na_2CO_3(aq)$ ■ 100 mL graduated cylinder ■ 250 mL beaker ■ hot plate or electric kettle ■ small test tube ■ rubber stopper to fit test tube ■ test tube rack ■ beaker tongs ■ test tube clamp

Time Required

- 30 to 40 minutes

Helpful Tips

- If you are using powdered salicylic acid (Aspirin^{TM}) instead of a solution, use an amount that is about the size of a match head.
- To expedite the process, have central or communal hot water baths ready before the lab begins. Remind students to label their test tube for easier identification.
- Use **BLM 14.0.3 (HAND) Launch Lab: Familiar Organic Compounds** to support this activity. Remove sections as necessary to meet the needs of students in your class.
- ***Expected Results:*** The reaction between salicylic acid and methanol is an esterification reaction and the product will be methyl salicylate. The odour of methyl salicylate is that of wintergreen.

Safety Precautions

- Ensure students read and understand "Safety in Your Chemistry Laboratory and Classroom" pages xii–xv in the student textbook.
- Since methanol is flammable, do not use a Bunsen burner or any other source of open flame in this lab.

- Advise students that methanol is toxic. Any spills on their skin should be rinsed with copious amounts of water.
- Remind students that $H_2SO_4(aq)$ is highly corrosive and that they should use with extreme caution. Any spills on skin or clothing should be rinsed with plenty of cold water.
- This would be an ideal time to review the appropriate technique for smelling substances in a lab with students.
- When heating the methanol, ensure students are pointing the mouth of the test tube away from others.
- Clearly demonstrate how and where students should dispose of waste materials when they have completed the lab.

Answers to Analysis Questions

1. Commercial products that contain methyl salicylate are those that exhibit the characteristic smell of "wintergreen" such as toothpastes, mouthwash, anesthetic ointments, and even rootbeer.
2. The common name for methyl salicylate is "oil of wintergreen."

Assessment Options

- Collect and assess students' reports and answers to Analysis questions.
- Use Assessment Checklist 2: Laboratory Report from Appendix A.

14.1 Introducing Organic Compounds

Student Textbook pages 538–543

Section Outcomes

Students will:

- define organic compounds and give examples of their origin, significance, and applications
- carry out an investigation comparing the properties of household organic and inorganic compounds.

Key Terms

organic compounds
inorganic compounds
allotrope

Chemistry Background

- For most of human history the only source of medicinal drugs available to healers were extracts of various plants. Today, somewhere around 75% of the global population still depend on traditional medicinal plants. Importantly, over 25% of prescription medications still contain one or more components obtained directly from plant extracts.
- The carbon atoms that form sheets of graphite and walls of carbon nanotubes are arranged in interconnected hexagonal rings. Each carbon atom is connected to three adjacent carbon atoms by exceptionally strong covalent bonds. The molecular symmetry of carbon nanotubes and strength of carbon-carbon bonding results in exceptional strength, elasticity, stiffness, and thermal conductivity. In addition, each carbon atom donates a delocalized pi electron to the network, resulting in conductivity equal to or better than that of metals.
- Hydrocarbon organic compounds are non-polar and soluble in non-polar solvents. Since these compounds do not dissolve in water, they do not form electrolytes and do not conduct electricity.
- Hydrocarbon derivative compounds may have polar regions and so may be slightly soluble in water. Organic acids will form weak electrolytes and exhibit some electrical conductivity in solution.
- Most organic compounds are essentially non-polar, resulting in relatively weak intermolecular forces. Consequently, boiling and melting points tend to be relatively low in comparison to inorganic compounds.

Teaching Strategies

- Discuss with students the nature of the carbon-carbon bonds that form for graphite, diamond, and fullerenes. Discuss how the hardness and thermal conductance of diamond is a function of its three-dimensional structure.
- Review the concept of covalent bonding and polar covalent bonding with your students. Use this reinforcement to help explain how the bonding between carbon atoms and other atoms may produce the intermolecular forces involved in hydrogen bonding. Have students explain how this would increase the solubility of hydrocarbons in water.
- The BLMs prepared for this section support the activities. You will find them with the Chapter 14 BLMs on the CD-ROM that accompanies this Teacher's Resource or at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs.

SUPPORTING DIVERSE STUDENT NEEDS

Hands-on learners might be interested in constructing a large model of a buckminister fullerene (C_{60}) for display purposes. Use Styrofoam™ balls to represent carbon atoms and plastic straws cut in half to represent chemical bonds.

Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes

Student Textbook page 539

Purpose

Students will use print and electronic resources to investigate the properties of the three allotropes of carbon – diamond, graphite, and fullerenes.

Outcome

- 30-C2.3s

Advance Preparation

When to Begin	What to Do
2 weeks before	■ Arrange with a librarian for a research period for your class, and/or access to a computer lab with Internet access.
1 day before	■ Photocopy **BLM 14.1.1 (HAND) Thought Lab 14.1: Nanotubes, Buckyballs, and Allotropes.**

Materials
■ none required

Time Required

- 40 to 60 minutes

Helpful Tips

- This activity could be assigned as an extracurricular assignment, if necessary.
- There are numerous Internet sites with information regarding this topic. Encourage students to check more than one site, and have students reference the sites used to prepare their answers.
- Use **BLM 14.1.1 (HAND) Thought Lab 14.1.1: Nanotubes, Buckyballs, and Allotropes** to support this activity. Remove sections as necessary to meet the needs of students in your class.

Answers to Procedure Questions

1. Since the geometric form of the C_{60} allotrope reminded scientists of the geodesic domes and structures popularized by the architect Buckminster Fuller, the term "fullerene" was coined for the generic name of this allotrope.
2. The properties of graphite and diamond are almost the opposite of each other. Students might produce a chart similar to the following:

	Graphite	Diamond
Electrical conductivity	excellent – a conductor	poor – an insulator
Structural characteristics	sheets of interconnected hexagonal rings. Adjacent sheets are loosely bonded together by van der Waals forces.	tetrahedral arrangements of carbon atoms forming a partially filled face-centered cubic arrangement.
Hardness	soft	extreme
Colour	opaque grayish-black with a metallic sheen.	transparent and colourless, but structural flaws and impurities will result in coloured appearance.

3. Depending on their precise structure, fullerenes can be either metallic conductors or semiconductors. Fullerenes in the form of nanotubes can carry the highest electric current density of any known material.
4. Carbon nanotubes are tubes of planar interconnected hexagonal rings about a nanometer in diameter. Nanotubes have a metallic conductivity, extreme thermal conductivity, and are the stiffest and strongest known fibres. Technological uses for nanotubes include as strengtheners for carbon-epoxy composites, as molecular wires, as capsules for delivery of drugs on a molecular scale, and as possible additives for higher temperature superconducting materials.

Answers to Analysis Questions

1. Diamond is composed of carbon atoms bonded to each other in a rigid three dimensional lattice structure. In graphite, carbon atoms are tightly bonded together in sheets, with adjacent sheets being only loosely attracted to each other by van der Waals forces. The ability of adjacent sheets to slide relative to each other makes graphite "soft."
2. Nanotubes are extremely stiff but also amazingly elastic and able to stretch beyond 20% of their length. Replacing the carbon fibres presently used in carbon composite materials with nanotubes is expected to produce materials with many times the structural strength.
3. From a structural point of view, nanotubes are one special case of a fullerene. Although nanotubes exhibit many different properties, those properties are within the range observed for fullerenes in general.

Assessment Options

- Collect and assess students' reports and answers to Procedure and Analysis questions.

- Use Assessment Checklist 7: Independent Research Skills from Appendix A.

Investigation 14.A: Comparing Organic and Inorganic Compounds

Student Textbook pages 540–541

Purpose

Students will observe the solubility, conductivity, miscibility, and viscosity of hydrocarbons, hydrocarbon derivatives, and inorganic compounds and compare their observations with expected properties.

Outcome

- 30-C1.2s

Advance Preparation

When to Begin	What to Do
1 week before	■ Gather materials required.
1 day before	■ Have students formulate a hypothesis about the solubility and viscosity of hydrocarbons, hydrocarbon derivatives, and inorganic compounds in water, based on the presence of polar chemical bonds. ■ Photocopy **BLM 14.1.2 (HAND) Investigation 14.A: Comparing Organic and Inorganic Compounds.**
1 hour before	■ Set up stations for viscosity tests. Label burettes from 1 to 4 and fill burette 1 with 25 mL of ethanoic acid (vinegar), burette 2 with 25 mL of propanol, burette 3 with 25 mL of propylene glycol, and burette 4 with 25 mL of glycerol. After filling, clamp each burette into position and place an empty Erlenmeyer flask under each.
1 hour before	■ Place the propanol, ethanoic acid, pentane, and hexane or cyclohexane in a fume hood for ventilation of vapours. ■ Set out materials for each group.

Materials
■ deionized (or distilled) water, H_2O (ℓ) ■ ethanoic acid, $C_2H_4O_2$ (ℓ) (acetic acid or vinegar) ■ hexane, C_6H_{14} (ℓ) or cyclohexane, C_6H_{12} (ℓ) ■ propanol, C_3H_8O (ℓ) ■ pentane, C_5H_{12} (ℓ) ■ sodium chloride crystals, NaCl(s) (table salt) ■ sodium hydrogen carbonate, $NaHCO_3$(s) (baking soda) ■ calcium carbonate, $CaCO_3$(s) ■ salicylic acid crystals, $C_7H_6O_3$(s) ■ sucrose crystals, $C_{12}H_{22}O_{11}$(s) (table sugar) ■ naphthalene, $C_{10}H_8$ (s) (mothball crystals) ■ food colouring (red, green, or blue) ■ propane-1, 2-diol (propylene glycol), $C_3H_8O_2$ (ℓ) ■ propane-1, 2, 3-triol (glycerol), $C_3H_8O_3$ (ℓ) ■ 1 mL pipette or medicine dropper ■ well plate (12 or 24 wells are preferable) ■ conductivity tester ■ microspatulas or wood splint ■ test tubes ■ grease pen or marker ■ plastic wrap or Parafilm' ■ test tube rack ■ four 50 mL burettes ■ 2 double burette clamps ■ 2-ring stands ■ four 250 mL Erlenmeyer flasks ■ stopwatch ■ 4 funnels

Time Required

- 60 to 80 minutes for Part I
- 20 minutes for Parts II and III.

Helpful Tips

- Part I of this investigation will take the most time. If students are working in groups it may be beneficial to have the group split the tasks amongst themselves to speed up the process.
- Have students construct observation tables for this exercise in advance.
- Use **BLM 14.1.2 (HAND) Investigation 14.A: Comparing Organic and Inorganic Compounds** to support this activity. Remove sections as necessary to meet the needs of students in your class.
- ***Expected Results:***
  - Part I: Initially, only the ethanoic acid will conduct current. The sodium chloride, sodium hydrogen carbonate, calcium chloride, salicylic acid, and sucrose will dissolve in the water and, to some extent in the acetic acid. All of these solutes except sucrose will increase the conductivity of the solution. The naphthalene crystals will dissolve in the pentane and, to some extent, in the propanol. These solutions will still have zero conductivity.

- Part II: The water will be miscible with the ethanoic acid and propanol as seen by the food colouring being spread evenly through the mixture. The water will not be miscible with the pentane or hexane as indicated by the layering of the coloured water and the pentane or hexane.
- Part III: The ethanoic acid and propanol will flow through the burette nearly the same as water. The propanol will be slightly slower than the ethanoic acid. The propane-1,2-diol will be much slower than the ethanoic acid and the propanol. The propane-1,2,3-triol will be significantly slower than even the propane-1,2-diol.

Safety Precautions

- Ensure students read and understand "Safety in Your Chemistry Laboratory and Classroom" on pages xii-xv in the student textbook.
- Organic solvents are flammable. Do not use a Bunsen burner or any other source of open flame. Use of a hot plate is mandatory for this investigation.
- Advise students that propylene glycol is toxic. Any spills on their skin should be rinsed with copious amounts of water.
- Any solvents that are spilled should be immediately cleaned up.
- Clearly demonstrate how and where students should dispose of waste materials when they have completed the investigation.

Answers to Analysis Questions

1. Students should identify inorganic compounds as: deionized water, sodium chloride crystals, sodium hydrogen carbonate, and calcium carbonate. Organic substances should be identified as: ethanoic acid, propanol, pentane, salicylic acid crystals, sucrose crystals, hexane or cyclohexane, naphthalene crystals, propylene glycol, and glycerol.
2. Ionic solids will be sodium chloride crystals, sodium hydrogen carbonate, and calcium carbonate. Molecular solids will be salicylic acid crystals, sucrose crystals, and naphthalene crystals. There are no ionic liquids in this investigation. Molecular liquids are deionized water, ethanoic acid, propanol, pentane, hexane or cyclohexane, propylene glycol, and glycerol.
3. No. Students will find that several solvent-solute combinations contradict this statement.
4. Yes. In general, students will find this to be true. However, the rate of dissolution will often lead students to incorrectly conclude that a solute will not dissolve.
5. Students should observe that ethanoic acid and salicylic acid, which are both molecular substances, do conduct electricity to some extent.
6. Students should note that as the number of carbon-oxygen polar covalent bonds increases, the viscosity also increases. The presence of more polar bonds for a compound will result in greater intermolecular forces of attraction leading to a greater viscosity.

Answer to Conclusion Question

7. Student answers will depend on the quality of observations and nature of the hypotheses. Students should conclude that solubility and viscosity depend on the presence and abundance of polar bonds in a compound. In general, as the non-polar region of a molecule increases in size relative to the polar region, the solubility of a substance in water will decrease.

Assessment Options

- Collect and assess students' reports and answers to Analysis and Conclusion.
- Use Assessment Checklist 2: Laboratory Report from Appendix A.

Section 14.1 Review Answers

Student Textbook page 543

1. Some organic compounds include: methane, octane, nylon, polysterene, ehtanol, linen, and wool. Some inorganic compounds include: aluminium chloride (deodorant), calcium chloride (road salt), carbon dioxide, carbon monoxide, potassium chloride (fertilizer), sodium chloride (table salt), and sodium fluoride (toothpaste).
2. The key idea behind vitalism was that living organisms had the unique ability to produce organic compounds. The synthesis of organic compounds, such as urea by Wöhler and acetic acid by Kolbe, from inorganic starting materials showed this to be incorrect.
3. The three properties of carbon that allow it to form a large variety of compounds are: (i) it has four bonding electrons, which allows the formation of four strong covalent bonds to a variety of different elements; (ii) it can form single/double/triple covalent bonds and stable chains; (iii) carbon-based molecules can assume various geometric shapes.
4. The difference lies in how the carbon atoms are bonded to each other. For graphite, three valence electrons form covalent bonds with other carbon atoms to form sheets of carbon atoms. The fourth valence electron is delocalized across the sheet of carbon atoms making graphite an electrical conductor. Adjacent sheets of carbon atoms are held together by weak London dispersion forces allowing sheets to easily slide past each other. In diamond, each valence electron forms a strong covalent bond with an adjacent carbon atom in a three-dimensional lattice structure. Each bond is of identical strength giving great

hardness to the structure. With no delocalized electrons, diamond is an electrical insulator.

5. Silicon-silicon covalent bonds are weaker than carbon-carbon covalent bonds and are more unstable. Since these bonds are more easily broken, you are less likely to find silicon compounds.
6. The solubility of any compound is generally determined by whether the molecules of a solvent are able to interact with molecules of the solute. Solubility increases with the amount of intermolecular forces acting between solvent and solute molecules.
7. Organic compounds generally tend to be non-polar and so have poor solubility in a polar solvent such as water. In general, with the exception of carboxylic acids, organic compounds do not form ions when in solution and so do not conduct electricity. In most investigations these statements hold true. Carboxylic acids, with the exception of those with short carbon chains, are such weak acids that they generally do not ionize in solution and are poor conductors of electricity.

14.2 Hydrocarbons

Student Textbook page 544–564

Section Outcomes

Students will:

- name and draw structural, condensed structural, and line diagrams and formulas for saturated and unsaturated aliphatic and aromatic hydrocarbons
- construct molecular models to represent the structures of selected organic and inorganic compounds.

Key Terms

hydrocarbons
alkanes
saturated hydrocarbons
aliphatic compounds
homologous series
root
prefix
suffix
substituent groups
side groups
alkyl groups
alkenes
unsaturated hydrocarbons
alkynes
cyclic hydrocarbons
aromatic compounds
benzene
phenyl group

Chemistry Background

- The IUPAC nomenclature system specifies the exact locations of multiple bonds and functional groups in a carbon chain. Multiple bonds will form regions in which electrons are available for chemical reaction.
- Carbon-carbon single bonds (sigma bonds) are the strongest type of covalent bond due to the linear symmetry of how the electron orbitals from each atom overlap between the nuclei. If a second or third covalent bond is formed between those atoms, the overlap of electron orbitals results in a hybrid orbital (pi bond) with regions of electron density parallel to, but offset from, the direct line between the carbon nuclei. Electrons in these regions are farther from the atomic nuclei so do not form as strong a covalent bond as a sigma bond.
- Although pi bonds are weaker than sigma bonds, they only form as a multiple bond. The combination of a sigma bond and pi bond in a double or triple bond results in very strong covalent bonding between adjacent carbon atoms.
- Carbon typically forms a total of four bonds. If all are single bonds, the geometry of the molecular is tetrahedral. The presence of a double bond causes a trigonal planar geometry, and a triple bond will produce a linear geometry.

Teaching Strategies

- The understanding and use of the IUPAC naming system for organic chemistry is a key skill. Provide students with opportunities to practice drawing and naming both aliphatic, cyclic, and aromatic hydrocarbons.
- Molecular model kits are essential for this section. The ability to construct and manipulate models of organic molecules helps many students to remember the key points for converting names to structures, and structures to names. Be sure to inspect the molecular model kits before starting this section to ensure that all components are present.
- A number of overhead masters and quizzes have been prepared for this section. You will find them with the Chapter 14 BLMs on the CD-ROM that accompanies this Teacher's Resource or at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs

  Number (Type) Title
  14.2.1 (OH) Steps in Naming Alkanes
  14.2.2 (OH) Drawing Alkanes
  14.2.3 (OH) Naming Alkenes
  14.2.4 (OH) Drawing Alkenes
  14.2.5 (OH) Naming Cyclic Hydrocarbons
  14.2.6 (AST) Alphatic Hydrocarbons Quiz
  14.2.6A (ANS) Alphatic Hydrocarbons Quiz Answer Key
  14.2.7 (AST) Naming and Drawing of Hydrocarbons Quiz
  14.2.7A (ANS) Naming and Drawing of Hydrocarbons Quiz Answer Key

SUPPORTING DIVERSE STUDENT NEEDS

Many of the essential oils used in perfumes belong to a class of organic compounds known as terpenes. This class of hydrocarbon usually contains one or more carbon-carbon double bonds. The characteristic scent of turpentine is due largely to the compound ×-Pinene ($C_{10}H_{16}$). In the IUPAC system its name would be (1S,5S)-2,6,6-trimethylbicyclo[3.1.1]hept-2-ene. Challenge advanced students to construct this molecule with their molecular model kits.

Students with an interest in history might find the techniques and history of how essential oils are extracted to be of interest. Have students find out more about this topic and prepare a poster summarizing their research.

