3.2 Saturated and Unsaturated Hydrocarbons

Figure A3.7: Many popular snack foods contain saturated fats and trans fats.

Many people turn to greasy foods when they want a snack or a quick way to re-energize themselves on a busy day. The reason these foods are known to be a source of energy is that they all contain significant amounts of fat. Gram for gram, fat contains more food energy than does any other type of nutrient. These foods also share something else in common: it is likely that they all contain saturated fats and industrially produced trans fatty acids.

Food	Amount of Industrially Produced Trans Fatty Acids (g)
doughnut	1 to 3.2
large portion of French fries	2 to 6.8
bag of microwave popcorn	1 to 10.0

How does the arrangement of hydrogen atoms around the double bond in a trans fatty acid influence its properties? Why is Health Canada working with the food-service and food-processing industries to limit the content of trans fatty acid in foods sold in Canada? How are trans fatty acids made? Why did many manufacturers deliberately start adding trans fatty acids to processed foods in the 1980s?

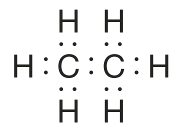
Fats and oils are both organic molecules that are rich in carbon and hydrogen atoms. To answer the preceding questions, once again you need to look at carbon compounds and their bonds.

Saturated Hydrocarbons

You already know that each carbon atom needs to have four bonds to be stable. For example, each carbon atom in an ethane molecule has stability because it is attached to three hydrogen atoms and another carbon atom. This makes a total of four bonds for each carbon atom. As a result of having the maximum number of bonds, carbon atoms are stable and no other atoms can be added to the molecule. Since each carbon in ethane has four bonds to four individual atoms, it is called a **saturated hydrocarbon**.

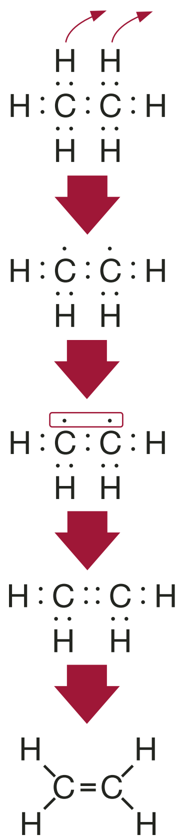
It is possible for a two-carbon molecule, like ethane, to exist with fewer hydrogen atoms. Look at what happens to a molecule when this occurs. If these two neighbouring carbon atoms each lose one hydrogen atom, they can form a double bond. If they each lose an additional hydrogen atom, a triple bond can form.

Ethane



All atoms in this molecule are stable because they each have a full outer energy level.

Making a Double Bond



Two hydrogen atoms leave the carbon chain.

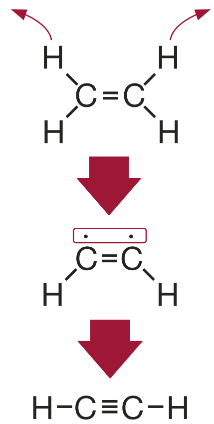
Both carbons have an unbonded electron. So, they are not stable until these unbonded electrons form a bond.

The closest thing to bond with is the electron from the other carbon.

Both carbons bond with each other to form a double bond. All carbon atoms are again stable.

The complete structural diagram shows the twisting that occurs to accommodate the double bonds.

Making a Triple Bond



Two hydrogen atoms leave the carbon chain on either side of a double bond.

The carbons are not stable until they form a bond. So, they bond, yet again, with each other to form a triple bond.

Each atom is stable in this molecule. The carbons each have four bonds: three from the other carbon and one from a hydrogen.

Note: Hydrocarbons with double and triple bonds are less stable than those with single bonds.

saturated hydrocarbon: a hydrocarbon containing only single covalent bonds between carbon atoms

unsaturated hydrocarbon: a hydrocarbon containing double or triple covalent bonds between carbon atoms

Molecules with double and triple bonds are called **unsaturated hydrocarbons**. They are given this name because they are missing their maximum number of bonds to hydrogen atoms. Because there are fewer hydrogen atoms in unsaturated hydrocarbons, they have a general chemical formula different from saturated hydrocarbons like alkanes.

