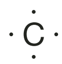
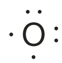
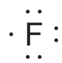
Chapter 3: Organic Chemistry

Practice, page 110

1. **a.**  Carbon has four unpaired electrons, so it needs four bonds to become stable.

b.  Oxygen has two unpaired electrons, so it needs two bonds to become stable.

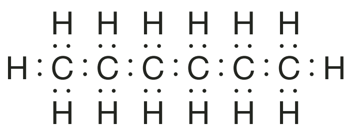
c.  Fluorine has one unpaired electron, so it needs one bond to become stable.

d.  Nitrogen has three unpaired electrons, so it needs three bonds to become stable.

2. Carbon is capable of producing the largest number of compounds because carbon can form more bonds to other atoms than any of the other substances on the list.

3. Fluorine has the most limited capacity to produce a large number of compounds because it can only bond to one other atom.

4. **a.**



b. It takes 14 hydrogen atoms to stabilize all of the carbon atoms in this molecule.

c. The chemical formula for this molecule is C_6H_{14}.

5. **a.** 

b.

CARBON AND SILICON ATOMS

Similarities	Differences
• They both have four unpaired valence electrons. • They are in the same chemical family. • They are non-metals.	• Silicon is larger, having 8 more electrons, 8 more protons, and 8 more neutrons. • Silicon's four valence electrons are in the third energy level, whereas carbon's are in the second energy level.

c. The valence electrons for silicon are farther away from the nucleus. Therefore, the attraction of the silicon nucleus for the shared electrons of a covalent bond is not as strong as it is for carbon. Long chains of silicon atoms are not as stable as long chains of carbons. This also explains why the bond between hydrogen and silicon is not as strong as the bond between carbon and hydrogen.

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6. The initial definition assumed that carbon molecules could be made only by living systems—they could not be made synthetically. Once a process was developed to make a synthetic, carbon-based molecule, many more carbon compounds were made and the definition had to be expanded.

7. A hydrocarbon is a molecule composed of only carbon and hydrogen atoms.

8. **a.** Complex organic molecules are composed of a large number of atoms held together in a unique arrangement. Today, it is difficult to devise a series of chemical reactions that produce an exact copy of a compound like the plant oil molecule.

b. There are many reasons why it is important to protect species from becoming extinct. Because 40% of the world's medicines are organic compounds discovered in natural species, any beneficial medicines that could have been derived from complex organic molecules made by species allowed to become extinct are lost. (Some of the other reasons for protecting species from extinction are covered in Unit D.)

Practice, page 116

9. **a.** An alkane is a type of hydrocarbon that contains single bonds between carbon atoms. Alkanes are described by the general formula C_nH_{2n+2}.

b. Continuous-chain alkanes are molecules that do not have branches of carbon atoms radiating from a longer chain of carbon atoms.

c. A Lewis dot diagram is a representation of atoms that depicts the symbols for the atoms and the valence electrons. In the case of molecules, this diagram shows the sharing of electrons to form a stable molecule.

d. A complete structural diagram is a diagram of a molecule that shows the bonds that exist due to the sharing of a pair of electrons between the atoms as a short line.

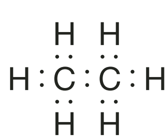
e. A condensed structural diagram is a diagram of a molecule that uses a short line to show carbon-carbon bonds but uses the chemical formula for carbon-hydrogen units.

f. A line structural diagram is a diagram of a molecule that shows the bonds only between carbon atoms as line segments.

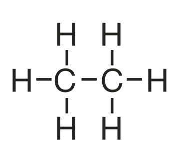
10. Only butane has single bonds between the carbon atoms, so only butane is an alkane. This is confirmed by the name of this compound; since it ends in *ane*, it must be an alkane.

11. Ethane consists of two carbon atoms that are singly bonded to one another.

Lewis Dot Diagram



Complete Structural Diagram



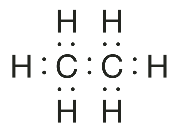
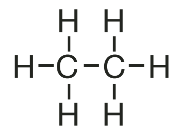
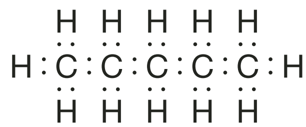
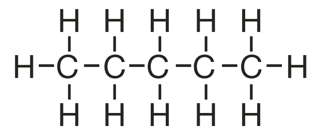
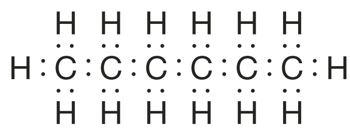
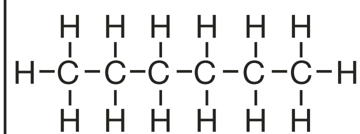
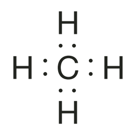
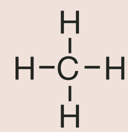
Line Structural Diagram

All diagrams communicate the number of carbons in the chain. The Lewis dot diagram shows each of the bonds as a pair of shared valence electrons. The complete structural diagram simplifies the Lewis dot diagram by replacing each pair of electrons with a short line.

The line structural diagram is the most concise of all the diagrams. It shows only the carbon-carbon bond. The carbon atoms are omitted as are the hydrogen atoms attached to the carbon atoms.

12. The first step is to count the number of carbon atoms in the chain. This can be used to identify the prefix in the name using the table of prefixes. Since this is an alkane, attach the suffix -*ane* to the prefix.

13.

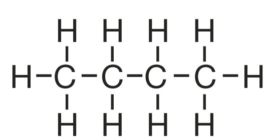
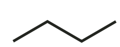
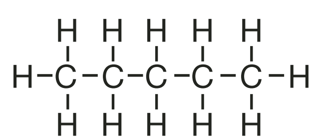
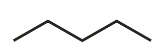
Chemical Formula	Name	Lewis Dot Diagram	Complete Structural Diagram	Application
C_2H_6	ethane			• gaseous fuels • starting compound for plastics
C_5H_{12}	pentane			• solvents • an ingredient in gasoline
C_6H_{14}	hexane			• solvents • liquid fuels • an ingredient in gasoline
CH_4	methane			• gaseous fuels

14. Hydrocarbon molecules can become very large; therefore, an efficient and concise means of representing them is often helpful.