Answers to Practice Problems 1–3

For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

Student Textbook page 549

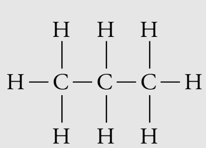
1. **(a)** 2-methylbutane
   (b) 2,2-dimethylpropane
   (c) 3-ethyl-2,5-dimethylheptane
   (d) 2,2,4,4-tetramethylhexane
   (e) 2,2,4-trimethyl-4-propylheptane
2. **(a)** 2,2,3-trimethylbutane
   (b) 5-ethyl-3-methylnonane
   (c) 4,5-diethyl-3-methylnonane
3. **(a)** heptane
   (b) 2,3-dimethylpentane
   (c) 4-ethyl-2,3-dimethylhexane

Answers to Practice Problems 4–9

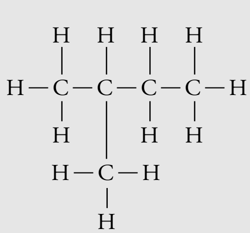
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

Student Textbook page 550–551

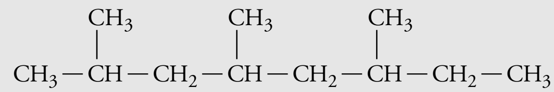
4. **(a)**



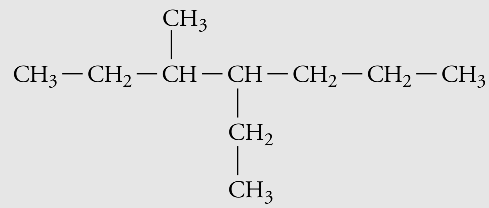
(b)



5. **(a)**

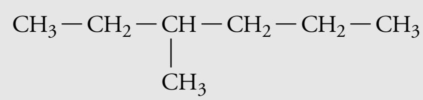


(b)

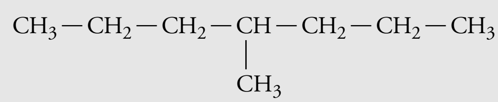


6.
(a) $CH_3CH(CH_3)CH_2CH(CH_3)CH_2CH(CH_3)CH_2CH_3$
(b) $CH_3CH_2CH(CH_3)CH(C_2H_5)CH_2CH_2CH_3$

7.
(a)



(b)



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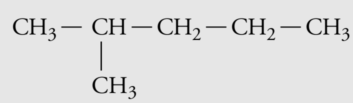
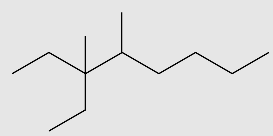
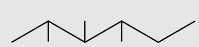


8.
(a)



(b)



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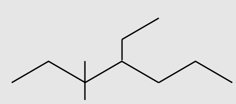

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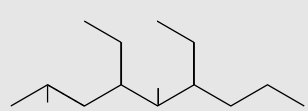


9. (a) The longest continuous chain has 6 carbons, not 5, with two methyl groups (CH_3^-) on carbons C_2 and C_4. The correct name is 2,4-dimethylhexane.

(b) The longest continuous chain of 6 carbons should be numbered from right to left. The correct name is 2,3-dimethylhexane.

(c) The longest continuous chain has 6 carbons, not 5, with an ethyl group ($C_2H_5^-$) and a methyl group (CH_3^-) on carbon C_3. The correct name is 3-ethyl-3-methylhexane.

Answers to Practice Problems 10–13

For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

Student Textbook page 554

10. (a) hex-3-ene

(b) hept-2-ene

11. oct-4-ene

12. 4,4-dimethylpent-2-ene

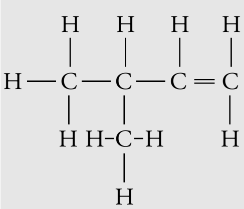
13. 3-ethyl-5-methyl-3-propylhex-1-ene

Answers to Practice Problems 14–15

For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

Student Textbook page 555

14. (a)



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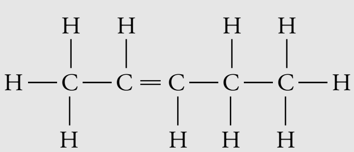

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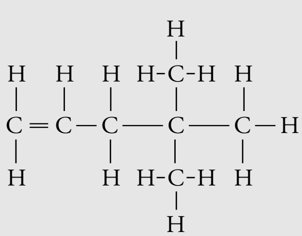
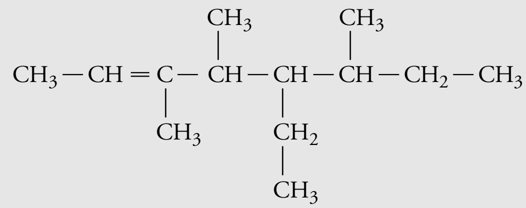


15. (a)



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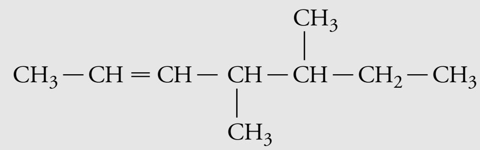

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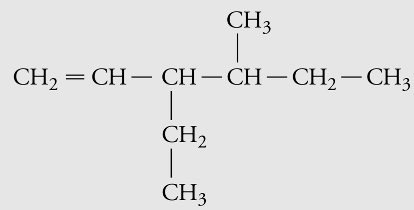

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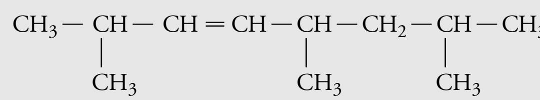


Answers to Practice Problems 16–17

Student Textbook pages 556–557

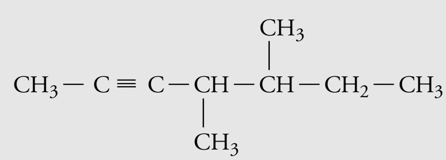
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

16. (a) 4,4-dimethylpent-2-yne

(b) 3-ethyl-5-methyl-3-propylhex-1-yne

17. (a) $CH_3-C\equiv C-CH_2-CH_3$

(b)



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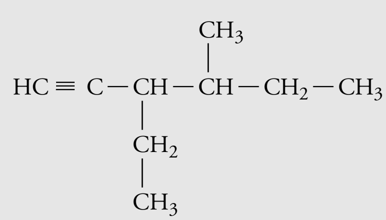

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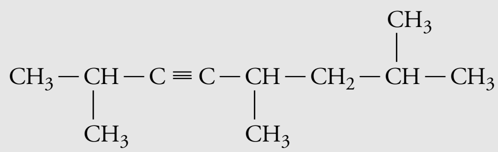


Answers to Practice Problems 18–23

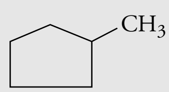
Student Textbook pages 559–560

For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

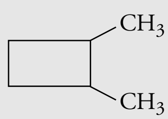
18. (a) methylcyclobutane

(b) 1-ethyl-3-methylcyclopentane

19. (a)



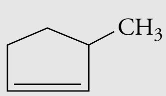
(b)



20. (a) 4-methylcyclooctene

(b) 3-methyl-5-propylcyclopentene

21. (a)



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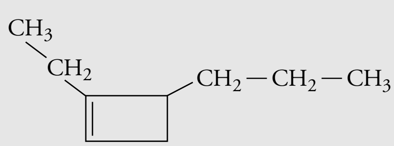
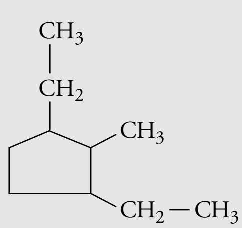


22. (a) 5-ethyl-3,4-dimethylcyclononene

(b) 3,5-diethylcyclohexene

23. (a)



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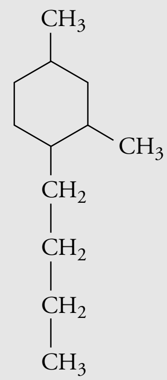


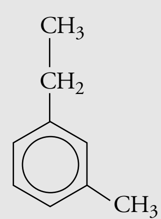
Answers to Practice Problems 24–27

Student Textbook page 562

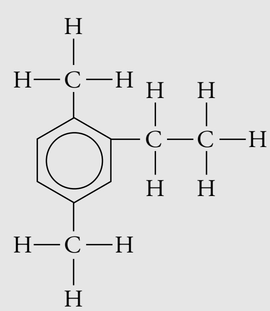
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

24. 1,3,5-trimethylbenzene

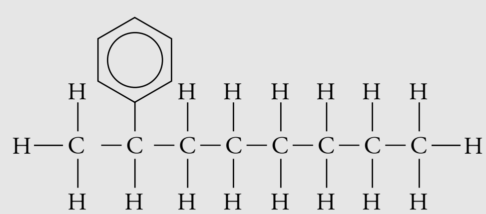
25. (a)



(b)



26.



27. 2,3-diphenylnonane

Investigation 14.B: Modelling Organic Compounds

Student Textbook page 563

Purpose

Students will practice constructing three-dimensional models from the given names for several organic compounds. Students will also inspect the results of adding a double or triple carbon-carbon bond on the structural rigidity and shape of a compound.

Outcomes

- 30-C1.3k
- 30-C1.3s

Advance Preparation

When to Begin	What to Do
1 week before	■ Gather the required materials. In particular, ensure that the molecular model kits have all the necessary components.
1 day before	■ Set out materials for each group. ■ Photocopy **BLM 14.2.8 (HAND) Investigation 14.B: Modelling Organic Compounds.**

Materials
■ molecular modelling kit

Time Required

- 40 to 50 minutes

Helpful Tips

- Remind students that when using molecular model kits each hole in the target "atom" must be filled by a chemical bond and each bond must terminate with another "atom."
- Use **BLM 14.2.8 (HAND) Investigation 14.B: Modelling Organic Compounds** to support this activity. Remove sections as necessary to meet the needs of students in your class.

Answers to Analysis Questions

1. The addition of a multiple bond eliminates the ability of a bond to rotate.

2. The addition of a multiple bond causes the molecule to take on a more linear shape.

3. Benzene is more planar than cyclohexane.

4. Molecules with multiple bonds are more difficult to construct. There is more stress in a multiple bond. Molecular model kits require flexible links to allow for construction of multiple bonds.

Answers to Conclusion Questions

5. The effect of an increasing number of multiple bonds is to make a molecule much more linear and more rigid.

6. Both carbonic acid and carbon dioxide do not contain any carbon-carbon bonds.

Assessment Options

- Collect and assess students' reports and answers to Analysis and Conclusion.
- Use Assessment Checklist 2: Laboratory Report from Appendix A.

Section 14.2 Review Answers

Student Textbook page 564

1. Aliphatic hydrocarbons are linear or cyclic chains of carbon atoms. Aromatic hydrocarbons all incorporate a benzene ring.

2. An empirical formula gives no indication of how atoms are bonded or located relative to each other. A structural diagram shows the bonding between atoms and allows for general predictions of physical and chemical properties.

3. A line structural diagram indicates the location and nature of any functional groups.

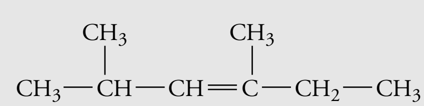
4. An unsaturated hydrocarbon contains carbon–carbon double or triple bonds while a saturated hydrocarbon does not. The lack of these bonds generally results in non-polar molecules with lower melting points, boiling points, and chemical reactivities.

5. (a) 2,4,4-trimethylpent-1-ene

(b) 2-ethyl-3,4,5,6-tetramethylcyclohept-1-ene

(c) ethylbenzene

6. (a)



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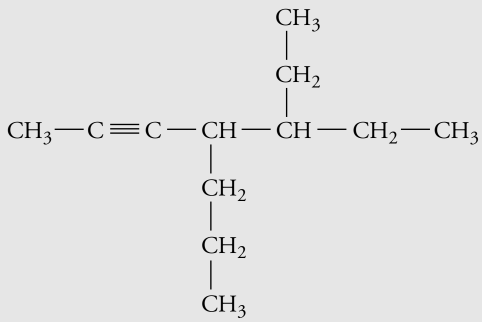

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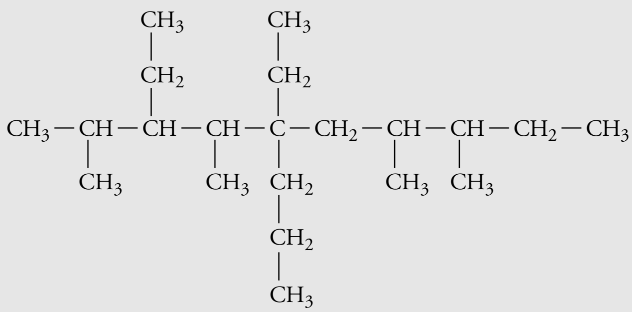

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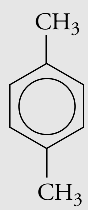

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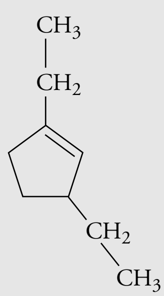
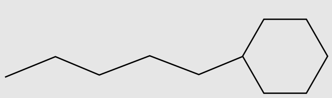
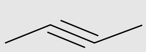


7. (a)



(b)



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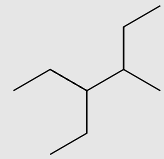


8. (a) The name indicates that this compound is an alkene. Therefore, it should have a double bond, not a triple bond. Numbering of the carbon atoms is according to highest priority for the double bond and lowest possible number for the methyl group. The correct name for this compound is 2-methyl but-2-ene.

(b) The cyclic nature of this compound must be specified in the name, as well as the presence of a double bond that is assigned position 1. In addition, positions of the ethyl and methly groups must be assigned in the order that gives the lowest possible position numbers. The correct name for this compound is 6-ethyl-3,4-dimethylcyclohexene.

14.3 Hydrocarbon Derivatives

Student Textbook pages 565–574

Section Outcomes

Students will:

- identify types of compounds from the functional groups, given structural formulas
- define structural isomerism as compounds having the same empirical formulas but different structural formulas
- compare the boiling points and solubility of examples of aliphatics, aromatics, alcohols, and carboxylic acids

Key Terms

functional group
alcohol
parent alkane
alkyl halides
carboxylic acid
carboxyl group
ester
structural isomers

Chemistry Background

- A functional group is an atom or small group of atoms that react in a characteristic fashion. The presence of a functional group in a compound will almost always produce a characteristic chemical reactivity.
- A functional group is simply described as a site in which electrons are readily available for chemical bonding. The chemical reactivity of a functional group is due to the distribution of electrons within that group.

- The polar nature of functional groups not only provides for characteristic reaction mechanisms but also gives rise to intermolecular forces (dipole interactions and hydrogen bonding) that control physical characteristics.
- Structural isomers are organic compounds that have the same number and type of atoms but a different bonding arrangement between those atoms. Due to the difference in bonding structure, isomers may have widely different chemical and physical properties.

Teaching Strategies

- As with the hydrocarbons, provide students with many opportunities to practice drawing and naming hydrocarbon derivatives.
- Use molecular model kits for this section. Be sure to inspect the molecular model kits before starting this section to ensure that all components are present.
- To introduce the concept of isomers, pre-assemble a molecular model of the ether methoxymethane (dimethyl ether) and, in front of your class, disassemble the model and then reassemble it to form ethanol. Place the following list on the board and have students explain why the two isomers have different properties despite the fact that they contain exactly the same number and types of atoms.

	Ethanol	Methoxymethane
Boiling point (ºC)	78.4	–23.6
Melting point (ºC)	–114.3	–141.5
Solubility in water $\frac{g}{100\ mL}$	fully miscible	2.4
Comments	colourless liquid resulting from natural fermentation. Used as a solvent and fuel additive.	colourless gas with a characteristic odour. Used as an aerosol spray propellant.

- A number of overhead masters have been prepared for this section. You will find them with the Chapter 14 BLMs on the CD-ROM that accompanies this Teacher's Resource or at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs.

Number (Type) Title
14.3.1 (OH) Naming and Drawing Alkyl Halides
14.3.2 (OH) Naming and Drawing Carboxylic Acids
14.3.3 (OH) Naming and Drawing Esters
14.3.4 (OH) Common Chemical Families and Their Functional Groups

SUPPORTING DIVERSE STUDENT NEEDS

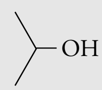
Many students benefit from the use of software packages to visualize and manipulate molecular shapes. Programs such as CHIME and RasMol may be downloaded for free from the Internet. A more powerful version of RasMol is now available.

Answers to Practice Problems 28–30

Student Textbook page 567

For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

28. (a) propan-1-ol
(b) butan-2-ol
(c) cyclobutanol
(d) pentane-2,3-diol
(e) 2,4-dimethylheptan-1-ol

29. (a) $CH_3 — OH$
(b)


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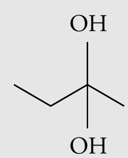

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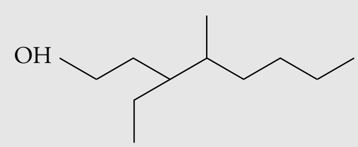

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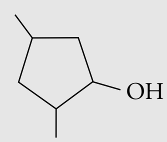


30. (a) pentane-1,3-diol
(b) 3,4-diethyldecan-1-ol
(c) 3-methylpentan-2-ol

Answers to Practice Problems 31–32

Student Textbook page 569

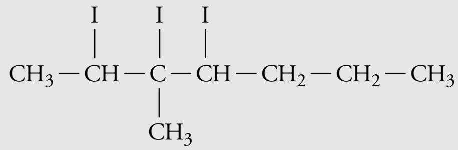
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

31. (a) 2-bromopropane
(b) 2,3-dichloro-4-fluorohexane

(c) 2,2-dibromo-4-methylpentane

32. (a) $CH_3 — CH_2 — Br$

(b)



Answers to Practice Problems 33–36

Student Textbook page 570

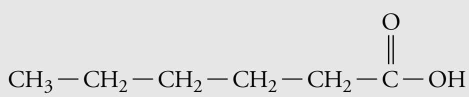
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

33. (a) propanoic acid

(b) 2,2-dimethylbutanoic acid

(c) 2-ethyl-4,5-dimethylhexanoic acid

34. (a)



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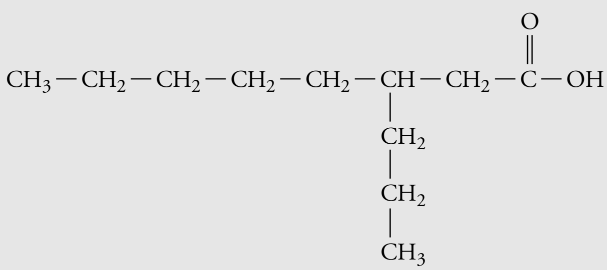

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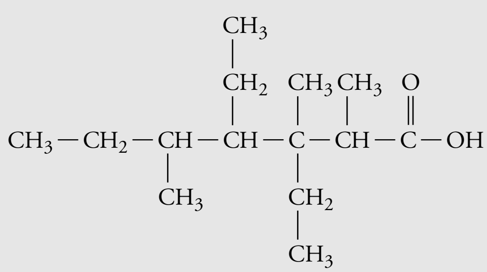
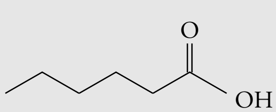


35. (a)



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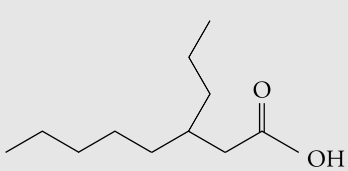

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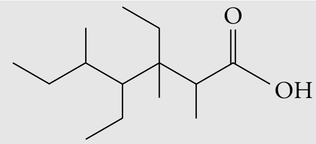
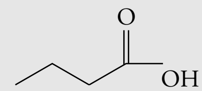
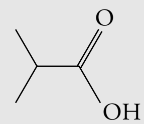


36. butanoic acid



2-methylpropanoic acid



Answers to Practice Problems 37–38

Student Textbook page 572

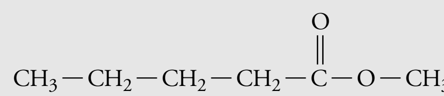
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

37. (a) ethyl methanoate

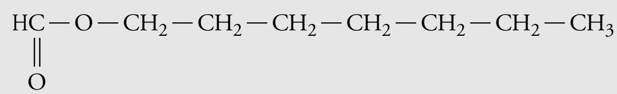
(b) methyl butanoate

(c) pentyl pentanoate

38. (a)



(b)



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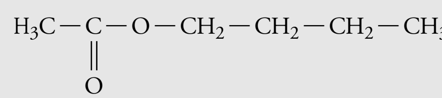

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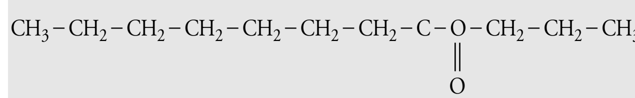

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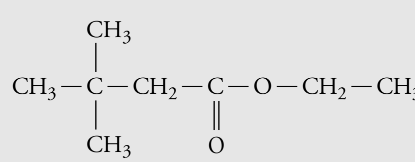

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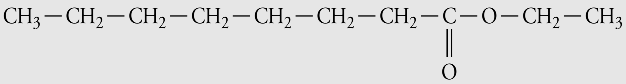

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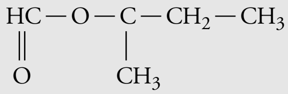
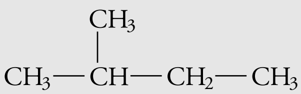


Answers to Questions for Comprehension 1–2

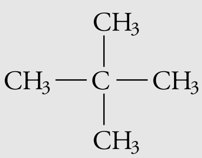
Student Textbook page 573

Q1. pentane $CH_3—CH_2—CH_2—CH_2—CH_3$

2-methylbutane



2,2-dimethylpropane



Q2. 1: $CH_3CH_2CH_2CH_2COOH$

2: $CH_3CH_2CH_2COCH_3$

Structure 1, a carboxylic acid, would probably have the higher boiling point because it can form hydrogen bonds with itself, which the ester (structure 2) cannot do.