Practice

19. Explain how the formation of a carbon-carbon double bond from a carbon-carbon single bond enables both of the carbon atoms to remain stable.

20. Explain how a hydrocarbon can have a triple bond.

21. Define the terms *saturated hydrocarbon* and *unsaturated hydrocarbon*.

The Difference Between Animal Fats and Plant Oils

Have you ever wondered why many foods containing fats and oils are so popular? In addition to being a rich source of food energy, these ingredients provide taste, consistency, and stability, and they help you feel full. Although many fats and oils help to maintain good health, others do not. To sort this out, you have to look at the shape of the molecules.

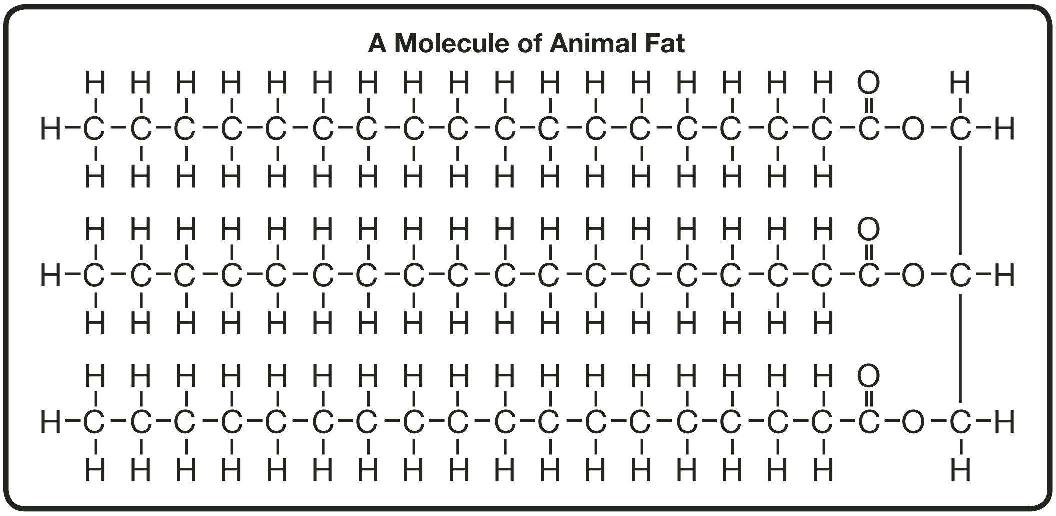


Figure A3.8: A molecule of animal fat contains three fatty acid chains.

The molecules of fats and oils found in foods consist of three connected chains of **fatty acids**. The properties of a fat or oil are determined by the particular fatty acids in these chains.

> **fatty acid:** an organic molecule consisting of a long chain of carbons with a COOH group at one end and a methyl group at the other end