Practice, pages 119 and 120

15. **a.** 2-methylbutane
b. 2,2-dimethylpropane
c. 3-methylpentane
d. 3,3-dimethylhexane
e. 3-methylhexane
f. 3-ethyl-3-methylhexane
g. 3-ethylhexane
h. 2,2,4-trimethylpentane
i. 4-methyl-4-propyloctane
j. 2,2,3-trimethylpentane

16.

Compound	Complete Structural Diagram	Line Structural Diagram	Chemical Formula
butane			$C_4H_{10}(g)$
pentane			$C_5H_{12}(l)$

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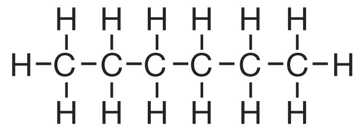
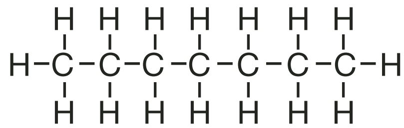
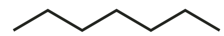
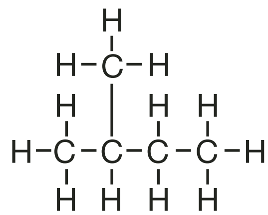
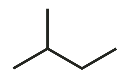
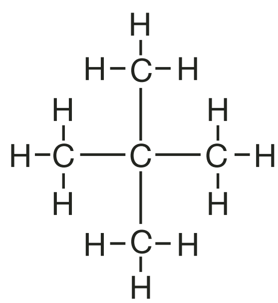
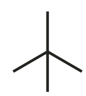
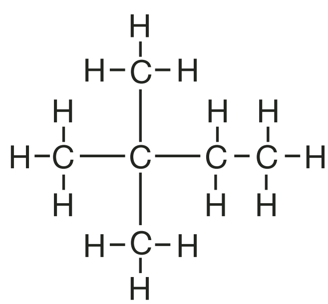
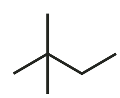
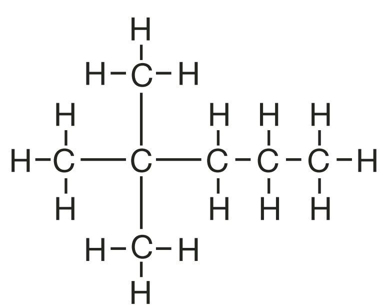
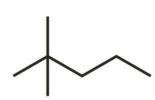
hexane			$C_6H_{14}(l)$
heptane			$C_7H_{16}(l)$
2-methylbutane			$C_5H_{12}(l)$
2,2-dimethylpropane			$C_5H_{12}(l)$
2,2-dimethylbutane			$C_6H_{14}(l)$
2,2-dimethylpentane			$C_7H_{16}(l)$

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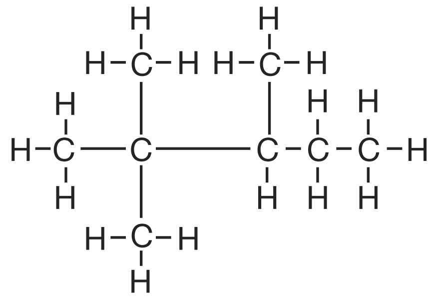
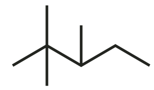
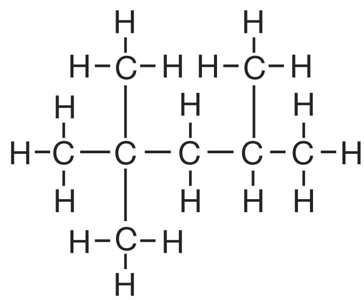
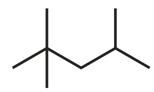
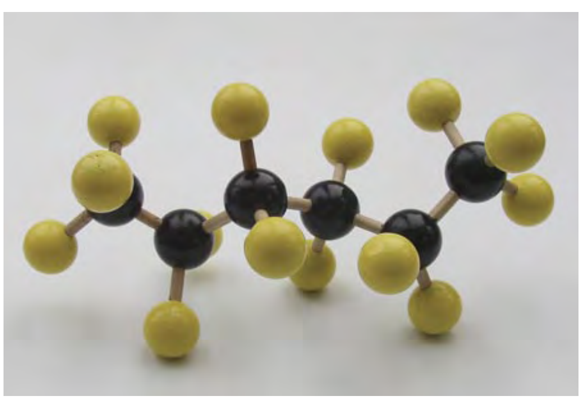
2,2,3-trimethylpentane			$C_8H_{18}(l)$
2,2,4-trimethylpentane			$C_8H_{18}(l)$

17.