Section 14.3 Review Answers

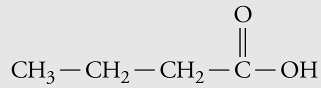
Student Textbook page 574

1. A functional group is a reactive centre for an organic molecule, and is either a polar covalent bond or a multiple bond.

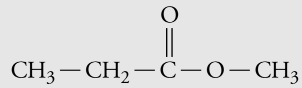
2. The closer the functional group is to the end of a carbon chain the more available it will be to participate in a chemical reaction.

3. An isomer may be defined as a compound that has the same empirical chemical formula as another compound, but with a different arrangement of atoms within the molecule.

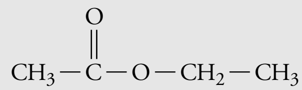
4. The three isomers of $C_4H_8O_2$ are:



butanoic acid



methyl propanoate



ethyl ethanoate

5. London dispersion forces are the most important intermolecular forces between non-polar molecules. For polar molecules, the most important forces are dipole-dipole bonding and possibly hydrogen bonding.

6. **(a)** 3-chloro-4-fluoro-2,2,3,4,5,5-hexamethylhexane

(b) methyl butanoate

(c) 2,4-dimethylheptan-1-ol

(d) 2-ethyl-4,5-dimethylhexanoic acid

(e) 4-ethyl-2,3-dimethylhexane

(f) 1-ethyl-2-methylcyclopentane

(g) 5,6-dimethylheptan-3-ol

(h) 2,5-dimethylhex-3-ene

(i) 1-bromo-3-chlorocyclobutane

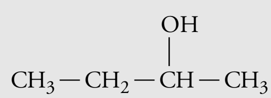
(j) 1,3,5-trimethylbenzene

(k) 3-methylhex-3-ene

(l) pentanoic acid

(m) methyl butanoate

7. **(a)**



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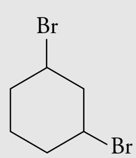

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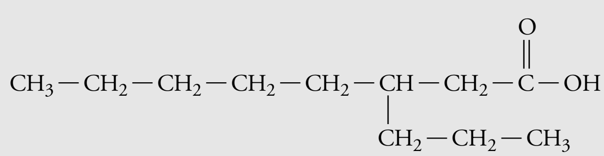

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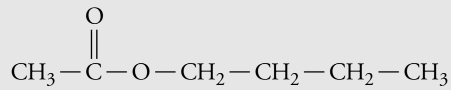
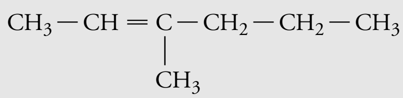


(e) $CH \equiv C-CH_2-CH_3$

(f)



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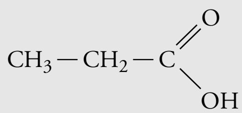

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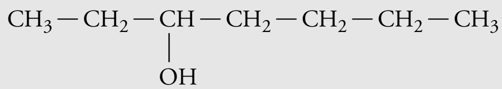

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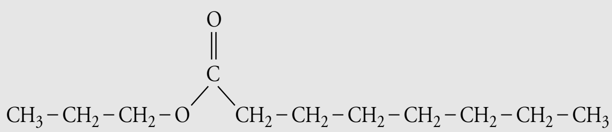

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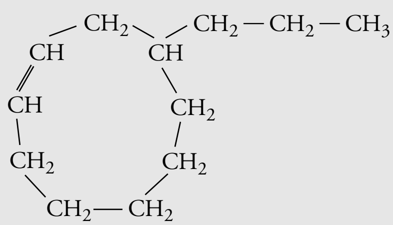

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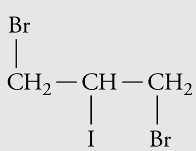


8. Both benzene and cyclohexane are flattened molecules with six carbons in a planar ring structure. These molecules can get very close to an adjacent molecule and so experience more London dispersion forces than hexane will. This greater amount of intermolecular forces will result in a higher boiling point.

14.4 Refining and Using Organic Compounds

Student Textbook pages 575–582

Section Outcomes

Students will:

- investigate the physical, chemical, and technological processes used to separate organic compounds from natural mixtures or solutions
- design a procedure to separate a mixture of organic compounds by fractional distillation
- describe the processes involved in bitumen recovery
- assess the risks and benefits and some positive and negative consequences for humans and the environment resulting from the process of bitumen recovery

Key Terms

petrochemicals
fractional distillation
cracking
steam cracking
catalytic cracking
hydrocracking
reforming
alkylation
coke
solvent extraction

Chemistry Background

- Alberta's oil sand deposits occupy an area over twice as large as the province of New Brunswick. In 2005, with only about 2% of the area involved in production, the output of marketable oil sands products was almost a million barrels per day.
- Roughly 2000 kg of oil sands must be processed to recover one barrel of crude oil. Steam injection for in situ mining and hot water extraction and processing require several barrels of fresh water, and over 40 million litres of natural gas for heating to produce one barrel of bitumen.
- The extraction and processing of oil sands to produce commercial grade products is extremely energy intensive and results in large amounts of greenhouse gas emissions.
- The boiling point of a compound is characteristic for that compound. A mixture of compounds will have a boiling point somewhere in between the lowest and highest boiling point of the compounds in that mixture. Distillation relies on the difference in boiling points between compounds in any mixture. The vapour that is produced in heating a mixture has a higher concentration of the most volatile compound in the original mixture. Cooling that vapour results in a liquid mixture with a higher concentration of the compound with the lowest boiling point.

Teaching Strategies

- Overhead masters and a quiz have been prepared for this section. You will find them with the Chapter 14 BLMs on the CD-ROM that accompanies this Teacher's Resource or at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs.

  Number (Type) Title
  14.4.1 (OH) Fractional Distillation Towers
  14.4.2 (OH) Petroleum Fractionation Products
  14.4.3 (AST) Fractional Distillation of Crude Oil Quiz
  14.4.3A (ANS) Fractional Distillation of Crude Oil Quiz Answer Key

SUPPORTING DIVERSE STUDENT NEEDS

At one point in the early history of oil exploration, drillers would curse their luck upon striking natural gas—deemed a safety hazard and worthless. At one time refineries would simply discard naptha and tar fractions as having little or no use. Your gifted students might be interested in finding out more about the history of the petrochemical industry. Have them investigate and prepare a short report on when and why the automobile industry changed this.

Connections (Social and Environmental Contexts): Tar Sands and Bitumen

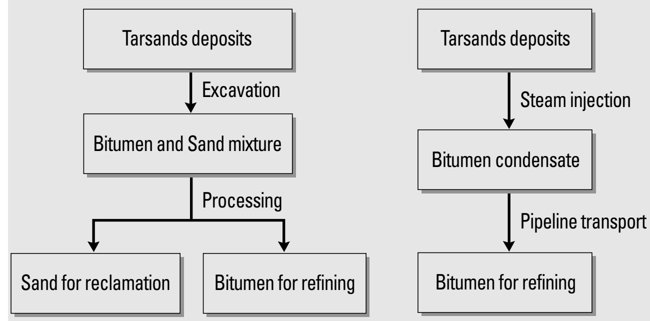
Student Textbook pages 576–577

Teaching Strategies

- Have your students compare their flowchart of the process of extracting crude oil from bitumen with the one given at the following web site: http://www.oildrop.org/Info/Centre/Lib/Papers/Suncor.ppt #1
- The Pembina Institute has a summary of the process of extraction of crude oil from the Athabasca oil sands. The summary is presented from an environmentalist point of view and is available from the following web site: http://www.oilsandswatch.org/osf-slide-show/index.php

Answers to Connections Questions

1. Student opinions as to the environmental impact of each method will vary depending on the type of environmental degradation they deem most serious. Open pit mining presents more mechanical damage to an ecosystem. In situ processing requires large amounts of fresh water, and presents more degradation of aquatic sources. Both processes require large amounts of heat obtained from the burning of natural gas and have corresponding high greenhouse gas emissions. Disruptions to animal habitat have resulted in disturbances in the natural predator–prey relationship of wolves and caribou. Water in tailings ponds is poisonous and great effort has to be made to prevent migratory birds from landing. Efforts include loud noises from cannon fire and mechanical scarecrows, including radar activated peregrine falcon robots to scare the birds away.



2. Students may wish to do a preliminary environmental assessment cataloguing flora and fauna, and establishing an index of species diversity. Future reassessments will show how the new ecosystem compares to the older measures. Species diversity is often a good measure of environmental degradation.
3. Any strategy listed should first concentrate on reducing (the most critical of the "3Rs" of lessening environmental impact) – less driving, lowering heating costs, reducing winter heat losses and summertime air conditioning costs, and reducing the amount of plastic packaging on consumer goods.

Investigation 14.C: Separate an Organic Mixture

Student Textbook page 581

Purpose

Students will design an experiment to separate a mixture of hydrocarbons into component fractions.

Outcome

- 30-C1.1s

Advance Preparation

When to Begin	What to Do
2–3 days before	■ Gather required materials.

When to Begin	What to Do
1 day before	■ Display the distillation apparatus and familiarize students with important aspects of its use. ■ Provide students with time to determine the boiling points of the various fractions involved. ■ Set out materials for each group. ■ Photocopy **BLM 14.4.4 (HAND) Investigation 14.C: Separate an Organic Mixture.**
1 hour before	■ Place the cyclohexane in a fume hood for ventilation of vapours.

Materials
■ corn oil ■ ethanoic acid ■ commercial grade cyclohexane ■ iodine crystals, $I_2(s)$ ■ distillation apparatus (varies) ■ boiling chips ■ cobalt chloride paper ■ litmus paper ■ wood splint or microspatula ■ 5 test tubes or 50 mL beakers ■ test tube rack ■ reference tables and access to library resources or the Internet

Time Required

- 40 to 60 minutes

Helpful Tips

- The traditional distillation apparatus is likely to be in short supply in most schools. For this investigation a simpler test tube setup may be used, although the results are not as precise as they would be with the traditional apparatus.
- As an alternate setup, a large test tube is fitted with a two-hole rubber stopper having a thermometer inserted in one hole and a bent glass tube inserted into the other. The bulb of the thermometer should be close to the bottom of the stopper. The end of the bent glass tube is placed level with the bulb of the thermometer and the other end is connected to a length of clear plastic tubing. The mixture to be separated is placed in the test tube with several boiling chips, the rubber stopper is inserted, and the clear plastic tubing will lead into one of two small test tubes that are resting in a beaker of cold water. The heating apparatus consists of a large (600 mL) beaker, half full of sand, into which the large test tube with the rubber stopper is embedded. When the temperature begins to rise sharply, the clear plastic tubing is shifted to the other test tube. Students should use only 40 to 50 mL of the mixture being distilled. Best results are obtained if the heating is allowed to proceed slowly and evenly.
- Corn oil starts to boil just after 246 °C, so it will remain in the distillation flask or test tube.
- Use **BLM 14.4.4 (HAND) Investigation 14.C: Separate an Organic Mixture** to support this activity. Remove sections as necessary to meet the needs of students in your class.
- ***Expected Results:*** The cyclohexane will distill off first. Some time should pass before the vinegar (ethanoic acid) begins to distill. After no more solution appears to be vapourizing and condensing, once more, some time will pass before the corn oil begins to distill. The separation will probably not be separated entirely, but the separation should be quite efficient.

Safety Precautions

- Ensure students read and understand “Safety in Your Chemistry Laboratory and Classroom” on pages xii-xv in the student textbook.
- Organic solvents are flammable. Do not use a Bunsen burner or any other source of open flame. Use of a hot plate is mandatory for this investigation.
- Advise students that any solvents that are spilled should be immediately cleaned up, and that any spilled on their skin should be rinsed off with plenty of water.
- Remind students that all organic solvents are toxic, so they should avoid inhaling or ingesting them.
- Warn students that iodine is a severe skin irritant and will stain skin and clothing. They should avoid all contact with skin and mucous membranes. Advise students to use a wood splint or microspatula to obtain and deliver the material used.
- Clearly demonstrate how and where students should dispose of waste materials when they have completed the investigation.

Answers to Analysis Questions

1. Students should find that it is difficult to completely separate the vinegar and cyclohexane with only one attempt. The difference in boiling points of fractions should ideally be greater than 40 °C for easy separation. Therefore, it is likely that at least some water, and possibly ethanoic acid, will appear with the cyclohexane.
2. Complete separation will be unlikely given the closeness of the boiling points.

3. Collection containers were switched when the temperature began to rise quickly.
4. Most answers will likely focus on more closely monitoring the temperature. However, students who have done outside reading may mention using a vacuum apparatus for increased efficiency.

Answer to Conclusion Question

5. Students are likely to note that the distillation procedure in this case is not as effective as could be desired.

Assessment Options

- Collect and assess students' reports and answers to Analysis and Conclusion questions.
- Use Assessment Checklists 1: Designing an Experiment and 2: Laboratory Report from Appendix A.

Section 14.4 Review Answers

Student Textbook page 582

1. Petroleum is a complex mixture of gaseous and liquid hydrocarbons in the form of natural gas, crude oil, and bitumen.
2. A petrochemical is a basic hydrocarbon raw material derived from petroleum, which is used to prepare plastics and other synthetic materials.
3. Each fraction has a different boiling point and molecular weight. This causes each fraction to condense at a different level within the fractionating tower.
4. Each hydrocarbon fraction has a unique range of boiling points. A large furnace vapourizes these fractions. Several plates inside a tower collect condensates from the rising vapourized fractions at levels where the temperature is just below the boiling points of those fractions. Larger hydrocarbons have higher boiling points, so they condense first at lower positions in the tower. Smaller hydrocarbons with lower boiling points rise higher in the tower to cooler levels before they can condense.
5. The cracking process uses heat to break larger hydrocarbon molecules into smaller more useful fragments. The reforming process uses heat, pressure, and catalysts to convert small molecules into more useful larger and/or aromatic fragments.
6. In cracking, large molecules are broken into smaller fragments. In reforming, smaller molecules are joined together to make larger molecules. Both processes involve catalysts.
7. The tube is switched when the temperature begins to rise drastically. Heat added to a substance during a change in state (vapourization) increases the distance between molecules but not their motion, so the temperature stays constant. Once one fraction is boiled away, there will be a shift to a new boiling point for the next fraction. Heat added causes molecules to move faster and the temperature will rise quickly until the next boiling point is reached.
8. Physically, the extraction requires draining of muskeg lands and stripping off of surface soils (overburden), damaging wildlife habitats and traditional lands of several indigenous peoples. Distribution of water from surface sources is altered and degraded in the separation and recovery process of bitumen. Upgraders release greenhouse gasses, sulfur dioxide, and nitrogen oxides into the atmosphere.

Chapter 14 Review Answers

Student Textbook pages 584–585

Answers to Understanding Concepts Questions

1. Organic compounds involve molecules in which carbon-carbon and carbon-hydrogen bonds are prevalent.
2. The concept of "vitalism" focussed on the idea that living creatures had the unique ability to form organic compounds. This concept was eventually rejected when organic compounds were synthesized from inorganic compounds in the laboratory.
3. Carbon has four valence electrons, which allow it to form strong covalent bonds with a variety of different elements. Carbon can form single, double, and triple bonds resulting in chains, rings, and sheets.
4. Most carbon-containing compounds are organic, although inorganic compounds can contain carbon. There are many millions of different organic compounds, but only about a quarter of a million inorganic compounds. Inorganic compounds are relatively small compared to most organic compounds. Most organic compounds are large and have a relatively high molecular mass.
5. Students might prepare something similar to the chart below.

	Alkanes	Alkenes	Alkynes
Polarity	non-polar	non-polar	non-polar
Boiling point	lower than similar-sized alkenes and alkynes	usually slightly higher than similar sized alkanes but lower than similar-sized alkynes.	higher than similar-sized alkanes and alkenes.
Degree of saturation	saturated	unsaturated	unsaturated
Reactivity	less reactive than alkenes and alkynes	more reactive than alkanes but less reactive than alkynes	more reactive than alkanes and alkenes

6. **(a)** An aromatic hydrocarbon is one based on the aromatic benzene group.

(b) Aliphatic hydrocarbons are not based on the benzene ring. They are compounds in which carbons form chains and non-aromatic rings. The electrons that form the double bonds in benzene are delocalized and do not react in the same way as the double and triple bonds in aliphatic hydrocarbons.

7. **(a)** C_nH_{2n+2}

(b) C_nH_{2n}

(c) C_nH_{2n-2}

(d) C_nH_{2n}

(e) C_nH_{2n-2}

8. **(a)** aliphatic

(b) aromatic

(c) aliphatic

(d) aliphatic

(e) aromatic

9. **(a)** 2,3,4-trimethylpentane

(b) ethylcyclohexane

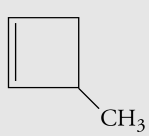
(c) 4-ethyl-4,5-dimethyloctane

(d) 2,3-dimethylpent-2-ene

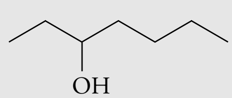
(e) 1-ethyl-2-methylbenzene

(f) 3-methylbut-1-yne

10. No, that is not the correct name. Numbering priority is given to the double bond, with it being between positions 1 and 2. The correct name for this compound is 3-methylcyclobutene.



11. **(a)**



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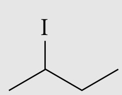

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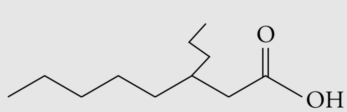

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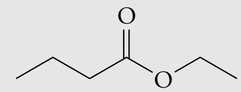


12. **(a)** hexanoic acid

(b) methyl butanoate

(c) cyclopentanol

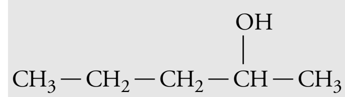
(d) 3-methylhexan-3-ol

(e) 1-bromo-2-iodoethene

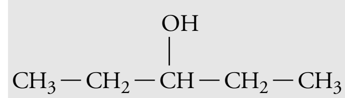
13. The eight isomers are:

$CH_3-CH_2-CH_2-CH_2-CH_2-OH$

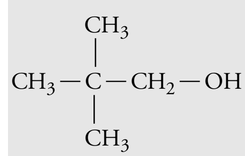
pentan-1-ol



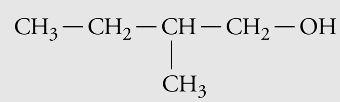
pentan-2-ol



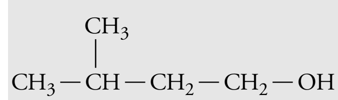
pentan-3-ol



2,2-dimethylpropan-1-ol



2-methylbutan-1-ol



3-methylbutan-1-ol

$CH_3-O-CH_2-CH_2-CH_2-CH_3$

butylmethyl ether*

$CH_3-CH_2-O-CH_2-CH_2-CH_3$

ethylpropyl ether*

*The students are not expected to name the ethers.

14. The carboxylic acid is slightly more polar than the ester because the polar covalent bonds between carbon and oxygen are at the end of the molecule and are more exposed. With more polarity, the carboxylic acid will be more soluble in water than the ester.

15. As the number of atoms (length) of an aliphatic compound increases, the number of London dispersion force interactions between adjacent molecules will increase. As a result of this, the boiling point will increase.

16. These hydrocarbon fractions have a different range of boiling points. Larger hydrocarbons, with higher boiling points, will condense at lower positions in the tower

where temperatures are highest. Smaller hydrocarbons, with lower boiling points, remain in the gaseous state and will rise higher in the tower to cooler levels before they can condense.