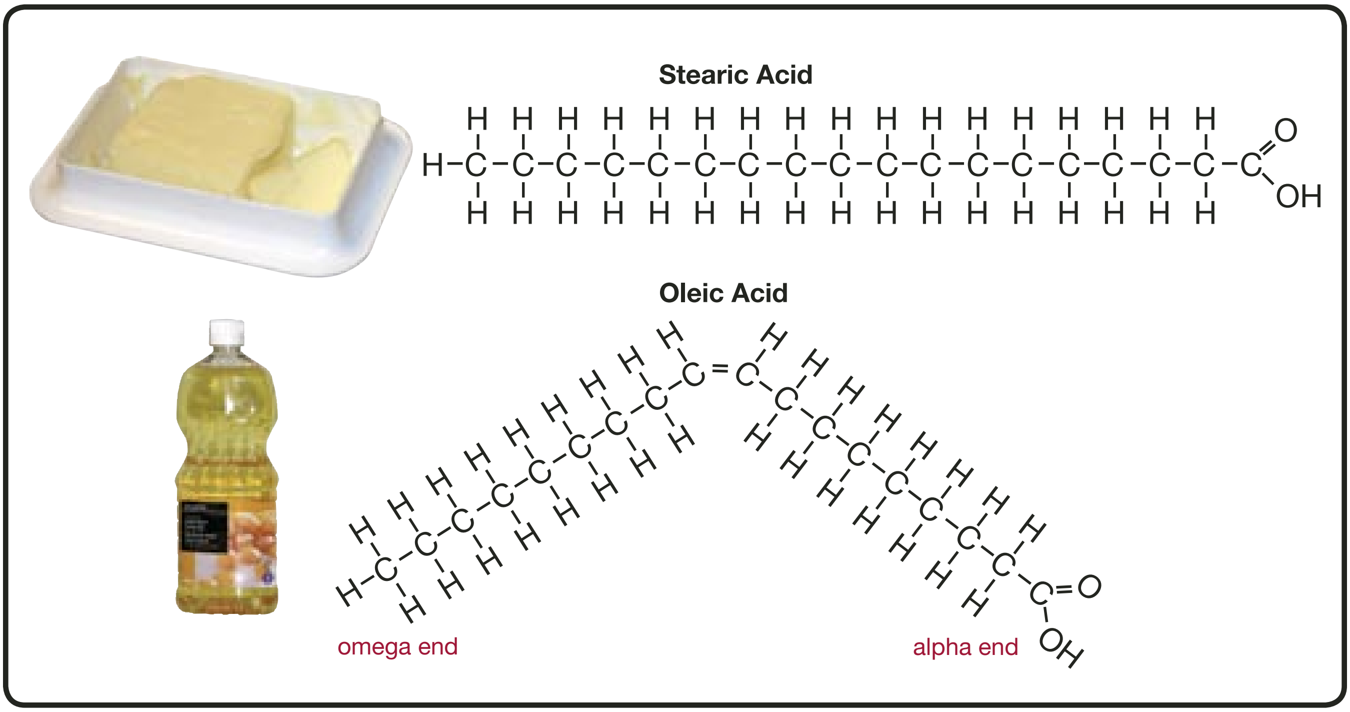


Figure A3.9: Butter is made from saturated fats, which contain saturated fatty acids. Corn oil is made from unsaturated fats, which contain unsaturated fatty acids.

What accounts for the different shapes of these two molecules? Looking closely, you should notice that the carbon chain in the stearic acid is a saturated hydrocarbon, whereas the oleic acid from the plant oil has a double bond and is an unsaturated hydrocarbon. That is, the carbon chain in the stearic acid contains only single bonds between carbon atoms and the carbon chain in the oleic acid contains at least one double bond.

Notice that the unsaturated oleic acid has a bend in the chain at the location of the double bond. The two missing carbon atoms on each side below the double bond create a gap that allows the molecule to bend.

This bend means that groups of oleic acid molecules are like crooked twigs. They don't pack together as closely as the straight chains of stearic acid. Since the oleic acid molecules are further apart, the forces of attraction between adjacent molecules are weaker; therefore, it takes less energy to separate these molecules so that they can move freely over one another. This helps explain why oleic acid is a component of an oil, which is a liquid at room temperature. The closer packing and greater forces of attraction between molecules helps explain why stearic acid is a component of a fat, which is a solid at room temperature.

Oleic acid is an omega-9 fatty acid. The end of the molecule with the COOH group is called the alpha end; the part that terminates with a methyl group is called the omega end. Since the double bond occurs after the ninth carbon, counting from the omega end, this is an omega-9 fatty acid. Your body can produce small amounts of omega-9 fatty acids, but you can also get it from your diet—through olive oil, almonds, and other nuts.