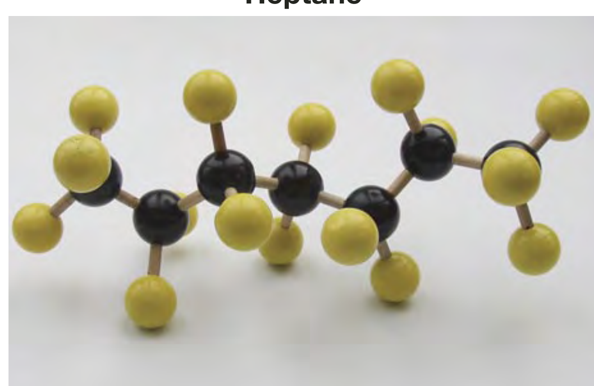
Butane

Pentane

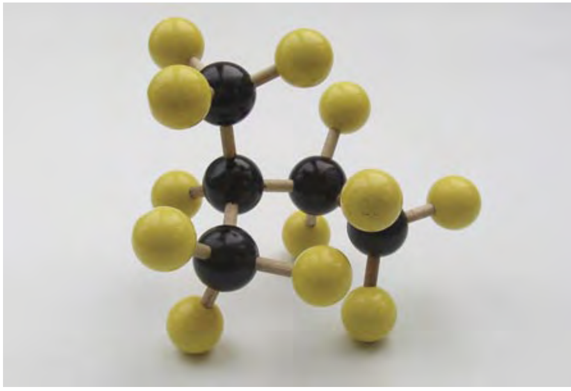
Hexane



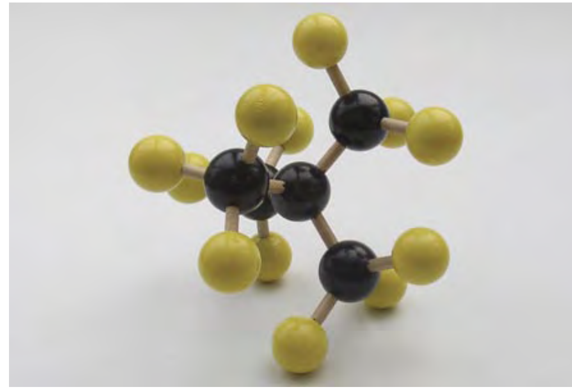
Heptane



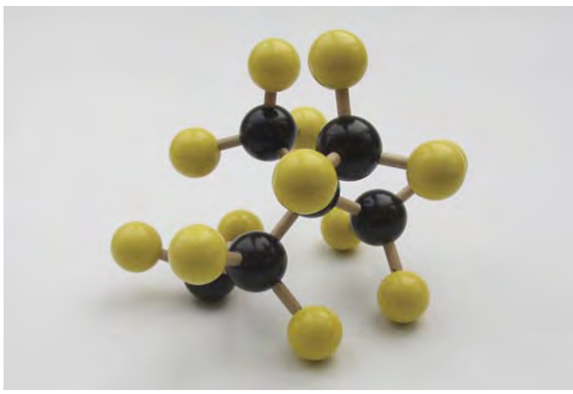
2-methylbutane



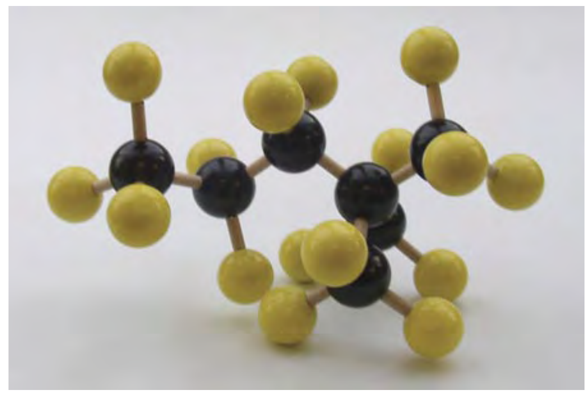
2,2-dimethylpropane



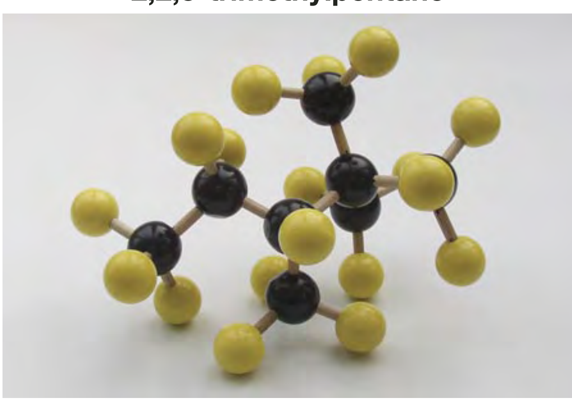
2,2-dimethylbutane



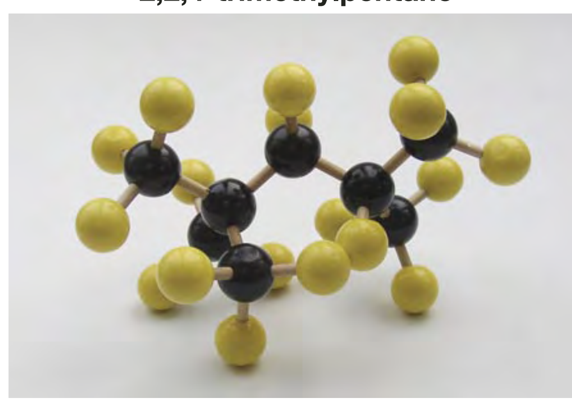
2,2-dimethylpentane



2,2,3-trimethylpentane



2,2,4-trimethylpentane



18. **a.** No, each compound does not have a unique chemical formula. For example, $C_5H_{12}(l)$ describes pentane, 2-methylbutane, and 2,2-dimethylpropane.

b. The IUPAC name of a compound is a better description of the compound because it uniquely matches the compound. A chemical formula can be shared by more than one compound.

3.1 Questions, page 121

Knowledge

1. **a.** A carbon chain is a linking of carbon atoms by covalent bonds within a molecule.

   b. A branched alkane is an alkane with small chains of hydrocarbon atoms radiating out from longer parent chains.

   c. A condensed structural diagram is a diagram that represents an organic molecule by using a short line to show carbon-carbon bonds but uses the chemical formula to show carbon-hydrogen units.

   d. A line structural diagram is a diagram that represents an organic molecule where the ends of each line segment represent the positions of carbon atoms.

   e. A parent chain is the longest continuous chain of carbon atoms in a molecule.

   f. An alkyl group is a group of carbon atoms that radiate from a parent chain in a branched alkane.

2. Do you recall playing with interlocking blocks when you were younger? The type of block that gets used the most is the block that is most flexible—able to make solid connections to many of the other pieces. If building molecules with atoms is comparable to building things with blocks, carbon is like the type of block that connects well to many other blocks. The following properties of carbon illustrate this point:

   - Carbon atoms have the ability to bond to four different atoms, providing an opportunity to bond many times. Often, there are many possible arrangements of the bonds, providing multiple ways to produce unique molecular structures.

   - The covalent bonds to carbon atoms tend to be quite stable because the valence electrons are only in the second energy level and, therefore, are quite close to the nucleus. The result is a strong attraction to the shared electrons, which means the resulting molecules are stable.

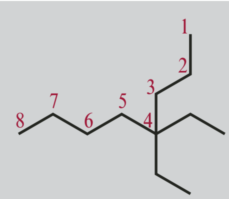
   Carbon's versatility as an atomic building block for molecules accounts for the fact that there are a large number of carbon compounds on Earth.