Answers to Applying Concepts Questions

17. An alkane is more soluble in benzene because it is non-polar and like dissolves like. Alcohols are polar.

18. CH_3CH_2COOH is likely to have the highest boiling point because of hydrogen bonding.

19. A bromine or potassium permanganate test will distinguish between an alkane and an alkene.

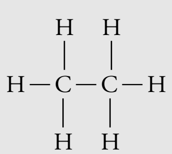
20. **(a)** Benzene has a six-membered ring structure in which six electrons are shared by all six carbon atoms. These shared electrons are said to be delocalized.

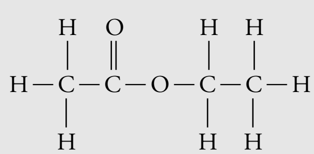
(b) No, the branches are typically named and numbered before the root is named. It is also misleading to write that there are three double bonds when the structure is actually a resonance structure.

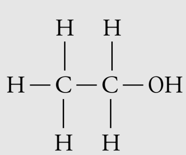
21. First, based on the empirical formula C_6H_{12}, only cycloalkane and alkene are possible. Next, determination of the boiling point could be performed, with comparison to the literature values for cyclohexane and the hexenes. In addition, bromine water or potassium permanganate could be reacted with the unknown to test for the presence of a double bond. The disappearance of colour would indicate hexene, the maintenance of colour would indicate cyclohexane. Reaction with iodine could also be used as a test, with the generation of a magenta colour indicating that the unknown was cyclohexane.

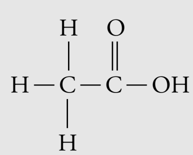
22. **(a)** A-ethane, B-ethyl ethanoate, C-ethanol, and D-ethanoic acid.

(b)


ethane


ethyl ethanoate


ethanol


ethanoic acid

Answers to Making Connections Questions

23. As the world's population grows and technological advances are made, the demand for energy is increasing rapidly. These developments, coupled with the fact that fossil fuels are nonrenewable resources that require millions of years to be produced, give people cause to worry that the world may run out of fossil fuels.

24. Alkanes

– gasoline and other fuels for cars and other engines

– natural gas to heat homes

– lubricating oils

– wax for candles

– asphalt and tar for paving and roofing

Alkenes

– ethene is used to ripen fruits and vegetables after shipping

– used to make plastics

Akynes

– acetylene (ethyne) is used in welding torches

Cyclic Hydrocarbons

– found in steroid hormones

Aromatic Hydrocarbons

– includes styrene and toluene

– flavours and aromas – including wintergreen, vanilla and cinnamon

Alcohols

– used for solvents

– component in antifreeze

– fuels or fuel additives

– antiseptics

– component of alcoholic beverages

Alkyl Halides

– chloroform was used as an anesthetic

– CFCs (chlorofluorocarbons) were used as refrigerants and propellants

Carboxylic Acids

– vinegar is used as a flavouring

– citric acid is found in fruit

Esters

– both natural and artificial flavours and fragrances (including perfume)

25. The tar-like substance is likely a long chain alkane, which is non-polar; therefore a non-polar solvent will remove the substance. Of the three substances, the least polar, the vegetable oil, would be most likely able to dissolve the tar-like substance.

CHAPTER 15 REACTION OF ORGANIC COMPOUNDS

Curriculum Correlation

General Outcome 2: Students will describe chemical reactions of organic compounds.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–C2.1k define, illustrate and provide examples of simple addition, substitution, elimination, esterification and combustion reactions	**Combustion Reactions, Section 15.1, p. 588** **Addition, Elimination, and Substitution Reactions, Section 15.1, p. 589** **Addition Reactions, Section 15.1, pp. 590-591** **Elimination Reactions, Section 15.1, p. 593** **Substitution Reactions, Section 15.1, pp. 593-594** **Esterification Reactions, Section 15.1, pp. 594-595** **Sample Problems: Addition, Substitution, Elimination, and Esterification Reactions, Section 15.1, p. 596**	**Questions for Comprehension: 1-6, Section 15.1, p. 589** **Practice Problems: 1-6, Section 15.1, pp. 596-597** **Section 15.1 Review: 1-6, pp. 602** **Chapter 15 Review: 1, 3, 10, pp. 616-617** **Chapter 15 Test** Unit 7 Review: 15-20, 28, 29-31, 34-36, pp. 620-623
30–C2.2k predict products and write and interpret balanced equations for the above reactions	**Combustion Reactions, Section 15.1, p. 588** **Addition, Elimination, and Substitution Reactions, Section 15.1, p. 589** **Addition Reactions, Section 15.1, pp. 590-591** **Elimination Reactions, Section 15.1, p. 593** **Substitution Reactions, Section 15.1, pp. 593-594** **Esterification Reactions, Section 15.1, pp. 594-595** **Sample Problems: Addition, Substitution, Elimination, and Esterification Reactions, Section 15.1, p. 596**	**Questions for Comprehension: 1-6, Section 15.1, p. 589** **Practice Problems: 1-6, pp. 596-597** **Section 15.1 Review: 1-6, pp. 602** **Chapter 15 Review: 1, 2, 5-7, 10, 16 -20, pp. 616-617** **Chapter 15 Test** Unit 7 Review: 15-20, pp. 620-623
30–C2.3k define, illustrate and provide examples of monomers, e.g., ethene, polymers, e.g., polyethylene, and polymerization in living systems, *e.g., carbohydrates, proteins and nonliving systems, e.g., nylon, polyester, plastics*	**Polymer Chemistry, Section 15.2, pp. 603-605** **Sample Problem: Classifying a Polymerization Reaction, Section 15.2, p. 606**	**Practice Problems: 7-12, pp. 606-607** **Section 15.2 Review: 1-5, p. 614** **Chapter 15 Review: 2, 8-17, 19, 20, 24, 28, pp. 616-617** **Chapter 15 Test** Unit 7 Review: 18-20, 29, 31, 34, 35, pp. 620-623

	Student Textbook	Assessment Options
30–C2.4k relate the reactions described above to major reactions for producing energy and economically important compounds from fossil fuels.	**Organic Reactions and the Petrochemical Industry in Alberta, Section 15.2, pp. 609** **Risks of the Polymer Industry, Section 15.2, pp. 610-611** **Natural Polymers, Section 15.2, pp. 611-613**	**Questions for Comprehension: 1-6, Section 15.1, p. 589** **Section 15.2 Review: 1-7, p. 614** **Chapter 15 Review: 18-28, pp. 616-617** **Chapter 15 Test** Unit 7 Review: 32, 33, 35, 36, pp. 620-623
Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)		
30–C2.1sts develop an understanding that science and technology are developed to meet societal needs and expand human capability by ■ *describing processes for obtaining economically important compounds from fossil fuels, (e.g., compare hydro-cracking and catalytic reforming, describe bitumen upgrading)* ■ *describing major reactions of the petrochemical industry in Alberta, e.g., production of methanol, ethylene glycol, polyethylene, polyvinyl chloride (PVC), urea, formaldehyde* ■ *investigating the application of nanoscience and nanotechnology in the petrochemical industry and the medical sciences*	**Thought Lab 15.1: Fossil Fuels and Climate Change, Section 15.1, p. 589**	**Thought Lab 15.1: Fossil Fuels and Climate Change: 1-3, Section 15.1, p. 589** **Chapter 15 Review: 18-28, pp. 616-617** Unit 7 Review: 32-36, pp. 620-623
30–C2.2sts develop an understanding that science and technology are influenced and supported by society and have influenced, and been influenced by, historical development and societal needs by ■ *describing processes involved in producing gasoline, e.g.,* ■ *adjusting octane rating* ■ *reducing sulfur content* ■ *adding compounds such as oxygenated additives (blending with ethanol)*	**Thought Lab 15.1: Fossil Fuels and Climate Change, Section 15.1, p. 589**	**Thought Lab 15.1: Fossil Fuels and Climate Change: 1-3, Section 15.1, p. 589** **Chapter 15 Review: 18-28, pp. 616-617** Unit 7 Review: 32-36, pp. 620-623
30–C2.3sts develop an understanding that science and technology have both intended and unintended consequences for humans and the environment by ■ *assessing the positive and negative effects of various reactions involving organic compounds, relating these processes to quality of life and potential health and environmental issues, e.g.,* ■ *burning fossil fuels and climate change* ■ *production of pharmaceuticals and foods* ■ *byproducts (CO_2, dioxins) of common reactions* ■ *recycling of plastics* ■ *impact of CFCs, HCFCs on the ozone layer* ■ *transfats in the diet* ■ *assessing the implications of the development of nanoscience and nanotechnology for application in the petrochemical industry and the medical sciences on society and the environment.*	**Thought Lab 15.1: Fossil Fuels and Climate Change, Section 15.1, p. 589** **Connections: Trans Fat in the Diet, Section 15.1, p. 592** **Thought Lab 15.2: Problem Solving with Organic Compounds, Section 15.1, pp. 599-601**	**Thought Lab 15.1: Fossil Fuels and Climate Change: 1-3, Section 15.1, p. 589** **Connections: Trans Fat in the Diet: 1-3, Section 15.1, p. 592** **Thought Lab 15.2: Problem Solving with Organic Compounds: 1-3, Section 15.1, pp. 599-601** **Chapter 15 Review: 18-28, pp. 616-617** Unit 7 Review: 32-36, pp. 620-623

	Student Textbook	Assessment Options
Skill Outcomes (Focus on problem solving)		
Initiating and Planning		
30–C2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ predicting the ester formed from an alcohol and an organic acid ■ describing procedures for safe handling, storage and disposal of materials used in the laboratory, with reference to WHMIS and consumer product labelling information ■ *designing a procedure to prepare a polymer.*	**Investigation 15.A: Preparing Esters, Section 15.1, pp. 597-599** **Investigation 15.B: Modelling and Making Polymers, Section 15.2, pp. 607-608**	**Investigation 15.A: Preparing Esters: 1-4, Section 15.1, pp. 597-599** Unit 7 Review: 31, pp. 620-623 **Investigation 15.B: Modelling and Making Polymers: 1-8, Section 15.2, pp. 607-608**
Performing and Recording		

30–C2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
■ performing an experiment to investigate the reactions of organic compounds
  ■ *synthesizing a polymer, e.g., nylon or "slime"*
  ■ *producing an ester*
  ■ *investigating methods of making soap*
■ *using library and electronic research tools to collect information on, e.g.,*
  ■ bitumen upgrading
■ *determining the octane ratings of gasoline*
■ *the costs and benefits of supporting the petrochemical industry.*
	Chapter 15 Launch Lab: Comparing the Reactivity of Alkanes and Alkenes, p. 587
	
	Thought Lab 15.2: Problem Solving with Organic Compounds, Section 15.2, pp. 599-601
	
	Investigation 15.B: Modelling and Making Polymers, Section 15.2, pp. 607-608
		Chapter 15 Launch Lab: Comparing the Reactivity of Alkanes and Alkenes: 1-4, p. 587
		
		Thought Lab 15.2: Problem Solving with Organic Compounds: 1-3, Section 15.2, pp. 599-601
		
		Investigation 15.B: Modelling and Making Polymers: 1-8, Section 15.2, pp. 607-608

Analyzing and Interpreting		
30–C2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ using appropriate chemical symbols and nomenclature in writing organic chemical reactions	**Investigation 15.B: Modelling and Making Polymers, Section 15.2, pp. 607-608**	**Investigation 15.B: Modelling and Making Polymers: 1-8, Section 15.2, pp. 607-608**
■ investigating sources of greenhouse gases, i.e., methane, carbon dioxide, water and dinitrogen oxide (nitrous oxide) and analyze their contribution to climate change ■ using models to illustrate polymerization ■ *analyzing a process for producing polymers* ■ *analyzing efficiencies and negative byproducts related to chemical reaction processes in organic chemistry.*	**Thought Lab 15.1: Fossil Fuels and Climate Change, Section 15.1, p. 589** **Investigation 15.B: Modelling and Making Polymers, Section 15.2, pp. 607-608**	**Thought Lab 15.1: Fossil Fuels and Climate Change: 1-3, Section 15.1, p. 589** **Investigation 15.B: Modelling and Making Polymers: 1-8, Section 15.2, pp. 607-608**
Communication and Teamwork		
30–C2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ using advanced menu features within a word processor to insert tables, graphs, text and graphics when preparing a report on an issue related to society's use of organic chemistry.	**Thought Lab 15.2: Problem Solving with Organic Compounds, Section 15.2, pp. 599-601**	**Thought Lab 15.2: Problem Solving with Organic Compounds: 1-3, Section 15.2, pp. 599-601**

Chapter 15

Reactions of Organic Compounds

Student Textbook pages 586–617

Chapter Concepts

Section 15.1 Types of Organic Reactions

- Combustion, addition, elimination, substitution, and esterification are five types of organic reactions.
- Complete balanced equations can be predicted and written for combustion, addition, elimination, substitution, and esterification reactions.
- Energy is released from fossil fuels through combustion reactions.

Section 15.2 Polymers and the Petrochemical Industry

- Two types of polymerization reactions, addition and condensation, produce synthetic, and natural polymers.
- Organic reactions are used to produce economically important compounds from fossil fuels.

Common Misconceptions

- Students may find it difficult to differentiate between the reaction conditions for the elimination of an alcohol and the reaction conditions for the substitution of an alcohol. Although both reactions involve an alcohol and an acid, the type of acid used is the key. If the acid used is sulfuric acid, the reaction will be an elimination. However, if the acid is a hydrogen halide, then the reaction will be a substitution.
- Students are exposed to many misconceptions regarding the possibility of enhanced global warming. The most serious of these is that students commonly state that the greenhouse effect is bad because it causes global warming. In fact, without this effect the temperature at Earth's surface would only be an average of about –19 °C, much too cold to support life. The real issue is that greenhouse gases in the atmosphere that are due solely to human sources are increasing at a geometric rate. Many of these gases are much more effective greenhouse gases and take longer to remove from the atmosphere. Accordingly, there is a reasonable expectation that the presence of these gases may lead to an accelerated or enhanced warming effect close to Earth's surface.
- It is easy for students to think that all organic molecules that are associated with living matter are not harmful. However, many organisms produce poisons and toxins. In addition, there has been a great deal of publicity regarding the ecological effects of synthetic organic compounds such as DDT and CFCs. Unfortunately, students often equate synthetic (human-made) to hazardous materials. When presenting the risks and benefits associated with organic compounds, be certain to include both natural and synthetic examples.

Helpful Resources

Books and Journal Articles

- White, R.M. "The Great Climate Debate," *Scientific American*. July 1990.
- Fenichell, S. Plastic: *The Making of a Synthetic Century.* HarperCollins, New York, 1996.
- Stinson, S.C., "Chemists Learn to Preserve Historical Polymers While Probing Their Nature," *Chemical and Engineering News*. September 9, 1996, p. 34. Tarazona, M.P., Saiz, E. "Models for Models: An Introduction to Polymer Models Employing Simple Analogies." *Journal of Chemical Education*. Vol. 75, 1998, p. 1425.

Web Sites

Web links for material related to this chapter can be found at **www.albertachemistry.ca**. Go to the Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web Links.

List of BLMs

Blackline masters (BLMs) have been prepared to support the material in this chapter. The BLMs are either for assessment (AST); use as overheads (OH); use as handouts (HAND), in particular to support activities. Most handouts and all assessment tools are supported by a BLM with the answers (ANS). The BLMs are in digital form, stored on the CD-ROM that accompanies this Teacher's Resource or on the web site at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs.

Number (Type) Title

15.0.1 (HAND) Launch Lab: Comparing the Reactivity of Alkanes and Alkenes

15.0.1A (ANS) Launch Lab: Comparing the Reactivity of Alkanes and Alkenes Answer Key

15.1.1 (HAND) Thought Lab 15.1: Fossil Fuels and Climate Change

15.1.1A (ANS) Thought Lab 15.1: Fossil Fuels and Climate Change Answer Key

15.1.2 (OH) Addition, Substitution, Elimination, and Esterification Reactions

15.1.3 (HAND) Investigation 15.A: Preparing Esters

15.1.3A (ANS) Investigation 15.A: Preparing Esters Answer Key

15.1.4 (HAND) Thought Lab 15.2: Problem-Solving with Organic Compounds

15.1.4A (ANS) Thought Lab 15.2: Problem-Solving with Organic Compounds Answer Key
15.1.5 (AST) Identifying Organic Reactions
15.1.5A (ANS) Identifying Organic Reactions Answer Key
15.2.1 (OH) Addition and Condensation Polymers
15.2.2 (HAND) Investigation 15.B: Modelling and Making Polymers
15.2.2A (ANS) Investigation 15.B: Modelling and Making Polymers Answer Key
15.3.1 (AST) Chapter 15 Test
15.3.1A (ANS) Chapter 15 Test Answer Key

Using the Chapter 15 Opener

Student Textbook pages 586–587

Teaching Strategies

- Reintroduce the concepts of what an organic compound is and how organic compounds differ from other chemical compounds. Remind students that organic chemistry is the study of those molecular compounds.
- Have students prepare a summary chart listing the types of organic compounds, diagrams for the associated functional groups, and the suffix used in IUPAC nomenclature.
- Students may need to be reminded of the rules for drawing structural formulas and naming organic compounds. For example, have students draw condensed structural formulas for the three isomers of C_4H_8.

Launch Lab — Comparing the Reactivity of Alkanes and Alkenes

Student Textbook page 587

Purpose

Students will react aqueous potassium permanganate, $KMnO_4(aq)$, with several samples of fat in order to identify a correlation between their physical properties and chemical structure.

Outcomes

- 30-C2.3sts
- 30-C2.2s

Advance Preparation

When to Begin	What to Do
1 week before	■ Gather the required materials.
2 to 3 days before	■ Prepare $KMnO_4$ solution (5 mmol/L) by dissolving 0.08 g of $KMnO_4$ in 100 mL of water. ■ Have students research the difference between saturated and unsaturated fats.
1 day before	■ Set out materials for each group. ■ Photocopy **BLM 15.0.1 (HAND) Launch Lab: Comparing the Reactivity of Alkanes and Alkenes.**

Materials
■ samples of vegetable oils, such as margarine, corn oil, and coconut oil ■ samples of animal fats, such as butter and lard ■ 5.0 mmol/L $KMnO_4(aq)$ ■ warm-water bath ■ hot plate ■ medicine droppers (one for each sample) ■ test tubes ■ test tube rack ■ stoppers

Time Required

- 60 to 80 minutes

Helpful Tips

- Oily droppers and test tubes are very hard to clean. Have a container of soapy water ready to put the used droppers and test tubes in as soon as they have been used.
- Potassium permanganate stains can be removed with a solution of sodium bisulfite.
- Students should generate a table, similar to the one shown below, to record their observations.

Sample material in test tube	State at room temperature	Observations after addition of potassium permanganate

- Most fatty foods contain a mixture of unsaturated and saturated fats – the difference lies in proportion. Beef fat contains approximately the same amount of saturated and unsaturated fat, while corn oil contains about 85 percent unsaturated fats and 14 percent saturated fats.
- Use **BLM 15.0.1 (HAND) Launch Lab: Comparing the Reactivity of Alkanes and Alkenes** to support this activity. Remove sections as needed to meet the needs of students in your class.
- ***Expected Results:*** Permanganate typically has a purple colour. It reacts with double or triple bonds to give a green or brown colour. Therefore, it will react with unsaturated fats but not with saturated fats. Since unsaturated fats are usually liquids at room temperature and saturated fate or often solid at room temperature, the trend should be that the permanganate changes colour when added to liquid fats but not with solid fats. However, when fats contain trans fats, they will tend to be solid but still react with permanganate. The colours might not be easy to interpret as a result of the presence of other compounds in the samples.

Safety Precautions

- Ensure students read and understand "Safety in Your Chemistry Laboratory and Classroom" on pages xii-xv in the student textbook.
- Students should be warned that potassium permanganate will stain clothing and skin. Advise them that if any is accidentally spilled on their skin or clothing, they should wash the area with copious amounts of water.
- Clearly demonstrate how and where students should dispose of waste materials when they have completed the lab.

SUPPORTING DIVERSE STUDENT NEEDS

This lab provides an excellent STS link in regards to a societal concern over dietary exposure to saturated fats, trans fats, and health. Advanced students may be interested in learning more about the chemistry associated with diabetes or Alzheimer's disease and consumption of dietary fats. Have the students prepare a one-page summary or poster outlining their findings.