It is the bent shape of this molecule—due to the arrangement of the double bond—that accounts for many of the healthy properties of this nutrient. In general, unsaturated fats and oils are healthier choices than saturated fats. On food labels, unsaturated fats and oils are often called **monounsaturated fats** and **polyunsaturated fats**.

The first part of each word has been added to describe the number of double bonds present in the molecules of each substance. *Mono* refers to one double bond, and *poly* refers to more than one double bond.

monounsaturated fat: a fat molecule that includes fatty acids having only one double bond

polyunsaturated fat: a fat molecule that includes fatty acids having more than one double bond

essential fatty acid: a fatty acid that the body cannot synthesize itself and must obtain from food

Essential Fatty Acids

Although it has become quite popular for people to reduce the amount of fat in their diets, not all fats are health hazards. In fact, some fats are essential to good health. That's why some fat is often included as an ingredient in an energy bar.

It is important to ensure that you eat foods with fats and oils that contain **essential fatty acids**. You need these nutrients for the formation of healthy cell membranes, for the proper development of the brain and the nervous system, and for the production of hormone-like substances that regulate body functions (e.g., blood pressure).

The essential fatty acids are the omega-3 and omega-6 fatty acids. Most people have no trouble getting enough omega-6 fatty acids, but it can be a challenge to get an adequate supply of omega-3 fatty acids. Sources for these include flaxseeds, salmon, and sardines.

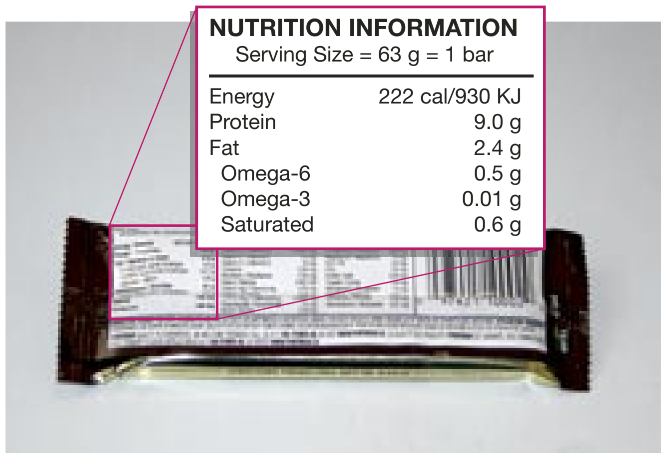


Figure A3.10: Nutrition information is printed on the package of every energy bar.

Practice

22. Explain why saturated fats tend to be solids at room temperature.
23. Sketch a diagram showing the omega end of an omega-3 fatty acid.
24. Sketch a diagram showing the omega end of an omega-6 fatty acid.
25. Explain the flaw in the statement, "A diet high in fat is very unhealthy. So, it is much better to have no fat in your diet."
26. Consider the list of ingredients shown in the energy bar in Figure A3.10.
    a. Identify the ingredient that is normally considered to be an unhealthy component in a food.
    b. Suggest reasons why a small amount of this ingredient has been added to an energy bar.

Try This Activity

Building Models of Hydrocarbons

Purpose

You will use a molecular kit to make models of the hydrocarbons listed in the procedure. Use the models to determine if the hydrocarbons contain only single bonds or if they contain double or triple bonds.

Materials

- molecular model kit

Science Skills

✓ Analyzing and Interpreting

Procedure

step 1: Copy the following table into your notebook.

Chemical Formula	Complete Structural Diagram	Only Single Bonds, a Double Bond, or a Triple Bond	Saturated or Unsaturated
C_5H_{12}			
C_5H_{10}			
C_5H_8			
C_8H_{14}			
C_4H_{10}			
C_7H_{16}			
C_6H_{12}			
C_4H_8			
C_7H_{12}			
C_3H_8			

step 2: For each compound, build a model of the molecule. Use your model kit to determine whether there are enough hydrogen atoms to saturate the molecule.

step 3: Complete the table for each molecule. Draw a complete structural diagram; and determine whether the molecule has only single bonds, whether it has at least one double or triple bond, and whether it is saturated or unsaturated. Since there is more than one way to construct each molecule, there are a number of possible responses for each of the structural diagrams.