3. There are a huge number of hydrocarbon compounds in existence. A consistent system of naming hydrocarbons ensures proper communication. As illustrated throughout this lesson, the chemical formula alone is not sufficient because there are so many variations of atomic structure for a given number of carbon and hydrogen atoms.

Applying Concepts

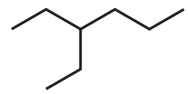
4. **a.** 2,2-dimethylpentane **b.** 3-ethylhexane **c.** 2,2,3,3-tetramethylbutane
   d. 3-ethylhexane **e.** 3-ethyl-4,5-dimethylheptane **f.** 4,4-diethyloctane

For question 4.f., note the numbering of the carbons. The two ethyl branches occur on carbon number 4.

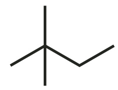


5. **Note:** Molecular models for the same compound can look quite different if they are flipped over or if the branches go in slightly different directions. The same thing can occur when you draw structural diagrams. There are many correct ways to draw these structures. Check your answers carefully against the sample answers provided.

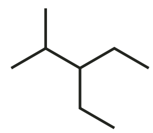
a. $CH_3-CH_2-CH-CH_2-CH_2-CH_3$
|
CH_2
|
CH_3



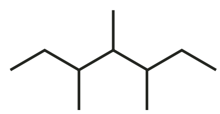
b. CH_3
|
$CH_3-C-CH_2-CH_3$
|
CH_3



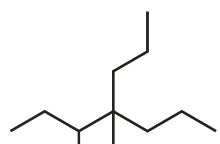
c. CH_3
|
$CH_3-CH-CH-CH_2-CH_3$
|
CH_2
|
CH_3



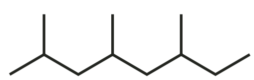
d. CH_3
|
$CH_3-CH_2-CH-CH-CH-CH_2-CH_3$
| |
CH_3 CH_3



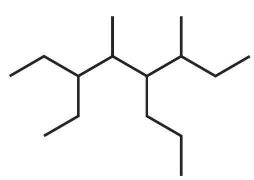
e. CH_3
|
CH_2
|
CH_2
|
$CH_3-CH_2-CH-C-CH_2-CH_2-CH_3$
| |
CH_3 CH_3



f. CH_3 CH_3 CH_3
| | |
$CH_3-CH-CH_2-CH-CH_2-CH-CH_2-CH_3$



g. CH_3 CH_3
| |
$CH_3-CH_2-CH-CH-CH-CH-CH_2-CH_3$
| |
CH_2 CH_2
| |
CH_3 CH_2
|
CH_3

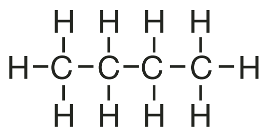


6. Answers will vary. A sample answer is given.

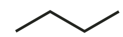
a. Butane is one example. It is used in lighters for lighting candles, tealights, and gas barbecues.

b. The complete structural diagram and line structural diagram of butane are as follows:

Complete Structural Diagram



Line Structural Diagram



c. Butane is used in lighters because it is a fuel. Butane lighters should not be stored in places subjected to high pressures and high temperatures or where they may come in contact with flames. Like matches, butane lighters should not be left unattended in places where young children are present.

Butane is a hydrocarbon derived from petroleum. The vapours should not be inhaled and the liquid should not be allowed to contact the skin, eyes, mouth, or parts of the digestive tract.

7. Answers will vary. A sample list, divided into categories, is given.

Fuels	Plastics	Synthetic Fabrics
• gasoline • diesel fuel • butane • jet fuel • propane	• polycarbonate (used in cellphones, water bottles, and hockey helmets) • polyethylene (used to make plastic bags) • polyvinyl chloride, PVC (used to make rain gear and plumbing pipes)	• polyester (used to make a variety of garments) • nylon (used to make carpets, tents, and windproof jackets)

Practice, page 123

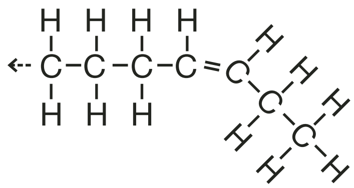
19. In the switch to the double bond, there is a sharing of a second pair of electrons between carbon atoms that enables each carbon atom to maintain a full outer energy level. In this way, both carbon atoms remain stable.

20. A hydrocarbon can have a triple bond if there is a deficiency of hydrogen atoms to create a full outer energy level. In this case, electrons between the two carbons will form covalent bonds to increase their stability.

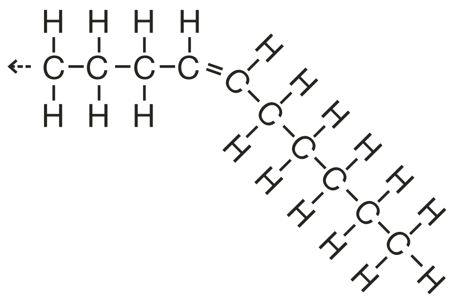
21. A saturated hydrocarbon is a molecule that has the maximum number of hydrogens because there are only single bonds between each carbon atom in the chain. An unsaturated hydrocarbon is a molecule that doesn't have the maximum number of hydrogen atoms bonded to it. These molecules must have at least one double or triple bond between carbon atoms in order for the carbons to have a full outer energy level.

Practice, page 125

22. Saturated fats tend to be solid at room temperature because the chains of saturated fatty acids within these molecules are straight. Because the chains are straight, the molecules can pack tightly together, allowing the attractive forces to hold these molecules together as a solid.

23. 

The double bond occurs after the third carbon, counting from the omega (or methyl) end of the molecule.

24. 

The double bond occurs after the sixth carbon, counting from the omega (or methyl) end of the molecule.

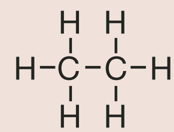
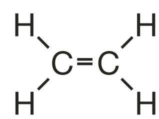
25. Although it is true that a diet high in fat is very unhealthy, it is not true that you should have no fat at all in your diet. Fat is an important nutrient because it is necessary for the formation of healthy cell membranes, the proper development of the brain and nervous system, and the production of hormone-like substances that regulate body functions (e.g., blood pressure). Rather than talk about all fats as being undesirable, it is more accurate to make the distinction that people should try minimizing their intake of saturated fat and trans fat while maintaining a healthy supply of the essential fatty acids. In exceptional circumstances, such as for explorers and hunters in Arctic climates, high-fat diets can be useful.