Answers to Analysis Questions

1. Most substances that caused a change in colour of the potassium permanganate solution upon mixing were liquid at room temperature. Students should note that coconut oil is an exception to this rule. Although it is liquid at room temperature, it does not cause a change in colour of the potassium permanganate solution.
2. Most substances that did not cause a change in colour of the potassium permanganate solution upon mixing were solids at room temperature. Students should note that coconut oil is an exception to this rule.
3. The physical property that appears to be related to the ability to cause a change in colour of the potassium permanganate solution, with one exception, is that the substance is a liquid at room temperature.
4. Unsaturated fats, which contain at least one carbon-carbon double bond, are liquid at room temperature. Therefore, compounds containing a double bond are able to react with potassium permanganate. Coconut oil, although a liquid at room temperature, is actually a saturated fat. Therefore, based on the absence of double bonds, it would not be expected to react with potassium permanganate.

Assessment Options

- Collect and assess students' reports and answers to Analysis questions.
- Use Assessment Checklist 2: Laboratory Report from Appendix A.

15.1 Types of Organic Reactions

Student Textbook pages 588–601

Section Outcomes

Students will:
- define and give examples of combustion, addition, elimination, substitution, and esterification reactions
- predict products, and write and interpret balanced equations for combustion, addition, elimination, substitution, and esterification reactions
- carry out an investigation to synthesize esters, and describe procedures for the safe handling of materials used in the laboratory
- relate the organic reaction types you have learned to reactions for producing energy from fossil fuels
- investigate sources of greenhouse gases and the issue of climate change
- describe how the science and technology of organic chemistry have developed to meet the needs of society and expand human capabilities
- assess some positive and negative consequences for humans and the environment of society's use of organic compounds
- work collaboratively in a team, communicating information and ideas about organic chemistry

Key Terms

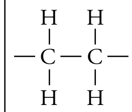
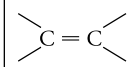
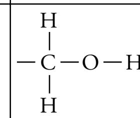
complete combustion reaction
addition reactions
elimination reaction
substitution reaction
esterification reaction
condensation reaction

Chemistry Background

- Organic compounds, such as alkanes, may undergo combustion reactions in the presence of oxygen. Combustion reactions are important for society because they are highly exothermic and, therefore, useful for domestic and industrial heating. However, some of the products formed have serious health and environmental problems associated with them.
- Alkenes and alkynes can undergo addition reactions, whereby atoms are added to the multiple bond resulting in the loss of that bond. Common small molecules that add to alkenes and alkynes include water, hydrogen, hydrogen halides, and halogens.
- Elimination reactions are effectively the reverse of addition reactions in that atoms are removed to form a carbon-carbon double bond. The two most important methods involve heating an alcohol in the presence of a strong acid, such as sulfuric acid, and heating an alkyl halide in a combination of a strong base and ethanol.
- Alcohols and alkyl halides commonly undergo substitution reactions. For example, when an alcohol reacts with hydrogen chloride or hydrogen bromide, the halogen atom replaces the hydroxide group on the alcohol to produce an alkyl halide.
- An esterification reaction is more generally referred to as a condensation reaction of an alcohol and a carboxylic acid to produce an ester and water. Esters are known to be responsible for the flavours and odours of many fruits and spices.

Teaching Strategies

- Molecular model kits are strongly recommended for this section. The hands-on aspect of building a molecular model and manipulating components to represent a chemical reaction seems to help many students visualize and remember the process. Be sure to inspect the molecular model kits before starting this section to ensure that all components are present.
- Reinforce that there are characteristic signs that identify the type of organic reaction that is occurring. Knowing the type of organic reaction will also help students predict the likely products of that reaction.
- Students often have difficulty predicting the products of reactions based on the structural orientation of the compounds represented. Point out to students that a structural formula does not represent the actual three-dimensional shape of the molecule. Its intent is to indicate how atoms are bonded together and may be shown in a different order. Both CH_3CH_2OH and $HOCH_2CH_3$ are valid ways to represent ethanol.
- Have students prepare a summary chart, similar to the one below, which lists the various types of organic compounds studied and characteristics of the associated chemical reactions.

Organic compound	Formula	Characteristic reactions
alkanes		substitution (of H, commonly by Cl or Br) combustion (to $CO_2 + H_2O$)
alkenes		addition across C=C substitution combustion (to $CO_2 + H_2O$)
alcohols		substitution (of H_2); substitution (of OH_2) elimination combustion (conversion to $CO_2 + H_2O$)

- An overhead master and quiz have been prepared for this section. You will find them with the Chapter 15 BLMs on the CD-ROM that accompanies this Teacher's Resource or at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs.

  Number (Type) Title
  15.1.2 (OH) Addition, Substitution, Elimination, and Esterification Reactions
  15.1.5 (AST) Identifying Organic Reactions
  15.1.5A (ANS) Identifying Organic Reactions Answer Key

SUPPORTING DIVERSE STUDENT NEEDS

- Most students find a model helpful when asked to prepare structural formulas. If molecular model kits are unavailable, have students use gum drops or jujubes to represent atoms. A package of toothpicks with both ends pointed can be used to represent chemical bonds. Assign the black gum drops or jujubes to represent carbon atoms and pick a standard color for other key atoms such as oxygen and hydrogen. Remember each black candy must have four toothpicks inserted, "oxygen" must have two toothpicks, and "hydrogen" only one toothpick.
- Emphasize to students who need extra help that chemical reactions depend on the functional group involved. Make sure students are able to recognize the various functional groups before examining organic reactions.
- Students with reading difficulties often overlook a key feature of the name of an organic compound, the suffix, which allows them to determine the nature of an organic compound. Have students use a highlight pen on worksheets and quizzes to help them identify this.
- The elimination reaction of an ester in a basic solution (saponification) is a key step in the making of soap. Ask advanced students to research traditional soap making methods and to identify the reactants and products of the saponification reaction.

Answers to Questions for Comprehension

Student Textbook page 589

Q1. (a) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

(b) $C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$

Q2. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

Q3. $2CH_3OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

Q4. $C_3H_7COOH(\ell) + 5O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$

Q5. $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$

Q6. The energy produced in the combustion of a hydrocarbon is from the breaking and reforming of chemical bonds during combustion. The energy required to break apart carbon–hydrogen and carbon–carbon covalent bonds is not as large as the amount of energy released as oxygen–hydrogen (O–H) and carbon–oxygen (C=O) covalent bonds form.

Thought Lab 15.1: Fossil Fuels and Climate Change

Student Textbook page 589

Purpose

Students will use text and electronic sources to research the effect that gaseous products from the combustion of fossil fuels such as natural gas, coal, and petroleum, have on global climate.

Outcome

- 30C-2.3s

Advance Preparation

When to Begin	What to Do
2 weeks before	■ Arrange with a librarian for a research period for your class, and/or access to a computer lab with Internet access.
1 day before	■ Review procedures for the following class with students. ■ Photocopy **BLM 15.1.1 (HAND) Thought Lab 15.1: Fossil Fuels and Climate Changes.**

Materials
■ none required

Time Required

- 60 to 80 minutes

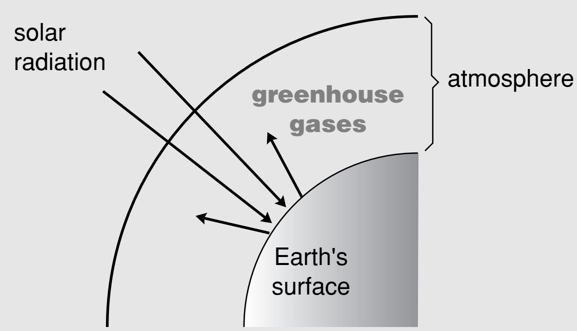
Helpful Tips

- This activity could be assigned as an extracurricular assignment, if necessary.
- The issue of climate change is a politically and emotionally charged one. Remind students to include references for their information, and to consider such things as the source of their information and the credibility of that source.
- Use **BLM 15.1.1 (HAND) Thought Lab: Fossil Fuels and Climate Change** to support this activity. Remove sections as necessary to meet the needs of students in your class.

Answers to Procedure Questions

1. (a) Students will generate many different diagrams. The features shown should include the following:

Radiant energy from the Sun is absorbed by the surface of Earth. Earth's surface re-radiates the energy, but at a longer wavelength. This energy is absorbed by greenhouse gases such as CO_2, H_2O, and CH_4, which causes warming of the lower atmosphere and surface. A simple diagram might appear as follows:



(b) Greenhouse gases are those gases in the atmosphere that selectively absorb electromagnetic radiation at the infrared wavelength range causing the chemical bonds joining adjacent atoms to stretch. When the chemical bonds return to the lower energy state, they emit an electromagnetic wave of slightly longer wavelength than that absorbed. This longer infrared radiation is absorbed by other gases in the atmosphere resulting in a warmer atmosphere.

2. (a) Concentrations of methane, carbon dioxide, and dinitrogen monoxide (nitrous oxide), all powerful greenhouse gases, are at levels significantly higher than those found in pre-industrial times. If the increasing trend continues many scientists argue that this will accelerate warming of the lower atmosphere causing an overall warming of Earth's surface and possible climate change.

(b) The main sources for dinitrogen monoxide and methane are related to human agricultural practices. The extensive use of nitrogen based fertilizers in agriculture is one of the biggest factors involved in production of dinitrogen monoxide. Both methane and dinitrogen monoxide are formed by microbes in the anaerobic conditions maintained in flooding of agricultural lands for rice farming. In addition, methane is generated as the natural byproduct of ruminant digestion and from landfills. The human production of carbon dioxide is primarily from fossil fuel burning. The rate of increase in the atmosphere is closely tied to the agricultural practice of cutting down tropical forests.

Answers to Analysis Questions

1. The burning of fossil fuels is expected to increase the level of greenhouse gases in the atmosphere. Although the amount of change that could result is still being hotly debated, it is expected that disruptions to global weather patterns leading to shifts in precipitation and vegetation patterns will affect most areas of the world. In addition, a warmer atmosphere is expected to lead to changes in the polar ice sheets with a corresponding change in sea level, and a general increase in severe storms in certain areas such as the tropics.
2. The agricultural practices of flooding arable land to produce rice crops and cutting down of tropical rainforest areas to produce pasture land are increasing the levels of greenhouse gases in the atmosphere. In addition, the destruction of tropical rainforest removes an important method of withdrawing carbon dioxide from the atmosphere.
3. Four possible methods are outlined below:
   (i) Electricity production is one of the largest sources of carbon dioxide emissions in developed countries. Therefore, reducing electricity use by turning off unnecessary lights and appliances, and buying energy efficient appliances is a good start.
   (ii) Reducing the amount of organic materials deposited in landfills can reduce the possibility of methane production.
   (iii) Reduction or changes to the way in which nitrogen based fertilizers are used may reduce production of nitrous oxide.
   (iv) Reduction in fossil fuel combustion by reducing automobile use and lowering household heating/cooling levels will reduce carbon dioxide emissions.

Assessment Options

- Collect and assess students' reports and answers to Procedure and Analysis questions.
- Use Assessment Checklist 7: Independent Research Skills from Appendix A.

Connections (Social and Environmental Contexts): Trans Fats in the Diet

Student Textbook page 592

Teaching Strategies

- Remind students of their observation in the Launch Lab that coconut oil, although liquid at room temperature, behaves like a saturated fat. Challenge your students to find the composition of coconut oil (also known as "copra" oil).

Answers to Connections Questions

1. The more highly hydrogenated a fat is, the higher its melting temperature. Therefore, if a fat product is too highly hydrogenated it will be too solid at room temperature.
2. Heart disease often develops over many years before becoming evident. In recent years, techniques have been developed to study the effects of low density lipoproteins (LDLs) and high density lipoproteins (HDLs) at the molecular level. Trans fats are thought to increase the levels of LDLs, which is now known to be associated with an increased risk of heart disease.
3. Yes. Dairy products and various meats will contain small amounts of trans fats. There is some evidence that conjugated linoleic acid has anticancer properties, acts to prevent cardiovascular disease associated with the atherosclerosis, and may be used in the treatment of diabetes.

Answers to Practice Problems 1–6

Student Textbook pages 596–597

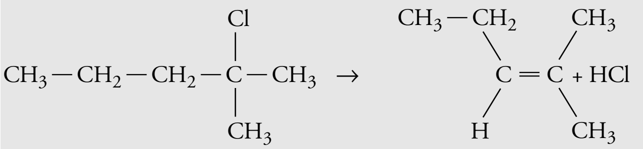
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

1. **(a)** addition
   (b) esterification
   (c) substitution
   (d) elimination
2. **(a)** pentan-2-ol $\xrightarrow{H_2SO_4}$ pent-1-ene + water

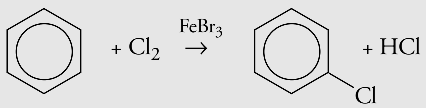
$$CH_3-\overset{\overset{OH}{|}}{CH}-CH_2-CH_2-CH_3 \xrightarrow{H_2SO_4}$$

$$CH_2=CH-CH_2-CH_2-CH_3 + H_2O$$

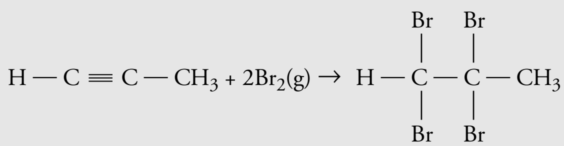
(b) 2-chloro-2-methylpentane → 2-methyl-pent-2-ene + hydrogen chloride



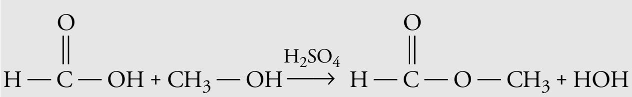
(c) benzene + chlorine gas $\xrightarrow{FeBr_3}$ chlorobenzene + hydrogen chloride



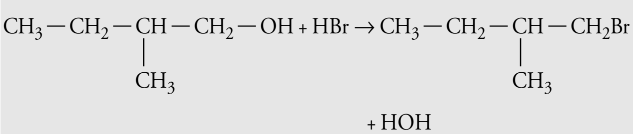
(d) propyne + bromine vapour (excess) → 1,1,2,2-tetrabromopropane



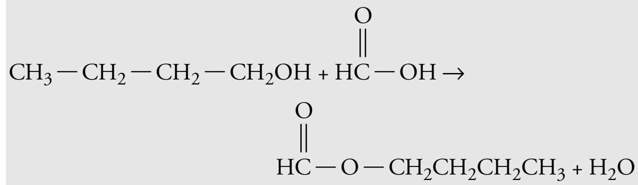
(e) methanol + methanoic acid $\xrightarrow{H_2SO_4}$ methyl methanoate + water



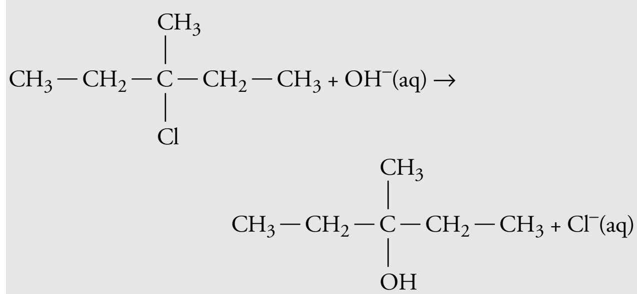
(f) 2-methylbutan-1-ol + hydrogen bromide → 1-bromo-2-methylbutane + water



3. **(a)** elimination
   (b) elimination
   (c) substitution
   (d) addition
   (e) esterification
   (f) substitution
4. $CH_2{=}CH - CH_3 + HOH \rightarrow CH_3 - CH(OH) - CH_3$
5. Step 1: An alkyl halide will react with a strong base $OH^-(aq)$ at room temperature to produce an alcohol; in a substitution reaction, butan-1-ol can be made from 1-chlorobutane in this manner.
   $CH_3 - CH_2 - CH_2 - CH_2Cl + OH^-(aq) \rightarrow CH_3 - CH_2 - CH_2 - CH_2OH + Cl^-$
   Step 2: Methanoic acid will react with the butan-1-ol to form butyl methanoate and water.



6. This reaction can be carried out in one step with a substitution reaction in the presence of a strong base.
   3-chloro-3-methylpentane + $OH^-(aq)$ → 3-methylpentan-3-ol + $Cl^-(aq)$



Investigation 15.A: Preparing Esters

Student Textbook pages 597–599

Purpose

Students will react several carboxylic acids with simple alcohols and then observe the characteristic odours produced as evidence for the synthesis of esters.

Outcomes

- 30-C2.1s
- 30-C2.2s

Advance Preparation

When to Begin	What to Do
1 week before	■ Gather the required materials.
1 day before	■ Place the sulfuric acid and butanoic acid in a fume hood for ventilation of vapours. ■ Set out materials for each group. ■ Photocopy **BLM 15.1.3 (HAND) Investigation 15.A: Preparing Esters.**

Materials
■ ice ■ distilled water ■ ethanoic acid ■ ethanol ■ propan-1-ol ■ butanoic acid ■ 6 mol/L sulfuric acid ■ 250 ml beakers (2) ■ 50 mL beakers (2) ■ 100 mL beaker ■ 10 mL graduated pipettes (2) ■ watch glass ■ hot plate ■ thermometer (alcohol or digital) ■ retort stand ■ 2 clamps ■ 4 plastic micropipettes ■ medicine dropper ■ rubber stopper or paper towel

Time Required

- 60 minutes

Helpful Tips

- To save time, you may wish to have the water heating on the hot plates before the students enter the laboratory.
- To avoid cross contamination, dedicate a pipette for each acid and alcohol.
- Use **BLM 15.1.3 (HAND) Investigation 15.A: Preparing Esters** to support this activity. Remove sections as necessary to meet the needs of students in your class.
- ***Expected Results:*** Ethanoic acid (acetic acid) is the main ingredient in vinegar. Butanoic acid has an unpleasant odour. It is partially responsible for the odour of rancid butter. The first ester, ethyl ethanoate, has the odour of glue or varnish remover. The second ester, propyl ethanoate has a fruity odour reminiscent of pears. The third ester, ethyl butanoate, also has a fruity odour and is sometimes described as similar to apples.

Safety Precautions

- Ensure students read and understand "Safety in Your Chemistry Laboratory and Classroom" on pages xii-xv in the student textbook.
- Since organic solvents are very flammable, do not use a Bunsen burner or any other source of open flame in this lab.
- Remind students that sulfuric acid, ethanoic acid, and butanoic acid are all highly corrosive and that they should use with extreme caution. Any spills on skin or clothing should be rinsed with plenty of cold water. Advise them to inform you of any spills.
- Make sure that all steps involving acids are carried out in a fume hood. All procedures are to be carried out in a well-ventilated area.
- Remind students of the appropriate method for smelling chemicals in a chemistry lab.
- Clearly demonstrate how and where students should dispose of waste materials when they have completed the investigation.

Answers to Analysis Questions

1. Students should observe the physical property of odour.
2. The production of an odour, which differs from the original reactants, is a key sign that a chemical reaction has occurred to form a new substance.

Answer to Conclusion Question

3. Student answers will vary depending on the alcohol and carboxylic acid used to produce the ester. The following table lists some of the possible products and their characteristic odours.

Carboxylic acid	Alcohol	Ester product	Ester odour
ethanoic acid	ethanol	ethyl ethanoate	peach
ethanoic acid	propan-1-ol	propyl ethanoate	pear
ethanoic acid	butan-1-ol	butyl ethanoate	banana
ethanoic acid	octan-1-ol	octyl ethanoate	orange
butanoic acid	methanol	methyl butanoate	apple
butanoic acid	ethanol	ethyl butanoate	pineapple/ peach
butanoic acid	butan-1-ol	butyl butanoate	apricot

Answer to Application Question

4. Some odours are associated with more than one ester. The table shown below provides some characteristic esters.

Name	Chemical structure	Odours
octyl ethanoate	$CH_3COOCH_2(CH_2)_6CH_3$	orange
ethyl butanoate	$CH_3CH_2CH_2COOCH_2CH_3$	pineapple
propyl ethanoate	$CH_3COOCH_2CH_2CH_2CH_2CH_3$	pear
methyl salicylate	$C_6H_4(OH)COOCH_3$	oil of wintergreen
methyl butanoate	$CH_3CH_2CH_2COOCH_3$	apple

Assessment Options

- Collect and assess students' reports and answers to Analysis, Conclusion, and Application questions.
- Use Assessment Checklist 2: Laboratory Report from Appendix A.