Analysis

1. Earlier, you discovered that the general formula for an alkane was C_nH_{2n+2}. Alkanes have only single bonds between the carbon atoms. Use this information to verify the results of your work with the models.
2. Consider the compounds in your table that have a double bond. Use the chemical formula for each of these compounds to develop a general formula for a hydrocarbon with a double bond.
3. Consider the compounds in your table that have a triple bond. Use the chemical formula for each of these compounds to develop a general formula for a hydrocarbon with a triple bond.

Naming Hydrocarbons with a Double or Triple Bond

You already know that an alkane is a hydrocarbon that contains only single bonds. A compound that has at least one double bond between two neighbouring atoms in its longest continuous chain of carbon atoms is called an **alkene**. A compound that has at least one triple bond along the longest continuous chain of carbon atoms is called an **alkyne**.

The rules for naming alkenes and alkynes are similar to naming alkanes, except for the following differences:

- If the compound is an alkene, the suffix *-ene* is used. If the compound is an alkyne, the suffix *-yne* is used.
- The double or triple bond must appear in the longest continuous chain of carbon atoms.
- Number the chain so that the carbons with the double or triple bond receive the lowest possible number.
- The location of the double or triple bond is communicated by a number, placed before the name of the longest continuous carbon chain.

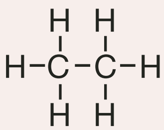
alkene: a hydrocarbon that has at least one carbon-carbon double bond; C_nH_{2n}

alkyne: a hydrocarbon that has at least one carbon-carbon triple bond; C_nH_{2n-2}

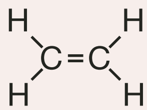
Example Problem 3.2

Name each hydrocarbon given.

a.



b.



c. H−C≡C−H

Solution

Each compound has a continous chain of two carbons. So, the prefix *eth-* is used.

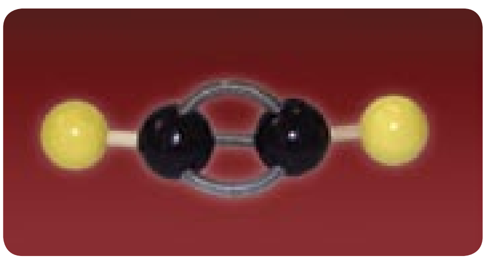
a. This hydrocarbon uses the suffix *-ane* because it is an alkane; it has only single bonds between the carbon atoms. Therefore, this is **ethane**.

b. This hydrocarbon uses the suffix *-ene* because it is an alkene; it has a double bond between the carbon atoms. Therefore, this is **ethene**.

c. This hydrocarbon uses the suffix *-yne* because it is an alkyne; it has a triple bond between the carbon atoms. Therefore, this is **ethyne**.

DID YOU KNOW?

Using the IUPAC naming system, the following molecule is called ethyne. The common name is acetylene.



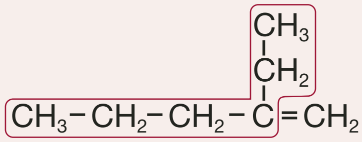
When acetylene is burned alone, it can produce temperatures of 2200°C; but when it is burned with oxygen, the flame temperature can approach 3300°C—hot enough to melt all commercial metals.

Oxy-acetylene welding uses this very hot flame to melt the edges of two pieces of metal that are brought together. The oxy-acetylene process can also be used to cut metal.

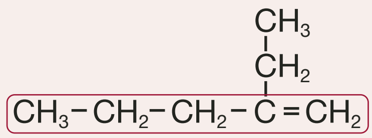
Example Problem 3.3

Identify which diagram correctly identifies the parent chain of an alkene molecule.

A.



B.