26. **a.** Saturated fat is normally considered a substance to be kept to a minimum in a diet.

b. It makes sense that an energy bar should contain some fat because fat contains more energy per gram than any other food. Another possible reason for the inclusion of saturated fat is that this might help to improve the taste, consistency, and stability of the bar, making it more appealing to eat.

Practice, page 129

27.

	Type of Hydrocarbon	Bonds Between Carbon Atoms in Longest Chain	General Chemical Formula	Example
Saturated	alkane	single bonds	C_nH_{2n+2}	Ethane: C_2H_6 
Unsaturated	alkene	one double bond	C_nH_{2n}	Ethene: C_2H_4 
	alkyne	one triple bond	C_nH_{2n-2}	Ethyne: C_2H_2 H−C≡C−H

Ethane: $n = 2$, $2n + 2 = 2(2) + 2 = 6$

Ethene: $n = 2$, $2n = 2(2) = 4$

Ethyne: $n = 2$, $2n - 2 = 2(2) - 2 = 2$

28. **a.** 3-hexene
b. 3-ethyl-2-pentene
c. 2,3-dimethyl-2-pentene
d. 2-propyl-1-pentene
e. 4-ethyl-5-methyl-2-octyne
f. 3,6-dimethyl-4-octyne

29. **a.** $CH_2=CH-CH_2-CH_2-CH_2-CH_3$

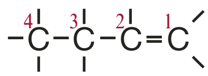
b. $CH_3-C\equiv C-CH_2-CH_3$

c. $CH_3-\underset{\underset{CH_3}{|}}{C}=CH-CH_2-CH_3$

d. $CH_3-\underset{\underset{CH_3}{|}}{CH}-C\equiv C-\underset{\underset{CH_3}{|}}{CH}-CH_2-CH_3$

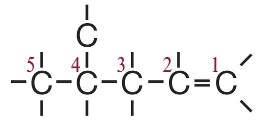
30. To accommodate the numbering of the carbons, the hydrogen atoms have been omitted in these complete structural diagrams.

a.



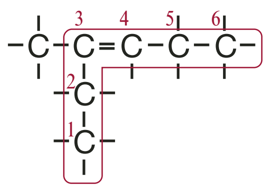
1-butene

b.



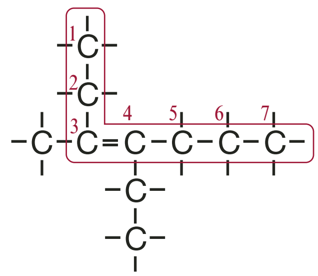
4-methyl-1-pentene

c.



3-methyl-3-hexene

d.



4-ethyl-3-methyl-3-heptene

Practice, page 132

31. Pentane has one more carbon than butane. Molecules with larger molecular masses have longer carbon chains, enabling stronger attractions between molecules. The stronger attractions result in higher boiling and melting points.

32. A double bond decreases the stability of a molecule. The additional pair of shared electrons between the two carbon atoms forces more electrons into a smaller space. Since the electrons repel each other due to their similar charge, the double bond is less stable than the single bond.

33. **a.** hexane, pentane, propane
b. pentane, 1-pentene, 1-butene
c. 2-octene, 2-heptene, 2-hexene

Practice, page 133

34. **a.** 2-hexyne, 2-hexene, hexane
b. 2-butyne, ethene, propane
c. 3-octyne, 2-hexene, heptane

Practice, page 135

35. The arrangement of the hydrogen atoms on the same side of the double bond in oleic acid provides a gap on the opposite side of the double bond. This enables the molecule to bend. The bent shape of this molecule prevents it from packing closely together with other molecules. Since the strong attractive forces associated with close packing are unable to rigidly hold the molecules in place, these molecules are in liquid form at room temperature.

The arrangement of the hydrogen atoms on either side of the double bond in elaidic acid means that this molecule is more symmetrical—it is straight. The straight shape allows close packing, strong attractive forces, and results in these molecules being in solid form at room temperature.

36. To solve the problem of making more-affordable, spreadable fat with no cholesterol, food scientists got the idea of hydrogenation: adding more hydrogen atoms to unsaturated fatty acid molecules found in vegetable oil. Once the adjustment of only partially hydrogenating the vegetable oil was made, the result was a spreadable fat that was cholesterol free. It seemed that the problem was solved.

However, an unintended problem was created when some of the unsaturated fatty acids that were not hydrogenated were transformed by this process into industrially produced trans fatty acids. These compounds have since been shown to have a greater health risk for heart disease than saturated fats, and they might cause other health problems because their structure is so different from regular fatty acids.

37. **a.** Dietary cholesterol is found in foods made only from animal products. Since margarine is made from plant oils, it does not contain cholesterol.

b. No, margarine is not automatically a healthier choice than butter. Although margarine does not contain cholesterol, it may contain trans fatty acids, which are also considered to be an undesirable substance in foods. It is important to read the nutrition facts labels on food to ensure that the substance is low in cholesterol, saturated fat, and industrially produced trans fat.

38. In the 1980s, many manufacturers began adding trans fats to processed foods—like cookies, crackers, and potato chips—to help these products stay crisp and crunchy over time. This had the effect of prolonging the shelf life of these products.

3.2 Questions, page 136

Knowledge

1. **a.** A saturated compound is a hydrocarbon that does not contain a double or triple bond.

b. An unsaturated compound is a hydrocarbon that has at least one double or triple bond.

c. An alkane is a type of hydrocarbon that has only single bonds between carbon atoms, described by the general chemical formula C_nH_{2n+2}.

d. An alkene is a type of hydrocarbon that has at least one carbon-carbon double bond, described by the general chemical formula C_nH_{2n}.

e. An alkyne is a type of hydrocarbon that has at least one carbon-carbon triple bond, described by the general chemical formula C_nH_{2n-2}.