Thought Lab 15.2: Problem Solving with Organic Compounds

Student Textbook pages 599–601

Purpose

Students will use the Internet and/or library resources to conduct research on the connections between societal needs and the science, technology, and environmental concerns associated with organic compounds.

Outcomes

- 30-C2.1sts
- 30-C2.2sts
- 30-C2.3sts
- 30-C2.2s
- 30-C2.4s

Advance Preparation

When to Begin	What to Do
2 weeks before	■ Arrange with a librarian for a research period for your class, and/or access to a computer lab with Internet access.
1 week before	■ Have students collect appropriate articles from the newspapers, magazines, or e-zines regarding the use of organic compounds.
1 day before	■ Review procedures for the following class with students. ■ Photocopy **BLM 15.1.4 (HAND) Thought Lab 15.2.: Problem Solving with Organic Compounds.**

Materials
■ none required

Time Required

- 60 to 80 minutes

Helpful Tips

- You may want to assign some issues that are specifically relevant to your community.
- Use **BLM 15.1.4 (HAND) Thought Lab 15.2: Problem Solving with Organic Compounds** to support this activity. Remove sections as necessary to meet the needs of students in your class.

Answers to Procedure Questions

Answers will depend on the issues selected by students. Some examples are included below.

From the article "Octane-Enhancing Compounds Reduce Engine Knocking":

1. Gasoline with a low octane number is less efficient in combustion and can lead to damage to a car engine.
2. The fuel additive tetraethyl lead acts as a catalyst to increase fuel efficiency and decrease knocking.
3. Compounds of lead from gasoline were emitted by cars in the form of lead oxides, and also gaseous lead(II) bromide formed in the reaction with the fuel additive ethylene dibromide. The neurological and developmental problems associated with these lead compounds are regarded as a serious environmental problem.
4. Current automobile fuels use organic fuel additives such as methyl tertiary-butyl ether (MTBE) or other alcohols to prevent knocking. Although tetraethyl lead was added to the list of controlled toxic substances for the 1999 Canadian Environmental Protection Act, this only applies to automobile fuels. Currently, aviation fuel and

recreational marine fuels still use tetraethyl lead as an antiknock agent.

5. MTBE is responsible for widespread contamination of groundwater and drinking water supplies as a result of its ability to dissolve in water. It biodegrades slowly and once into a groundwater supply produces an offensive “turpentine” like taste and odour, making water virtually unfit to drink. The United States Environmental Protection Agency (EPA) began proceedings in early 2000 to eliminate or limit the use of MTBE as a fuel additive.

For issues relating to the production and use of chlorofluorocarbons (CFCs):

1. To keep fresh food from spoiling, it is helpful to keep the food cold. Early refrigerators used substances such as ammonia or methyl chloride. Accidental releases of these toxic chemicals occasionally proved fatal.
2. Toxic refrigerants were replaced with stable and nontoxic CFCs, which are organic compounds.
3. Decades later, it was discovered that CFCs cause the depletion of the ozone layer, leading to increased risks of skin cancer and damage to crops and forests. CFCs are also greenhouse gases and contribute to global warming.
4. CFCs are no longer produced in Canada, and existing CFCs are being recycled. CFC substitutes such as hydrofluorocarbons are being introduced.
5. Both CFCs and hydrofluorocarbons are greenhouse gases, so they contribute to global warming. Hydrocarbons are flammable, so they pose a health risk.

For issues relating to production of pesticides, particularly DDT:

1. Insects and weeds destroy crops and spread disease.
2. The development of pesticides such as DDT dramatically reduced crop damage and the spread of diseases.
3. DDT and other chlorinated pesticides bioaccumulate and have toxic properties.
4. DDT and other chlorinated pesticides are either restricted or prohibited and are being replaced with other less harmful pesticides.
5. Substitute pesticides are often less effective and may also have unidentified environmental health risks.

Answers to Analysis Questions

1. Some of the benefits listed may include:
   - development and use of pharmaceutical drugs
   - development of polymers and other synthetic materials for clothing, packaging, and building components
   - development of effective synthetic pesticides to control disease and food spoilage
   - development of solvents for cleaning
   - development of adhesives for medical and construction purposes
   - development of synthetic fertilizers to increase agricultural yields
2. Some of the possible unintended results that have occurred include:
   - pollution of aquifers
   - destruction of stratospheric ozone
   - enhanced greenhouse effect
   - pesticide-resistant organisms
   - antibiotic-resistant bacteria
   - accumulation of plastics in the environment
   - development of chromosomal and developmental aberrations due to exposure to organic solvents
3. Regardless of the positions taken, it is important for students to be able to support their arguments with pertinent facts. A good strategy to follow is to have students compare the costs and benefits associated with their answers.

Assessment Options

- Collect and assess students’ reports and answers to Procedure and Analysis questions.
- Use Assessment Checklists 4: Performance Task Group Assessment and 7: Independent Research Skills from Appendix A.

Section 15.1 Review Answers

Student Textbook pages 602

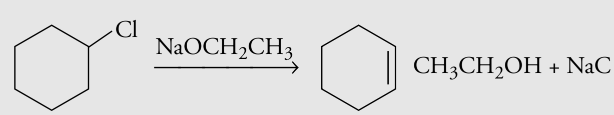
1. **(a)** addition
   (b) esterification
   (c) elimination
   (d) substitution
2. Students should produce answers similar to the following:
   (a) Addition reaction

$$\underset{\text{but-2-ene}}{CH_3CH = CHCH_3} + \underset{\text{water}}{H_2O} \xrightarrow{\text{acid catalyst}} \underset{\text{butan-2-ol}}{CH_3CH_2CH(OH)CH_3}$$

   (b) Esterification reaction

$$\text{methanol + pentanoic acid} \xrightarrow{\text{acid catalyst}} \text{methyl pentanoate + water}$$

   (c) Elimination reaction



chlorocyclohexane cyclohexene ethanol salt

(d) Addition reaction

$$CH_3CH{=}CHCH(CH_3)CH_3 + H_2 \rightarrow CH_3CH_2CH_2CH(CH_3)CH_3$$

4-methylpent-2-ene hydrogen 2-methylpentane

(e) Elimination reaction

$$CH_3CH_2CH_2CH_2CH_2I + OH^- \rightarrow CH_3CH_2CH_2CH{=}CH_2 + HOH + I^-$$

1-iodopentane hydroxide ion pent-1-ene water iodine ion

(f) Elimination reaction

$$CH_3CH_2CH_2CH(OH)CH_3 \xrightarrow{\text{acid catalyst}} CH_3CH_2CH{=}CHCH_3 + HOH$$

pentan-2-ol pent-2-ene (major) water

(g) Esterification reaction

$$CH_3CH(OH)CH_3 + CH_3CH_2CH_2C({=}O){-}OH \xrightarrow{\text{acid catalyst}}$$

propan-2-ol butanoic acid

$$CH_3CH_2CH_2C({=}O){-}O{-}CH(CH_3)CH_3 + HOH$$

2-propyl butanoate water

(h) Combustion reaction

$$CH_3C(CH_3){=}CH_2 + 6O_2 \rightarrow 4CO_2 + 4H_2O$$

2-methylprop-2-ene

3. Examples of possible answers are listed below.

(a) Elimination reaction

$$CH_3CH_2Cl + NaOCH_2CH_3 \rightarrow CH_2{=}CH_2 + NaCl + HOCH_2CH_3$$

(b) Addition reaction

$$CH_2 = CH_2 + H_2O \rightarrow CH_3CH_2OH$$

(c) Esterification reaction

$$CH_3CH_2OH + CH_3C({=}O)OH \rightarrow CH_3C({=}O)OCH_2CH_3 + H_2O$$

(d) Combustion reaction

$$CH_4 + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

(e) Substitution reaction

$$CH_3CH_2CH_2OH + HCl \rightarrow CH_3CH_2CH_2Cl + H_2O$$

4. The Launch Lab involved an addition reaction whereby two hydroxyl groups were added to the alkene, one on either side of the original double bond. The formation of a brownish precipitate was evidence of the formation of a new substance.

5. Human activities, especially related to combustion of fossil fuels, are contributing many greenhouse gases to the atmosphere. In addition, the cutting down of forests for agricultural lands removes areas where one of the most predominant greenhouse gases produced is naturally removed. The overall severity of the effect is still being debated but the likely result is that the warming effect produced may cause a shift in global air circulations. The corresponding changes to precipitation patterns may lead to widespread changes to the biosphere.

6. HFCs are more potent greenhouse gases than carbon dioxide, so they are one of the gases that are regulated under the Kyoto Protocol.

15.2 Polymers and the Petrochemical Industry

Student Textbook pages 603–614

Section Outcomes

Students will:

- define, draw, and give examples of monomers and polymers in living and non-living systems
- build models to illustrate polymers and polymerization
- perform an experiment to make a polymer product
- relate the organic reaction types you have learned to reactions for producing important compounds from fossil fuels
- analyze a process for producing polymers

Key Terms

polymer
monomer
plastics
addition polymerization
condensation polymerization
petrochemicals

Chemistry Background

- Polymers are formed in the sequential chemical reaction of small molecular units called monomers to form long chains. Regardless of the number or types of monomers used, polymers are classified according to the reaction used to synthesize them.
- Addition polymerization involves multiple addition reactions of alkene monomers to produce a polymer containing a reduced number of double bonds. Condensation polymerization involves monomers with two functional groups that undergo multiple condensation reactions to produce a polymer and another small molecule, usually water.
- Polymers are a class of organic compounds that are developed and produced on industrial scales. The ability to control polymerization reactions has given society a large

number of polymers with an incredibly wide range of properties.

- The physical properties of polymers are of primary interest for industrial purposes. Individual polymer molecules have a high tensile strength due to the covalent bonds between the carbons in the chain. All polymer molecules interact with adjacent polymer molecules by intermolecular forces and as a result hold together extremely well.
- One of the most useful synthetic polymers is polyvinyl chloride (PVC). Its uses include piping, siding, flooring, packaging, and insulation for wires. However, a serious problem associated with the manufacturing and disposal of PVC is the production of dioxins, which are toxic to animals.
- There are also numerous examples of natural polymers, such as cellulose and starch in plants. In addition, molecules such as proteins and DNA, which control cellular activity and contain genetic information, are polymers of amino acids and nucleotides, respectively.

Teaching Strategies

- Many students are unaware of how pervasive the use of plastics is in modern society. Have students inspect the classroom to identify items that contain plastic, and make a list of the items on the chalkboard. This is a good activity to do as a classroom discussion to open this section.
- Reinforce the fact that there are both natural and synthetic polymers. It might be instructive to have students choose a polymer to research and write a report on. Examples could include silk, rayon, cellophane, Bakelite™, Teflon™, vulcanized rubber, chewing gum, and nylon. Have students include how the polymer was discovered, how it is used, and any interesting facts about it.
- A quick and easy demonstration of the characteristics of polymers can be done using Teflon™ tape (PTFE = polytetrafluoroethylene). Divide students into small groups and give each group several 10 cm lengths of Teflon tape. Have the students rest the Teflon tape onto a folded paper towel and, using a permanent pen, carefully write a short message onto the tape. The pen nib tends to catch on the tape so warn the students to write carefully. Once the ink is dried, have students pull the tape across its width to distort the writing. The tape can be stretched to several times its own width without tearing. Have students inspect their written message. Now have students pull on the ends of the tape to restore the tape to its original shape. Again, have students inspect the message, which should be restored to its original shape. Inform students that the polymers within Teflon form strong intermolecular bonds that could be destroyed if the tape is stretched sideways too much. The polymer molecules that make up the tape have orientations parallel to the tape.
- **BLM 15.2.1 (OH) Addition and Condensation Polymers** has been prepared for this section. You will find it with the Chapter 15 BLMs on the CD-ROM that accompanies this Teacher's Resource or at **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, BLMs.

Chemistry File: Try This

Student Textbook page 603

This model illustrates the important feature of polymers being composed of repeating subunits. In addition, the chain formed from the linked paper clips has flexibility and tensile strength, like most polymers. However, monomers in polymers are not likely to be as rigid as the paper clips and bonds between the monomers are probably more restrictive than the connections between the paper clips.

Students may also come up with other similarities and differences between polymers and their paper clip model.

Answers to Practice Problems 7–12

Student Textbook pages 606–607

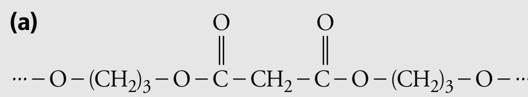
For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

7. polymethylmethacrylate (commonly known as PMMA)

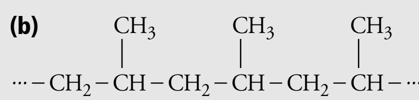
8. **(a)** condensation polymerization
(b) addition polymerization
(c) condensation polymerization

9.

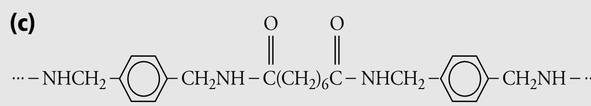
(a)



(b)



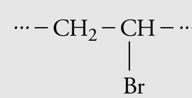
(c)



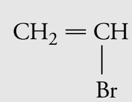
10. **(a)** addition polymer
(b) condensation polymer and a polyamide, or nylon
(c) condensation polymer and a polyester
(d) condensation polymer and a polyester

11.

(a) repeating unit:



monomer:



(b) repeating unit:

$$\cdots-NH-CH_2-NH-\overset{\displaystyle O}{\overset{\|}{C}}-CH_2CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-\cdots$$

monomers:

$$H_2N-CH_2-NH_2 \qquad HO-\overset{\displaystyle O}{\overset{\|}{C}}-CH_2CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-OH$$

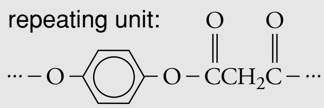
(c) repeating unit:

$$\cdots-O-CH_2CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-\cdots$$

monomer:

$$HO-CH_2CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-OH$$

(d) repeating unit:



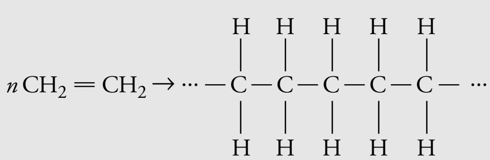
monomers:

12. Step 1 Production of ethene. C_2H_4.

An alkyl halide can undergo elimination to produce an alkene when heated in the presence of a strong base, such as sodium ethoxide ($NaOCH_2CH_3(aq)$) mixed with an ethanol solvent.

$$CH_3 - CH_2Br \xrightarrow{NaOCH_2CH_3} CH_2 = CH_2 + H_2O + Br^-$$

Step 2 Polymerization



Investigation 15.B: Modelling and Making Polymers

Student Textbook pages 607–608

Purpose

Students will investigate the nature and properties of polymers by constructing molecular models of vinyl alcohol and polyvinyl alcohol (PVA). Students will then prepare cross-linked polymer "slime" using sodium tetraborate decahydrate (borax).

Outcomes

- 30-C2.2s
- 30-C2.3s

Advance Preparation

When to Begin	What to Do
1 week before	■ Gather the required materials. In particular, ensure that the molecular model kits have all the components.
1 day before	■ Set out materials for each group. ■ Assign students the task of finding out what a cross-linked polymer is. ■ Photocopy **BLM 15.2.2 (HAND) Investigation 15.B: Modelling and Making Polymers.**

Materials
Part 1 ■ molecular model kits (1 per group) **Part 2** ■ pieces of polyvinyl alcohol bags (totaling about 20 cm^2) ■ 10 mL of very hot water ■ food colouring ■ 5 mL of 4% borax solution ■ hot plate or kettle ■ 10 mL graduated cylinder ■ 50 mL beaker ■ stirring rod

Time Required

- 60 to 80 minutes

Helpful Tips

- PVA laundry bags, if you can find a source, are highly preferable for this activity since they are designed to dissolve easily in hot tap water during a wash cycle.
- Prepare the boiling water for students and dispense it into the beakers.
- The fluidity of the "slime" polymer produced will depend on the molecular weight of PVA used. Higher molecular weights produce a stiffer slime, while lower molecular weights will produce a more fluid slime.
- Slime can be stored for fairly long periods of time in sealed plastic sacks to prevent evapouration.
- Try adding a few drops of Lysol® or another type of antibacterial cleaner to the borax solution. This will retard the growth of mold that might occur if storing the final product.
- The slime can be disposed of in a plastic bag in the garbage. Alternately, leave the gel out to dry. The sodium polyacrylate powder left behind can be reused. Avoid

inhaling the powder since it absorbs water readily and can be irritating to eyes and mucous membranes.

- Clean up with hot water and soap.
- Use **BLM 15.2.2 (HAND) Investigation 15.B: Modelling an Making Polymers** to support this activity. Remove sections as necessary to meet the needs of students in your class.
- ***Expected Results:*** As soon as the students add the borax solution to the PVA solution, it will begin to thicken. If a ball of slime is lying on the benchtop, it will slowly flatten out. If a ball of slime is stretched slowly, it will stretch out in a long string. If it is pulled rapidly, it will snap and break.

SUPPORTING DIVERSE STUDENT NEEDS

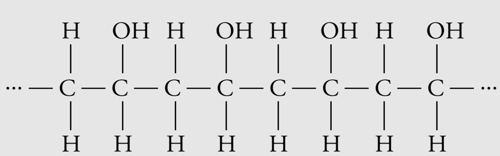
Some students may be curious about the effect of adding differing amounts of borax to make the slime. If time allows, have students start with a small amount of borax and gradually add more to make slimes of various consistencies.

Safety Precautions

- Ensure students read and understand "Safety in Your Chemistry Laboratory and Classroom" on pagese xii-xv in the student textbook.
- Remind students to be careful when working with the hot water.
- Clearly demonstrate how and where students should dispose of waste materials when they have completed Part 2 of the investigation.

Answers to Part 1 Procedure Questions

2. (b) The structure of polyvinyl alcohol can be represented as follows:



4. (a) Since each strand has hydroxyl side groups, you would expect to see some amount of hydrogen bonding between two strands of the polymer.

(b) Since the hydroxyl side groups are present, you would also expect to see interactions with water molecules, making this polymer soluble in water.

Answers to Analysis Questions

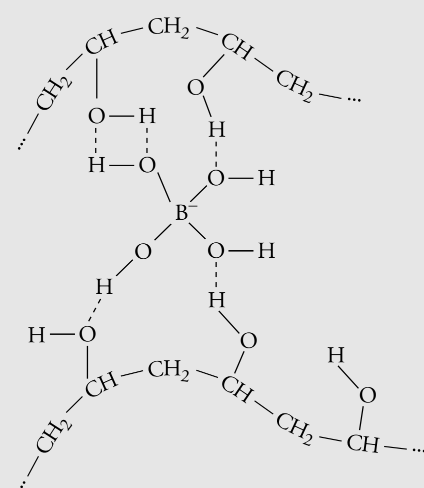
1. PVA is formed by an addition reaction since there is no side product formed in the reaction of the vinyl alcohol monomers. In addition, since the vinyl alcohol monomer only has one functional group it will not undergo condensation polymerization.

2. PVA dissolves in water because the presence of many hydroxyl side groups allows the water to form hydrogen bonds with the PVA strands.

3. The students should observe the following properties:

Action of ball of slime	Observations
dropped onto bench top	ball of slime bounces (or shatters depending on how much borax was reacted with PVA)
pulled slowly apart	slime stretches
pulled quickly apart	slime snaps into two pieces
left to sit on the bench top	slime spreads out into a layer

In each case the reason is due to how the PVA chains are cross-linked. When sodium tetraborate is dissolved into water it quickly reverts to boric acid ($H_3BO_3(aq)$), which then accepts hydroxide groups from the water to form a boron ion complex, $B(OH)_4^-$. Hydrogen bond cross-links are formed between the hydroxide groups of the boron ion complex and adjacent strands of the PVA to produce the polymer (see diagram below). This type of cross-linking gives the polymer elasticity.



Answers to Conclusions Questions

4. (a) Polyvinyl alcohol bags could be used as water soluble containers to store used hospital linens and garments for relatively safe handling. The bag and contaminated contents can both be added to a washing machine, where the bag would dissolve in the hot water leaving only the items to be washed.