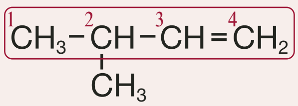
Solution

Diagram A is incorrect. Even though diagram A identifies the longest chain, this chain does not include the double bond. Diagram B is correct because the parent chain includes the double bond.

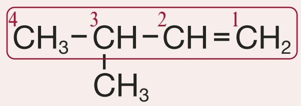
Example Problem 3.4

Identify which diagram correctly numbers the carbons in the parent chain.

A.



B.

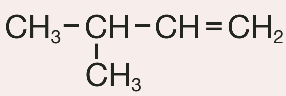


Solution

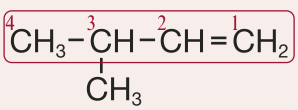
Diagram A shows the double bond occurring after carbon number 3. This is not the lowest number. Diagram B shows the double bond occurring after carbon number 1. Because 1 is less than 3, diagram B is correct.

Example Problem 3.5

Correctly name the following hydrocarbon.



Solution



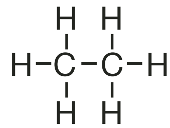
The double bond for this molecule is between carbon 1 and carbon 2. Use the smaller number to communicate its position. Therefore, the name of this hydrocarbon is

3-methyl-1-butene

methyl branch on carbon 3 — double bond after carbon 1

Practice

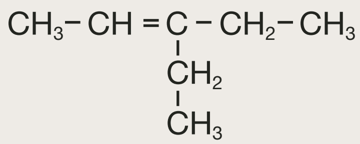
27. Copy and complete the following table into your notebook. The first line has been completed for you.

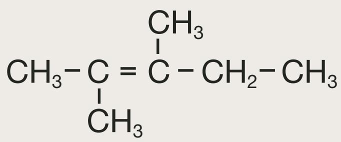
	Type of Hydrocarbon	Bond Between Carbon Atoms in Longest Chain	General Chemical Formula	Example
Saturated	alkane	single bonds	C_nH_{2n+2}	Ethane: C_2H_6 
Unsaturated		one double bond	C_nH_{2n}	
		one triple bond	C_nH_{2n-2}	

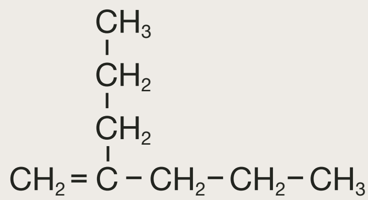
n = 2
2n + 2 = 2(2) + 2
= 6

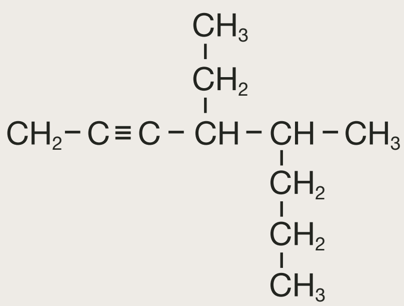
28. Name the following compounds.

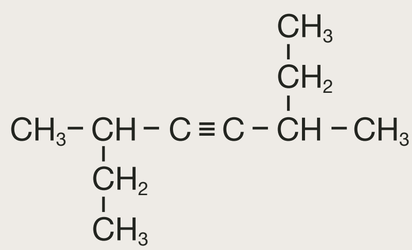
a. $CH_3-CH_2-CH=CH-CH_2-CH_3$

b. 

c. 

d. 

e. 

f. 

29. Draw condensed structural diagrams for the following compounds.

a. 1-hexene
b. 2-pentyne
c. 2-methyl-2-pentene
d. 2,5-dimethyl-3-heptyne

30. The following compounds are named incorrectly. Draw a complete structural diagram of the compound; then name it correctly.

a. 3-butene
b. 2-methyl-4-pentene
c. 2-ethyl-2-pentene
d. 2,3-diethyl-2-hexene

Saturated and Unsaturated Compounds in Food

You have just finished exploring many of the different hydrocarbons that exist. You know that there are alkanes, alkenes, and alkynes. As stated earlier, butter is produced from fats containing saturated carbon chains and, therefore, has properties more like an alkane. Margarine, on the other hand, is produced from oils containing primarily unsaturated carbon chains and, therefore, has properties more like an alkene. So, which is the healthier food choice—butter or margarine?