2. An increase in the number of carbon atoms results in an increase to the melting and boiling points within the alkane, alkene, or alkyne groups of hydrocarbons. This is because as the carbon chains get larger, there is a greater force of attraction between adjacent chains; so, they tend to have a greater resistance to a phase change that involves giving molecules more energy of motion. It is also due to the fact that as the molecules get larger, their mass increases. This tends to make them have a greater resistance to changes in their motion.

3. Alkanes have only a single carbon-carbon bond, whereas alkenes have a carbon-carbon double bond. This double bond is under stress and is, therefore, more fragile. It follows that the presence of a double bond in an alkene makes it more chemically reactive.

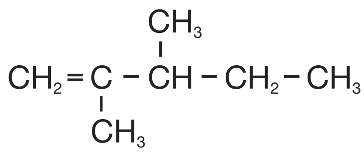
4. Alkenes have a carbon-carbon double bond, whereas alkynes have a carbon-carbon triple bond. This triple bond is quite stressed due to the mutual repulsion of the three pairs of electrons in one area. This makes the triple bond even more fragile than the double bond. This is why alkynes are chemically more reactive than alkenes.

Applying Concepts

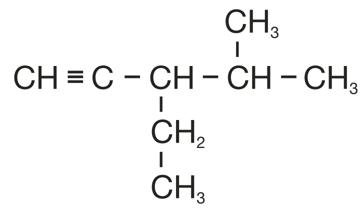
5. **a.** 5-methyl-3-heptyne **b.** 3-ethyl-5-methyl-2-heptene

6. Octane has a higher boiling point and is a liquid at the temperatures in which a car would operate. The liquid form is far more convenient and much safer than having a gas (if methane or ethane were to be used) that would have to be stored under pressure somewhere in the vehicle.

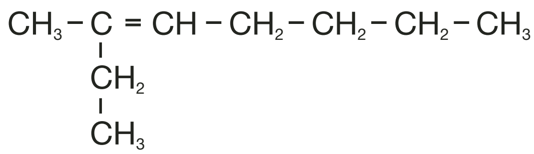
7. **a.**



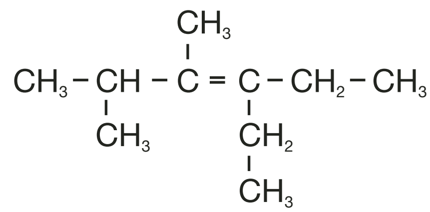
b.



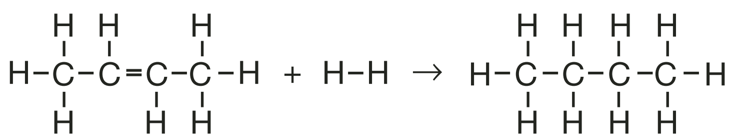
c.



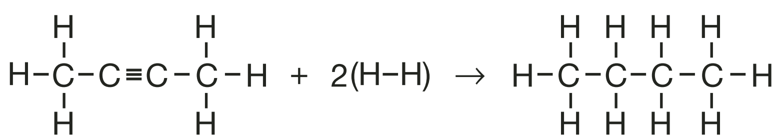
d.



8. **a.**



b.



9. Each reaction shows carbon-carbon double and triple bonds being converted into carbon-carbon single bonds. These reactions are called hydrogenation reactions—more hydrogen atoms are added to each of the molecules for every bond that is broken.

10. The tub of margarine would be the best choice because it contains the least amounts of saturated fat, trans fat, and cholesterol.

People who eat foods that have high quantities of saturated fat, industrially produced trans fat, and dietary cholesterol have been shown to have a greater risk of contracting heart disease. A diet rich in saturated fat, industrially produced trans fat, and cholesterol can cause blood vessels to develop deposits on their internal lining that may restrict the flow of blood. Many biochemists and nutritionists are concerned that industrially produced trans fat may cause other health problems because the fatty acids in these molecules are so different than the fatty acids found in the foods produced by nature.

Practice, page 142

39. The following steps describe fractional distillation:

step 1: The petroleum is vaporized in a hot furnace.

step 2: The petroleum vapour is placed into a tall column.

step 3: The hot vapours rise inside the column. As the vapour moves away from the heat source, it cools.

step 4: As the vapour cools, the molecules condense to form liquids at different places in the tower. By condensing at different locations in the tower, the fractions can be collected separately.

step 5: Fractions with high boiling points—the largest molecules in the mixture—will condense first at the bottom of the column. Fractions with lower boiling points—the smallest molecules in the mixture—condense higher in the column. Those fractions that are gaseous at normal temperatures are collected at the top of the column as gases.

40. a. This equation states that an octane molecule is cracked to form two molecules of ethene, one molecule of propene, and one molecule of methane.

b. The octane and the methane are alkanes, since both of these compounds can be described by the general formula for alkanes, C_nH_{2n+2}. The ethene and propene are both alkenes since they can be described by the general formula for alkenes, C_nH_{2n}.

c. $n_{C_2H_4} = 152.5 \text{ mol}$

$n_{C_8H_{18}} = ?$

$$\frac{n_{C_8H_{18}}}{n_{C_2H_4}} = \frac{coefficient_{C_8H_{18}}}{coefficient_{C_2H_4}}$$

$$\frac{n_{C_8H_{18}}}{n_{C_2H_4}} = \frac{1}{2}$$

$$\begin{aligned} n_{C_8H_{18}} &= \frac{1}{2} \times n_{C_2H_4} \\ &= \frac{1}{2} \times 152.5 \text{ mol} \\ &= 76.25 \text{ mol} \end{aligned}$$

The reaction will require 76.25 mol of $C_8H_{18}(l)$.

41. ethane: $C_2H_6(g)$, ethene: $C_2H_4(g)$, other substance: ?

$C_2H_6(g) \rightarrow C_2H_4(g) + ?$

To balance this equation, the right side needs two more hydrogen atoms. This would be in the form of hydrogen gas, $H_2(g)$.

$$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$$

3.3 Questions, page 143

Knowledge

1. **a.** Petroleum is a natural resource containing a mixture of liquid hydrocarbons that is believed to have formed from the decomposition of ocean-dwelling organisms, under extreme heat and pressure over millions of years.

   b. A fraction is a collection of molecules with similar boiling points, collected during fractional distillation of crude oil.

   c. Refining is an industrial process that separates, purifies, and alters raw materials.