(b) Polyvinyl alcohol is used either as a compounding agent or as a direct binding agent with cellulose, depending on the adhesive and application use. One common use is for the quick-setting adhesive on the back of postage stamps.

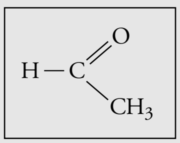
(c) Polyvinyl alcohol is used as an emulsifier and thickener for makeup products.

5. You could tell that changes occurred with the addition of the borax solution because the physical elasticity and stiffness of the cross-linked polymer are noticeably different. In addition, careful observation should indicate that an endothermic chemical reaction has occurred since the slime becomes noticeably cooler to the touch.

6. The polyvinyl alcohol polymer and “slime” polymer are both fluid-like substances. However, polyvinyl alcohol is significantly less viscous than the “slime” polymer.

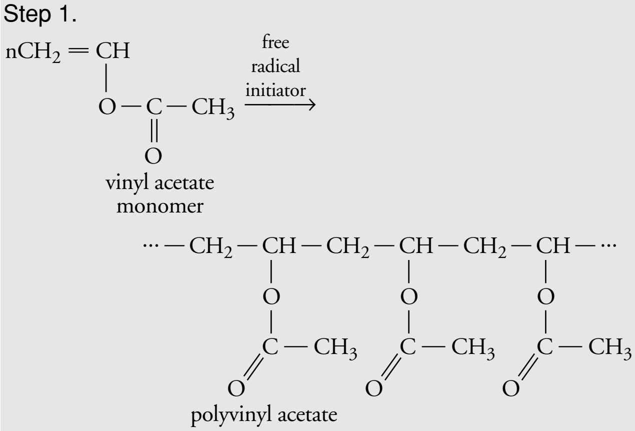
Answer to Application Question

7. The structure of ethanal is indicated below. Polyvinyl alcohol is obtained by the saponification of polyvinyl acetate, which is in turn obtained from the polymerization of vinyl acetate monomers.

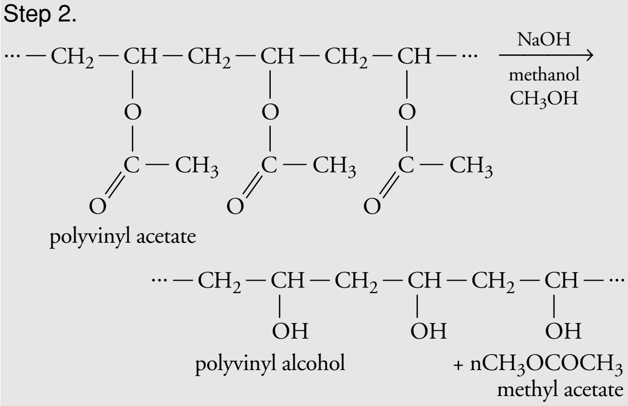


ethanal

Step 1.



Step 2.



Answer to Extension Question

8. Most students should find that hydrogen and oxygen atoms are needed to build the monomers. From this, the students should conclude that condensation reactions require the removal of a functional group (hydroxyl for many polymerization reactions).

Assessment Options

- Collect and assess students’ reports and answers to Procedure, Analysis, Conclusions, Application, and Extension questions.
- Use Assessment Checklists 2: Laboratory Report and 7: Independent Research Skills from Appendix A.

Chemistry File: Web Link

Student Textbook page 611

The recycling industry can make use of most polymer plastics if they are clean and can be identified. Plastic containers are labelled using a standard industry code to inform you of the type of polymer used in that product. The symbols are:

Type 1 and 2 are most commonly recycled. Type 7 is for mixed plastics and has almost no recycling potential. Once a plastic product is recycled and the polymer is used to manufacture a new product, it is identified as being recycled by placing an R in front of the previous designation.

The table below lists the polymers and most common polymer products that can be recycled. Some of the more common products formed from recycled polymer resins are also provided.

Code	Polymer type	Products commonly recycled	Recycled use
1 (PETE)	polyethylene terephthalate	■ beverage containers	■ fleece clothing, fiberfill for insulation, strapping. ■ soft drink bottles and other beverage containers ■ carpeting
2 (HDPE)	high density polyethylene	■ milk and juice containers ■ shampoo and detergent bottles ■ food containers for dairy products	■ toys ■ flooring ■ plastic pipe for wastes ■ plastic crates ■ plastic trash cans

Code	Polymer type	Products commonly recycled	Recycled use
3 (PVC-V)	polyvinyl chloride or vinyl	■ clear food packaging ■ wire insulation ■ oil bottles ■ plastic siding ■ plastic pipe ■ windows	■ plastic pipe and hoses ■ loose-leaf binders ■ plastic panel and sheets ■ mats and flooring
4 (LDPE)	low density polyethylene	■ plastic squeeze bottles ■ food bags ■ clothing ■ carpeting	■ floor tile ■ garbage bags ■ trash cans ■ fuel source for electrical energy generation at incinerator sites
5 (PP)	polypropylene	■ food containers ■ plastic caps ■ plastic straws ■ medicine containers	■ plastic sheets and trays ■ plastic holders and casing ■ brooms, rakes and brushes
6 (PS)	polystyrene	■ disposable plates, cups, and cutlery ■ egg cartons and meat trays ■ compact disk containers	■ thermal insulation ■ egg cartons ■ rulers ■ foam packaging
7	other	■ three and five gallon water bottles	■ plastic lumber

Since plastics are not readily degraded by biological action they create a waste disposal problem. Recycling the plastic removes about 20 percent of the waste going to landfills. In addition, the source of many of the monomers for making plastics polymers is fossil fuel. By recycling plastic, you are ultimately conserving these irreplaceable fuels.

Larger communities have some sort of recycling program in place. The biggest hurdle to any recycling program is what to do with the products collected. Shipping and handling costs to reprocess the plastics can be high. To find a site nearest you, the Earth911 organization has a website to help: http://www.earth911.org

Section 15.2 Review Answers

Student Textbook page 614

1. (a) A major difference between synthetic and natural polymers is how the monomer is obtained. For synthetic polymers the monomers are derived or extracted from petrochemicals, which undergo controlled chemical syntheses.

(b) Examples of natural polymers include cellulose, starch, proteins, and DNA. Three common synthetic polymers are polyethylene, polypropylene, and polyvinyl chloride.

(c) Glucose is the monomer in both cellulose and starch, amino acids are the monomers in proteins, and nucleotides are the monomers in DNA. Polyethylene is composed of ethene monomers, while propene monomers form polypropylene and vinyl chloride monomers form polyvinyl chloride.

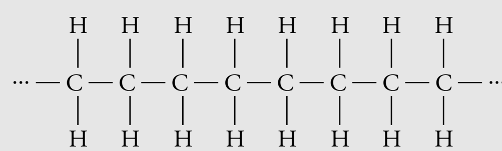
2. The reaction processes are classified as addition reactions and condensation reactions.

3. (a) a carboxyl group and an alcohol group

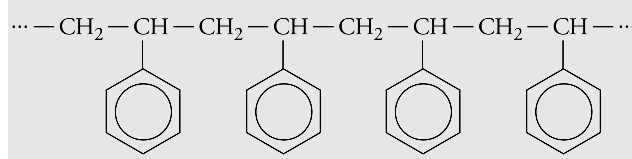
(b) a carboxyl group and an amino group

4. Student answers may depend on whether they use complete, condensed, or line structural formulas.

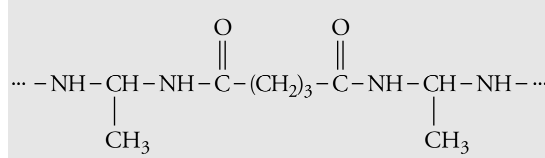
(a) Addition polymerization



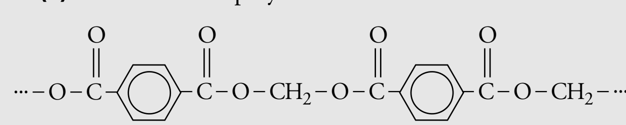
(b) Addition polymerization



(c) Condensation polymerization

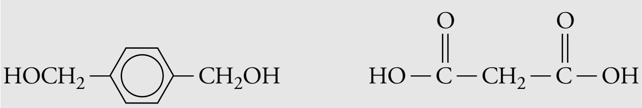


(d) Condensation polymerization



5. (a)

(b)



6. (a) There are several problems associated with society's use of synthetic polymers. The first is that the polymers formed are very stable and do not readily decompose. The living organisms that would normally carry out the decomposition lack the enzymes needed to attack the polymer bonds. The second major problem is that the monomers needed for the polymerization reactions are typically obtained from petrochemical sources, an inherently non-renewable source.

(b) The benefits obtained from synthetic polymers are that they are incredibly stable and have a wide range of properties that can be tailored to fit a particular technological or societal need.

(c) Regardless of the students' opinions, they should be able to provide rationale for their choices. Possible costs/risks that may be listed by the students include increasing levels of plastic garbage, overflowing landfills, and toxic by-products from the production of polymers.

7. The petrochemical industry uses alkanes obtained from fractional distillation of petroleum to prepare alkenes, which can then be modified by the various types of organic reactions to form the desired monomers. A good example is included in the student textbook, which is ethane being forced to undergo an elimination reaction to produce ethene and hydrogen gas. The ethene then undergoes an addition polymerization reaction to form polyethylene.

Chapter 15 Review Answers

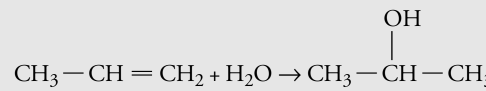
Student Textbook pages 616–617

Answers to Understanding Concepts Questions

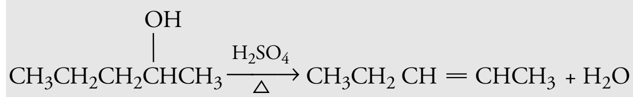
1. (a) A substitution reaction is characterized by a hydrogen atom or functional group being replaced by a different functional group. In this reaction, two compounds react to form two different products, without loss or gain of a multiple bond on the carbon atoms.

$$CH_3CH_2CH_2CH_2OH + HCl \rightarrow CH_3CH_2CH_2CH_2Cl + H_2O$$

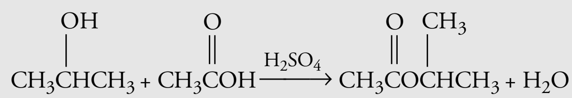
(b) An addition reaction involves reactions of alkenes and alkynes with small molecules, whereby atoms are added to the multiple bond resulting in the loss of that bond. Common small molecules that add to alkenes and alkynes include water, hydrogen, hydrogen halides, and halogens.



(c) An elimination reaction can be viewed as the reverse of an addition reaction, whereby atoms are removed from two carbon atoms in a reactant and a double bond forms between those two carbons in the organic product.



(d) In a typical esterification reaction a carboxylic acid reacts with an alcohol to form an ester and water.



(e) During a complete combustion reaction a hydrocarbon reacts with oxygen gas in the presence of a spark to produce carbon dioxide gas, water vapour, and energy. If not enough oxygen is present incomplete combustion produces the same products, as well as carbon and/or carbon monoxide.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

2. (a) A polymer is an organic molecule that consists of repeating units called monomers that are linked together by covalent bonds.

(b) A monomer is a small organic molecule that is the repeating unit in a polymer.

(c) Plastic is a synthetic polymer that can be moulded or heated to form specific shapes.

3. (a) elimination reaction

(b) combustion reaction

(c) esterification reaction

(d) addition reaction

(e) substitution reaction

4. Polymers are named after the monomer used to form them. In the case of polyethene, more commonly known as polyethylene, the monomer is ethene.

5. (a)

$$CH_3-CH=CH-CH_3 + Br_2 \longrightarrow CH_3-CHBr-CHBr-CH_3$$

2,3-dibromobutane

(b)

$$HOCH_2CH_2CH_2CH_2CH_3 + HBr \rightarrow BrCH_2CH_2CH_2CH_2CH_3 + H_2O$$

1-bromopentane, water

(c)

$$CH_3CH_2COOH + HOCH_3 \xrightarrow{H_2SO_4} CH_3CH_2COOCH_3 + H_2O$$

methyl propanoate, water

(d)

$$HO-CH_2CH_2CH_3 \xrightarrow[\Delta]{H_2SO_4} CH_2=CH-CH_3 + H_2O$$

propene, water

6. (a)

$$CH_3-CH_2-\overset{O}{\overset{\|}{C}}-OH + CH_3-CH_2-CH_2-OH \xrightarrow{acid}$$

$$CH_3-CH_2-\overset{O}{\overset{\|}{C}}-O-CH_2-CH_2-CH_3 + H_2O$$

propyl propanoate, water

(b)

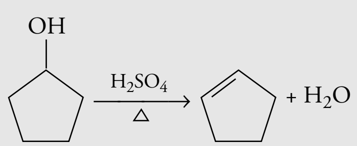
$$CH_3-CH_2-C\equiv CH + Cl_2 \rightarrow CH_3-CH_2-CCl=CHCl + Cl_2$$

1,2-dichlorobut-1-ene

$$\rightarrow CH_3-CH_2-CCl_2-CHCl_2$$

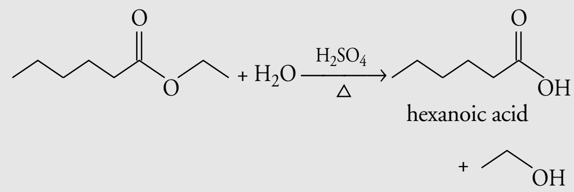
1,1,2,2-tetrachlorobutane

(c)



cyclopentene water

(d)

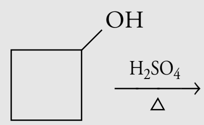


7. (a)

$$CH_3-CH_2-\overset{O}{\overset{\|}{C}}-OH + CH_3-CH_2-CH_2-CH_2-OH \rightarrow$$

propanoic acid, butan-1-ol

(b)



cyclobutanol

Answers to Applying Concepts Questions

8. The difference between a polymer and any other large molecule is that polymers are composed of repeating units of monomers. Large molecules are not necessarily composed of monomers. In addition, although the monomers used may be the same, individual polymer synthesis can result in products of varying length.

9. Proteins and starches are classified as polymers because they consist of repeating monomers of amino acids and glucose, respectively.

10. (a) An addition polymerization involves multiple addition reactions of alkene monomers to form polymers that lack the double bond.

$$CH_2=CH_2 \xrightarrow{catalyst} \cdots-CH_2-CH_2-\cdots$$

(b) A condensation reaction is one in which monomers with two or more functional groups undergo multiple condensation reactions to form a polymer and a second smaller product.

$$HOCH_2CH_2OH + H_2N-\overset{O}{\overset{\|}{C}}-NH_2 \xrightarrow{catalyst}$$

$$\cdots-CH_2-CH_2-NH-\overset{O}{\overset{\|}{C}}-NH-CH_2-CH_2-\cdots + H_2O$$

11. (a) The monomer used to make polypropene is propene, $H_2C=CHCH_3$

(b) Polypropene is an addition polymer.

(c) The common name for this polymer is polypropylene.

12. Although both nylon and polyester are condensation polymers, the difference between the two is that nylon monomers are linked by amide bonds and polyester monomers are linked by ester bonds.

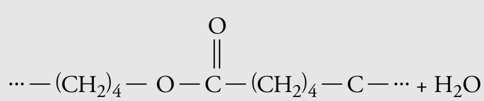
13. A protein is effectively a polyamide because the amino acid monomers are linked by amide bonds.

14. Both cellulose and starch are polymers of glucose monomers. The major difference between them is the orientation of the monomers relative to each other. This difference is due to how the glucose units are linked together. Cellulose contains beta linkages and starch contains alpha linkages. This results in the two molecules having different three-dimensional structures. While we have enzymes in our body that can recognize starch, which allows us to beak it down, we do not contain enzymes to break down cellulose. In addition, starch can also contain branched chains, while cellulose does not. These two molecules also have very different functions within plants. Starch is used as a storage mechanism for extra glucose and cellulose is used as a structural component.

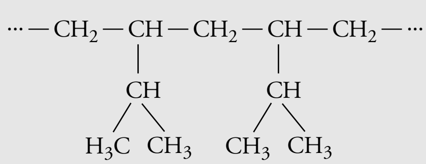
15. The difference between a protein and an amino acid is that amino acids are the monomers used to form the protein.

16. Students should produce structures similar to those below. Answers will depend on the type of structural formulas used to draw the products.

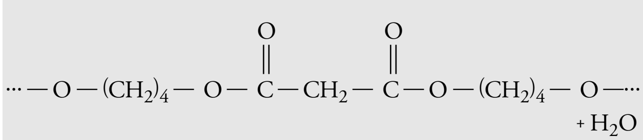
(a)



(b)



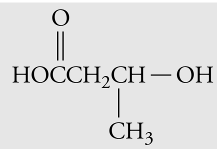
(c)



17. Students should produce structures similar to those below. Answers will depend on the type of formulas used to draw the monomers.

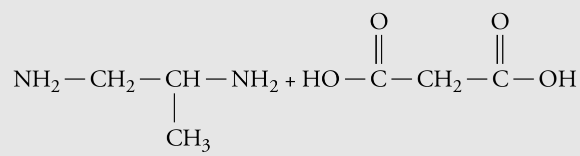
(a) $CH_2 = CH_2$

(b)

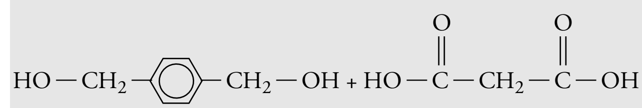


(c) $CH_2 = CHCH_2CH_3$

(d)

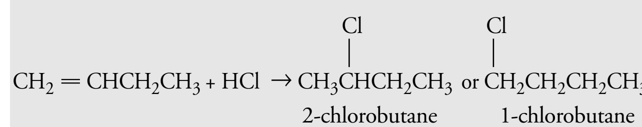


(e)



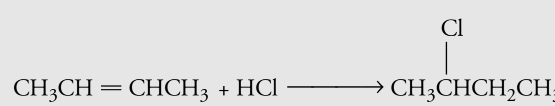
Answers to Making Connections Questions

18. Due to the location of the double bond in but-1-ene, there are two possible configurations when adding HCl across the double bond.



However, according to Markovnikov's rule, the hydrogen atom of HCl will attach to the carbon of the double bond that is already bonded to the most hydrogen atoms. Therefore, 2-chlorobutane is the major product formed.

When but-2-ene is used instead, the symmetrical nature of the molecule produces only one isomer,

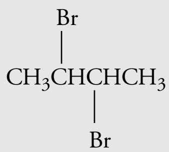


19. **(a)** Place the sample of oil or fat into a test tube. Add 10 to 15 drops of bromine water to the test tube, cover the end of the tube with a rubber stopper and shake. The loss of the reddish-brown bromine color is evidence for the addition of bromine atoms across a carbon-carbon double bond.

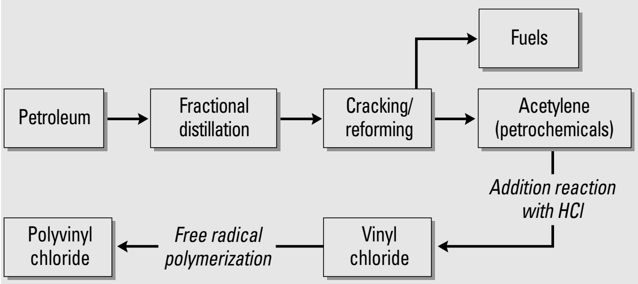
(b) Bromine is classified as highly volatile, toxic, and may cause severe burns to exposed tissue. All chemical tests should be performed in a fume hood; any spills should be immediately cleaned up. All waste products should be discarded into a container labelled "halogenated organic waste" for proper disposal by qualified lab personnel.

(c) This is an addition reaction. The color change indicates the disappearance of the bromine in solution to form 2,3-dibromobutane.

(d)



20.



21. (a) The development of organic fuel additives such as methyl tertiary-butyl ether (MTBE) allows for the use of lead-free fuels in automobiles and helps reduce the amount of lead, a heavy metal toxin, being released into the environment.

(b) Used polyethylene terephthalate (PET) is fully recyclable because, unlike other plastics, the polymers can be recovered. This is due to the fact the terephthalic acid (TPA) or dimethyl terephthalate (DMT) monomers used to produce the polymer give it a low melting temperature and so makes it easy to reform.