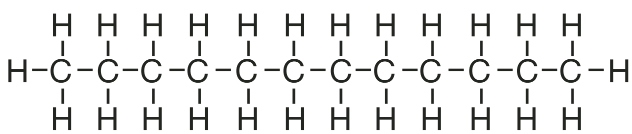
   d. Separation is the process of removing a substance from a mixture based on its physical or chemical properties.

   e. Fractional distillation is a process used to separate a liquid mixture by vaporizing it and then collecting the different components of the mixture as they cool down and condense at their appropriate boiling points.

   f. Cracking is a type of reaction in which hydrocarbons are broken down into smaller molecules by means of heat (thermal cracking) or catalysts (catalytic cracking).

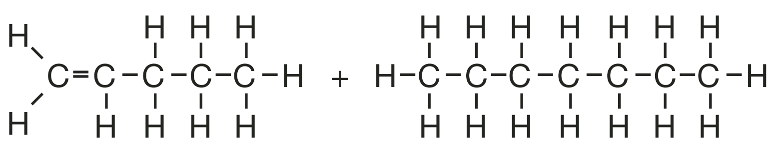
2. It is easier to manipulate smaller molecules in a chemical reaction to produce a desired product. If larger molecules are not broken in exactly the right spot along a carbon chain, the desired product will not be produced.

3. The two methods used to break large hydrocarbon chains are catalytic cracking and thermal cracking.

4. 

$C_{12}H_{26}(l)$

↓



$C_5H_{10}(l)$ $C_7H_{16}(l)$

$C_{12}H_{26}(l) \rightarrow C_5H_{10}(l) + C_7H_{16}(l)$

Applying Concepts

5. Crude oil is a natural resource that is collected from deep within Earth. Its components are used to produce many different products, such as plastics, gasoline, and synthetics.

6. The compounds found in the lower sections of a fractional distillation column are the larger hydrocarbons used to produce heavy fuel oil and to make bitumen—the oily component used in asphalt on roads.

7. The compounds found in the upper sections of a fractional distillation column are the smaller hydrocarbons (like methane, ethane, and propane) ideal for use in the production of other molecules (such as branched hydrocarbons), in the production of molecules for other reactions (such as for making plastics), and as a fuel to be used in refinery furnaces and consumer heating needs.

8. Fractional distillation is a method that could be used to separate two substances with different boiling points.

9. Industry needs effective and efficient methods for separating petroleum into its different fractions because if these methods were not available, too much energy would be required to complete the process of obtaining the required molecules. Also, there is a risk that much of the petroleum would be lost during an inefficient process and be unavailable for latter reactions.

Practice, page 144

42. a. Figure A3.17 shows the use of hydrocarbons because the vehicle needs hydrocarbons in the form of gasoline or diesel to operate. This is an obvious use of hydrocarbons. What is not so obvious is the synthetic materials manufactured from hydrocarbons used to make the interior of the car; the nylon used to make the seat belts; the paints, waxes, and other finishes applied to the vehicle's surfaces; and the plastics used to make the moulded dashboard and the knobs on the instrument cluster.

Figure A3.18 shows the use of hydrocarbons to make all the plastic bags and plastic containers. Beyond these, more obvious examples could be the synthetic fabrics (such as nylon and polyester) of the shoppers' clothing or the cosmetics of the female shopper, which may have hydrocarbon ingredients.

If you think about this on a deeper level, the use of hydrocarbons must also be involved in the acquisition of raw materials and the manufacturing and shipping of all of the consumer goods shown in each photograph. For example, even if the driver of the car was wearing a cotton sweater instead of a synthetic sweater, the cotton was likely grown on another continent, shipped to a place with low labour costs, and distributed to retailers in North America. All of that shipping was made possible with hydrocarbon fuels. The same thinking applies to the grocery shoppers, because many food items are grown in faraway places and shipped to grocery stores.

b. Many of the products mentioned in question 42.a. could not be easily replaced with other materials. The fuel for the vehicle cannot be immediately substituted with another product without redesigning the entire engine. However, given many of the environmental concerns that have been raised about the use of fossil fuels by vehicles, perhaps the engine should be redesigned and an alternative energy source identified. The moulded plastic products that make up so much of the vehicle's interior would also be difficult to replace because these materials are light, easily shaped, and quite durable. It is difficult to think of substitutes that are not petroleum based.

The plastic grocery bags could be replaced with non-disposable baskets made of metal, wood, or a natural fabric (e.g., canvas). The plastic containers could be replaced with glass containers that are readily recycled. Clothing made from synthetic materials could be replaced by natural products, like wool, cotton, and hemp.

However, all these products are made from raw materials that must be shipped to a manufacturing plant and then shipped to a local retailer. This means that even if consumer products based on hydrocarbons can be replaced, the current reliance on hydrocarbon fuels for shipping means that society's dependence upon hydrocarbons seems inescapable.

43. If someone said that we were entering the Silicon Age, they would be referring to the increasing role played by microprocessors that run on silicon-based computer chips.

Practice, page 146

44. When two atoms are joined by a covalent bond, their nuclei are simultaneously attracted to a shared group of electrons. It takes energy to overcome these attractive forces and to separate the two nuclei.

45. When the atoms are separate, they are in an unstable energy state because their outer energy levels are not filled. This unstable state is a high-energy state. When the atoms join to form a covalent bond, the result is a stable molecule. Since the energy of a stable molecule is lower, energy is released.

Practice, page 147

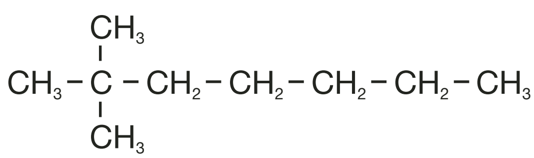
46. **a.** $C_5H_{12}(l) + 8\ O_2(g) \rightarrow 5\ CO_2(g) + 6\ H_2O(g)$

b. $C_5H_{10}(l) + 7.5\ O_2(g) \rightarrow 5\ CO_2(g) + 5\ H_2O(g)$

↓

$2\ C_5H_{10}(l) + 15\ O_2(g) \rightarrow 10\ CO_2(g) + 10\ H_2O(g)$

c.



$C_9H_{20}(l) + 14\ O_2(g) \rightarrow 9\ CO_2(g) + 10\ H_2O(g)$

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

e. $C_{12}H_{22}O_{11}(s) + 12\ O_2(g) \rightarrow 12\ CO_2(g) + 11\ H_2O(g)$

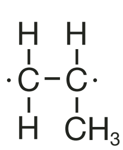
47. $C_8H_{18}(l) + 8.5\ O_2(g) \rightarrow 8\ CO(g) + 9\ H_2O(g)$

↓

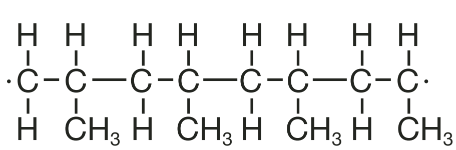
$2\ C_8H_{18}(l) + 17\ O_2(g) \rightarrow 16\ CO(g) + 18\ H_2O(g)$

Practice, page 149

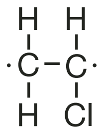
48. **a.** The repeating unit is



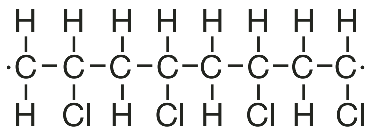
The polymer chain looks as follows:



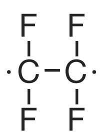
b. The repeating unit is



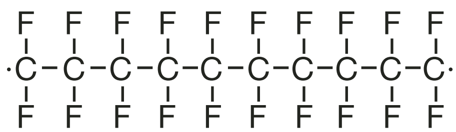
The polymer chain looks as follows:



c. The repeating unit is



The polymer chain looks as follows:



Practice, page 151

49. Option 1 does not address all the environmental concerns regarding this form of packaging because even if the rings are cut, this material still enters the environment as garbage that will not readily decompose.

50. One option would be to pass legislation that this form of packaging must be made from recyclable material and that $0.05 will be charged as a deposit each time one of these items is purchased and refunded when it is returned. This system is presently used for beverage bottles and cans in Alberta.

Another idea would be to ban this form of packaging. Manufacturers would be forced to either sell these items as single items or develop a more environmentally friendly form of packaging.

51. Answers will vary. A sample answer is given.

Many people argue that society seems to be completely designed around the automobile. Perhaps a completely new model of transportation needs to be conceived that puts a greater emphasis on mass transit systems and puts less emphasis on vehicles for individuals. The huge number of vehicles currently on the road all require vast amounts of petroleum to both manufacture and operate them.

The heavy use of plastics in packaging is another area many people think needs to be addressed. This packaging not only requires great amounts of petroleum to be manufactured, it also contributes to the problem of waste management.

3.4 Questions, page 151

Knowledge

1. **a.** Hydrocarbon combustion is a reaction of a hydrocarbon with oxygen to produce carbon dioxide and water vapour.

   b. Polymerization is a reaction where many short hydrocarbon molecules are joined together to form very long hydrocarbon chains.

   c. A polymer is a large hydrocarbon molecule formed by a polymerization reaction.

2. Collisions between the reactants and an external source of energy, such as a match, destabilize chemical bonds, resulting in unbonded atoms. The unbonded atoms attempt to achieve greater stability by forming chemical bonds that produce the products of the reaction. Since the energy released by the forming of the new bonds is greater than the energy input needed to break the original bonds, the overall result is that energy is released to the environment.

3. A double bond in the starting compound is broken, leaving unbonded electrons. This is the basic unit that repeats throughout the polymer chain. Bonds form between unbonded electrons on neighbouring polymer units, creating a larger molecule.

Applying Concepts

4. **a.** $C_6H_{14}(l) + 9.5\ O_2(g) \rightarrow 6\ CO_2(g) + 7\ H_2O(g)$

   $\downarrow$

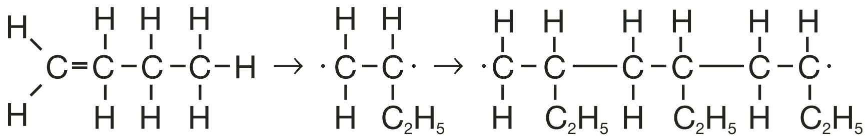
   $2\ C_6H_{14}(l) + 19\ O_2(g) \rightarrow 12\ CO_2(g) + 14\ H_2O(g)$

   b. $C_7H_{16}(l) + 11\ O_2(g) \rightarrow 7\ CO_2(g) + 8\ H_2O(g)$

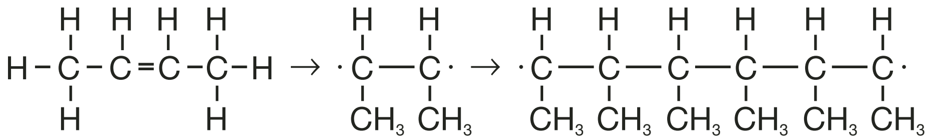
5. **a.** The 2-methylhexane requires more oxygen because it is a larger molecule. It requires 11 mol of oxygen to completely combust versus 9.5 mol of oxygen to combust hexane.

   b. The 2-methylhexane produces more carbon dioxide and water. This is indicated by the balanced chemical equation for the reaction, which shows the combustion of 2-methylhexane producing an additional mole of water and carbon dioxide.

   c. The 2-methylhexane releases more energy because this molecule has a larger molecular mass and it is composed of more atoms. Therefore, it should store more potential energy than a smaller molecule like hexane.

6. 

1-butene repeating unit polymer chain



2-butene repeating unit polymer chain

7. One reason for each country to use hydrocarbons wisely is that hydrocarbons are a finite resource. If they are used unwisely, they may not be available for use in the future. Another reason is that how these materials are used can have a dramatic effect on the environment. Practising energy conservation with fuels and encouraging the recycling of polymers are strategies that can help reduce some of the harmful environmental effects.