22. There are many possible answers. One useful method is to question whether the author of the article or web site stands to gain financially if they convince individuals that their argument is valid. To assess the possibility of bias it is often useful to look at the mission statements or goals of any sponsoring organization for that author. Few sponsors allow for a purely unbiased treatment. In addition, sources that are peer-reviewed by other individuals in that research community tend to be less biased, since experimental data supporting the author's claim is scrutinized.

23. The properties that make plastics so useful include their ability to be made into any desired shape, and their ability to bend and warp without breaking.

24. One useful way to increase the efficiency of recycling in any community is to decrease the amount of category 3 through 7 plastics. The economic and logistical difficulties in recycling these plastics means that they are merely put into landfills at present. If consumers buy items that have plastics from categories 1 and 2, they can increase the likelihood of re-use because the plastics can be easily recycled.

25. (a) Currently the production of biofuels is limited by technological problems. It is not cost effective to work directly with cellulose so the industry uses biological fermentation to produce methanol and ethanol. These alcohols provide less energy than gasoline when combusted and so are relatively expensive to use. In addition, the infrastructure to deliver biofuels to consumers is lacking.

(b) Unlike fossil fuels, biofuels are ultimately a renewable resource and tend to be cleaner burning to produce less greenhouse gas emissions.

(c) In Alberta, the petroleum industry would need to be retooled to focus less on fuels and more on petrochemicals, which is an expensive undertaking. In addition, the agricultural sector would need to focus on growing plants that are not used for food or fibre.

(d) Student should be able to provide a rationale for their opinion. A good way to focus on this is to have students make a list of pros and cons for comparison.

26. Students who disagree are likely to include reasons that focus on the extreme usefulness of synthetic polymers for things such as clothing and building materials. Those students who agree are likely to focus on the environmental release of toxins or current demand on non-renewable fossil fuels to produce those polymers.

27. The amino acids in the beverage are the monomers used to form protein in muscles. Athletes might believe that if they increase the amount of amino acids they consume, it will result in an increase in muscle mass.

28. Ensure that models for both starch and cellulose are built so that students can see the different three-dimensional structures for these molecules.

Career Focus: Ask a Chemical Safety Expert

Student Textbook pages 618–619

Teaching Strategies

- If possible, invite an individual whose profession involves dealing with issues surrounding chemical and environmental safety. They may include, for example, individuals conducting chemical research, those who are involved in monitoring safety procedures in research labs, or those who establish safety regulations for the environment.
- Discuss with students chemical safety issues that are relevant to the experiments they have conducted.
- Discuss aspects of environmental safety issues that are relevant to students' particular neighbourhoods or issues that they have heard of through the news or media. For example, is the use of pesticides in their town or city

prohibited? Do they know of any by-laws regarding the use of such chemicals?

- For information on pesticide management in Alberta, go to http://www3.gov.ab.ca/env/protenf/pesticide/
- The following web sites may be of interest to students interested in pursuing occupations mentioned in this Career Focus.
  - http://www.alis.gov.ab.ca/occinfo/Content/RequestAction.asp?aspAction=GetHTMLProfile&format=html&OCCPRO_ID=71001558
  - http://techworks.asttbc.org/pdf/enviro.pdf
  - http://www.cchrei.ca/_student/ee/profile.asp?wp=en&id=1
  - http://www.ryerson.ca/undergraduate/admission/programs/occhealth.html

Answers to Go Further Questions

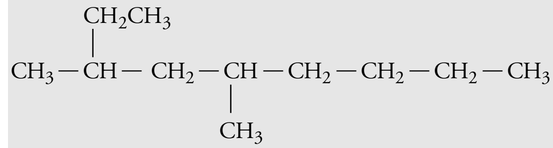
1. Student should address the desirability to have specific facts about the cause and effect relationship between the nature of a pesticide and its potential effects, the dose-response relationship of that pesticide, and the potential for bioaccumulation and biomagnification of that pesticide.
2. It is desirable to have a working knowledge of the properties of any new organic substance. Informed decisions about whether or not to use a substance require facts to base those decisions on. The obvious benefit of reducing the number of fires related to use of computers and televisions would need to be balanced against the potential risks such a substance may pose in the future.
3. Student answers should include whether any new substances have been introduced to the workplace, the location and operation of any air-conditioning units that may be introducing new substances, the personal habits and activities of those involved, and the time of onset of sickness for each employee.

Unit 7 Review Answers

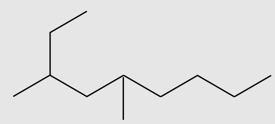
Student Textbook pages 620–623

Answers to Understanding Concepts Questions

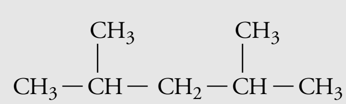
1. Carbon has four bonding electrons, which allow the formation of four strong covalent bonds to a variety of different atoms. In addition, carbon can form single, double, and triple covalent bonds with other carbon atoms to produce stable chains and networks of atoms.
2. Historically, an organic compound was defined as being formed by a living organism. The key idea behind this was that living organisms had some mysterious “vital force” that gave them the unique ability to produce organic compounds
3. The synthesis of organic compounds such as urea and acetic acid from inorganic starting materials required scientists to abandon the concept of “vital force.”
4. Organic compounds are those in which carbon atoms are nearly always bonded to each other, to hydrogen atoms, and often to atoms of other elements.
5. **(a)** The condensed structural formula is



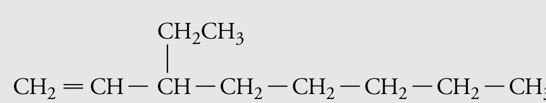
   (b) The line structural formula is



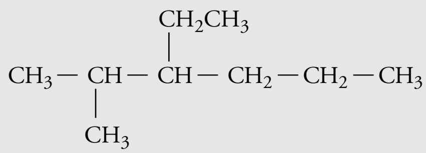
   (c) The empirical molecular formula is $C_{11}H_{24}$
   (d) The expanded molecular formula is $CH_3CH(CH_2CH_3)CH_2CH(CH_3)CH_2CH_2CH_2CH_3$
6. Each of compounds are aliphatic hydrocarbons.
   (a) 3,4-dimethylheptane
   (b) 4-methylheptane
   (c) 2,2-dimethylpropane
   (d) 1-ethyl-2-methylcyclohexane
7. **(a)** 3-ethyl-4-methylhex-1-ene
   (b) 3-methylcyclopentene
   (c) ethylbenzene
   (d) 3-methylpent-1-ene
8. **(a)** substituted alkene
   (b) substituted cycloalkene
   (c) substituted aromatic
   (d) substituted alkyne
9. The electrons that make up the second bond in each double bond of benzene are not just shared by the two adjacent carbon atoms but are shared equally among all six carbons. Electrons that behave in this way are called *delocalized electrons.* The circle indicates delocalized electrons.
10. **(a)** 2,4-dimethylpentane



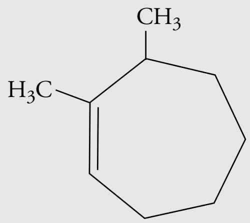
   (b) 3-ethyloct-1-ene



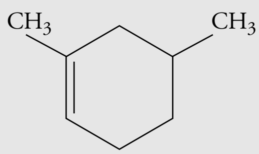
(c) 3-ethyl-2-methylhexane



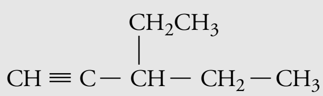
(d) 2,3-dimethylcycloheptene



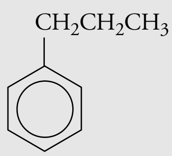
(e) 2,4-dimethylcyclohexene



(f) 3-ethylpenty-1-ne



(g) propylbenzene



(h) non-3-yne

$$CH_3-CH_2-C\equiv C-CH_2-CH_2-CH_2-CH_2-CH_3$$

11. **(a)** carboxylic acid (carbonyl group): 5-methyloctanoic acid

(b) alcohol (carboxyl group): 5-ethyl-3-methyloctan-2-ol

(c) alkyl halide (halogen): 3-chloropentane

(d) alkyl halide (halogen): 2-bromo-4-methylpentane

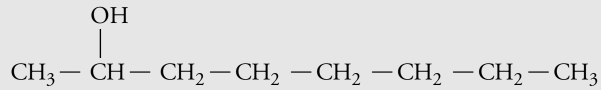
(e) alcohol (carboxyl): butan-2-ol

(f) ester: methyl butanoate

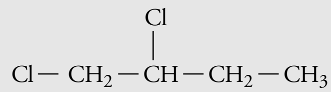
(g) ester: methyl 3-methylbutanoate

(h) alkyl halide (halogen): 3-bromo-2-chloro-4-fluorohexane

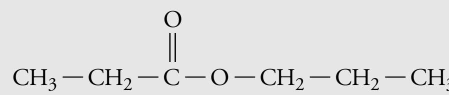
12. **(a)**



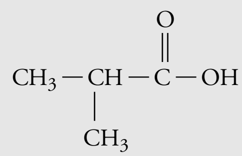
(b)



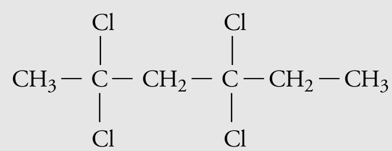
(c)



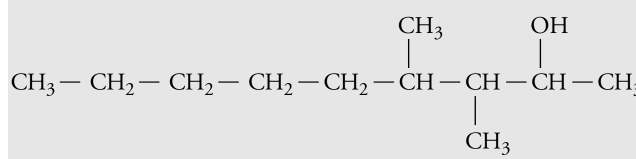
(d)



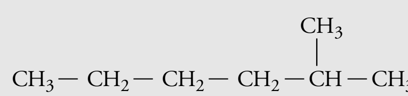
(e)



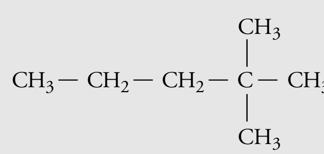
(f)



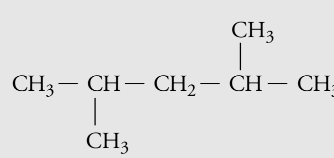
13. Three isomers that have the empirical formula, C_7H_{16} are:



2-methylhexane



2,2-dimethylpentane



2,4-dimethylpentane

14. Fractional distillation involves successive heating, evapouration, cooling, and condensation. Hydrocarbon components, called fractions, have a range of boiling points and relative densities. Separation of these fractions can be performed by heating. Fractions vapourize, rise upward in the tower, and condense onto plates placed at strategic locations where the temperature is just below the boiling point of a particular fraction.

15. (a) $CH_3CH_2CHICHICH_3$

(b) $CH_3CH_2CH_2Cl + HOH$

(c) propyl methanoate + water

(d) hept-1-ene + water

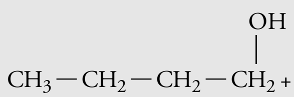
(e) $CH_3CHClCH_2CH_2Cl + HOH$

(f) $CH_3C(CH_3)CH_2 + NaBr + HOCH_2CH_3$

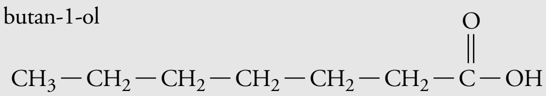
16. (a) $CH \equiv CH$

ethyne

(b)



butan-1-ol

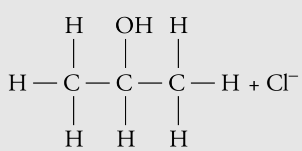


heptanoic acid

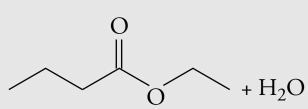
(c) $CH_2 = CH - CH_3 + H_2$ (with platinum catalyst)

propene hydrogen gas

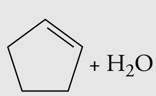
17. (a)



(b)



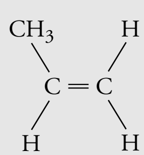
(c)



(d) $BrCH_2CH_2CH_2CH_2CH_3 + H_2O$

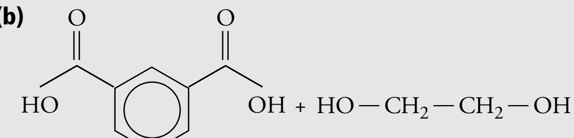
18. The monomers are:

(a)



propene

(b)



terephthalic acid

ethylene glycol

19. For A addition polymerization occurred. For B condensation polymerization occured.

20. (a) addition

(b) condensation

Answers to Applying Concepts Questions

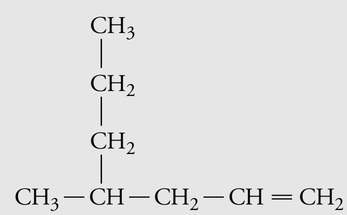
21. The alkane has 12 hydrogen atoms. The general equation for an alkane is C_nH_{2n+2}

22. The alkyne has 7 carbon atoms. The general equation for an alkyne is C_nH_{2n-2}.

23. The simplest test to distinguish between the two would be a piece of litmus paper. The carboxylic acid would turn blue litmus red. Alternately, boiling point determination would also allow for identification since the boiling point of pentanoic acid is higher than that for pentan-1-ol.

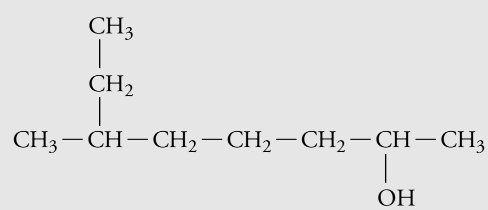
24. The correct names and structures are as follows:

(a)



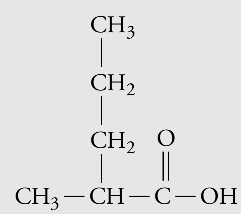
4-methylhept-1-ene

(b)



6-methyloctan-2-ol

(c)



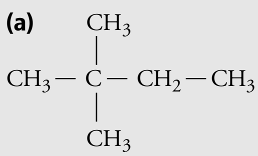
2-methylpentanoic acid

25. Structural isomers have the same molecular formula but different structural formulas. (a) and (f) are structural isomers; (c) and (e) are also structural isomers.

26. The alcohol will dissolve in water and has a characteristic sharp odour that will easily separate it from the other two compounds. Both hex-2-ene and benzene are non-polar and will have similar boiling points. Hex-2-ene is much more reactive than benzene and will undergo an addition reaction in the presence of aqueous bromine. The bromine solution, which is originally brown, will become lighter or colourless as the bromine is consumed (see ChemistryFile page 590).

27. In each case the number of bonds to carbon was incorrect. Correct structures and names are as follows. Student answers may depend on how they decide to reduce the bond order.

(a)



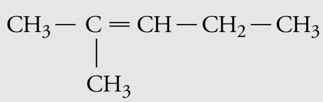
2.2-dimethylbutane

(b)

$CH_2 = CH - CH_2 - CH_3$

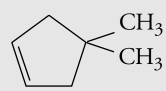
but-1-ene

(c)



2-methylpent-2-ene

(d)



4,4-dimethylcyclopentene

28. In an addition reaction a small molecule is added across a double or triple carbon-carbon bond. In a substitution reaction a hydrogen atom or functional group is replaced by another functional group.

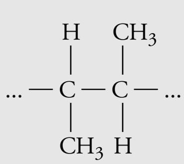
29. To form a polyester the monomers being combined must have two functional groups – one at each end of the molecule. For one of the monomers this will be a carboxyl group, for the other this will be a hydroxyl group.

30. The mixing of chloroethane and sodium hydroxide will produce ethanol and sodium chloride in a substitution reaction. The reaction of ethanol and propanoic acid, with heating and the addition of a strong acid will produce the ester ethyl propanoate and water.

31. Monomer (top)

Polymer (bottom)

$CH_3 - HC = CH - CH_3$



Procedure:

1. Dissolve the but-2-ene in a non-polar solvent such as mineral oil.
2. Add the catalyst and heat the solution to begin polymerization

Safety Precautions:

- But-2-ene is a gas at room temperature, is mildly toxic and highly flammable. Keep away from open flame. The gas will be stored under pressure and may explode when heated.
- Mineral oil and the polymer formed are both flammable.

Answers to Making Connections Questions

32. (a) fractional distillation

(b) crude oil

(c) bubble cap—it diverts rising vapours from below, increasing the efficiency of capture

(d) Steam enters at F, heating the crude oil so that many of the components vapourize

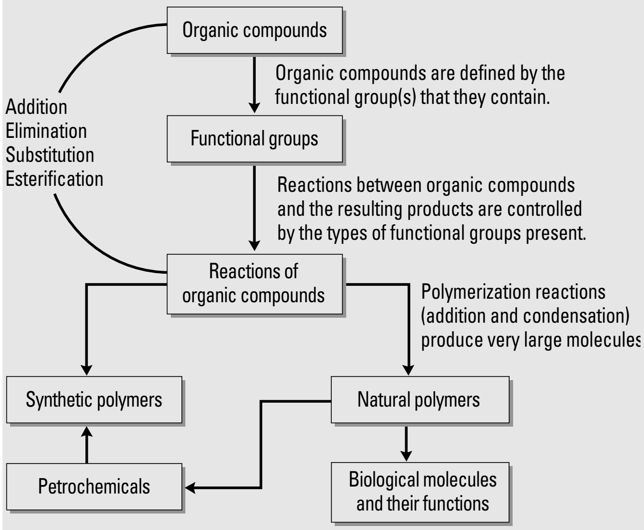
(e) Compounds containing more than 20 carbon atoms, which do not vapourize, exit at E

(f) The substances that exit from A to G are mixtures of hydrocarbons, with the shortest chain mixtures at the top (at A), and the longer chains (up to 20 carbons) exiting at E.

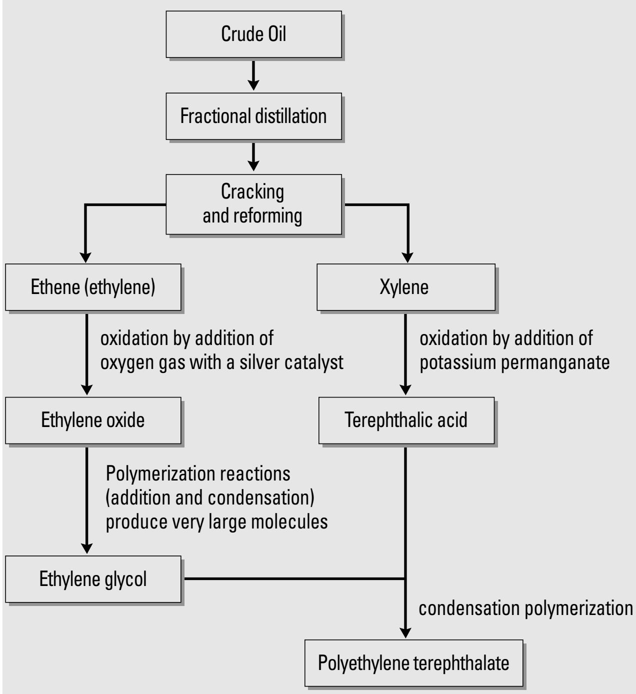
(g) The shorter the carbon chain, the weaker the intermolecular bonds holding the molecules together, therefore the lower the boiling point. Substances are collected based on their boiling points. The lower the boiling point, the higher they will collect in the tower, as they are collected when they condense. The substances with higher boiling points will condense lower in the tower.

33. Student answers will reflect the fact that the impact of organic compounds on health and lifestyle is so enormous. Every aspect of modern life is filled with uses, and sometimes abuses, of organic compounds. Examples could include pharmaceuticals, food additives, plastics and other polymers, and various types of fuels.

34. Student responses (and the amount of detail) will depend on how they perceived their learning process. One sample that a student may conceive of is shown below. The amount of detail will vary from one concept map to another.



35. One possible flowchart is illustrated below.



36. Student answers will likely include some of the following points. The public often believes that "natural" is safer and better than "synthetic," even if the compounds are identical. This is evident in natural and artificial flavourings, and with natural and artificial sweeteners. The public is prepared to pay a premium for "organic" or "natural" products, without knowing or understanding the differences between them. In order for consumers to make informed product choices, they have to thoroughly research the differences between the products. Many manufactured products have strict guidelines around labelling, while there are few if any guidelines around "natural" products.