Part of the answer to this question lies in the differences in the physical and chemical properties of saturated and unsaturated compounds. Remember that the physical properties of a substance include a substance's state at room temperature, solubility, colour, melting point, and boiling point. The chemical properties of a substance explain how stable and reactive the substance is.

Is there a relationship between the properties of the different groups of hydrocarbons and their chemical structure? In the next investigation, you have an opportunity to identify any trends and explain why they may exist.

Investigation

Connecting Chemical and Physical Properties to Structure

Purpose

You will use molecular models to represent various hydrocarbons and suggest how their structure might influence their properties.

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting

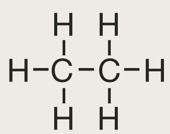
Materials

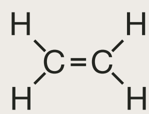
- molecular model kit

Procedure

step 1: Read through the analysis questions so you know what to look for as you build your models.

step 2: Use the molecular kit to construct each of the following molecules:





$H-C\equiv C-H$

Remember that the black balls in your model kit represent carbon atoms, the yellow balls represent hydrogen, and the connectors between the balls represent the bonds between the atoms.

Analysis

Use your models to answer the following questions:

1. Which model is the most rigid?
2. Which model is the most flexible?
3. On which model are the bonds under the most stress?
4. On which model are the bonds under the least stress?
5. Which model has the largest mass? Which has the smallest?
6. Choosing between hydrocarbons with single, double, or triple bonds, which group will have bonds that are the easiest to break? Support your answer.
7. Choosing between hydrocarbons with single, double, or triple bonds, which group will have bonds that are the most difficult to break? Support your answer.
8. Which of the three hydrocarbons will have the greatest reactivity? Support your answer.
9. Order the molecules from most reactive to least reactive. Explain how you came to your conclusion.
10. Predict which molecule will require the most energy to make it move around. Support your answer.
11. Particles in a liquid move freely over one another, taking the shape of their container. This is due to the fact that the particles in a liquid have a greater energy of motion than particles in a solid. Suggest another reason why saturated fats tend to be solid at room temperature and unsaturated fats tend to be liquid at room temperature.

Try This Activity

Investigating Hydrocarbon Boiling Points

Science Skills
✓ Analyzing and Interpreting

Purpose

You will graph data for the boiling points of both alkanes and alkenes. You will then analyze the graphs to find trends in the data.

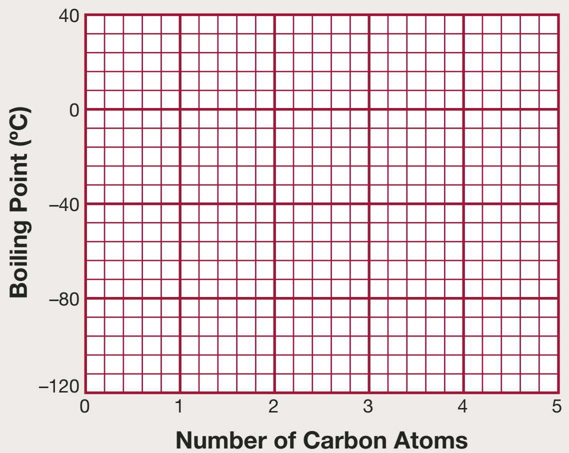
Procedure

1. Copy and complete the following table in your notebook.

	Name of Compound	Chemical Formula	Number of Carbon Atoms	Boiling Point (°C)
Alkanes	ethane			−88.6
	propane			−42.0
	butane			−0.5
Alkenes	ethene			−103.7
	propene			−47.5
	1-butene			−6.0

2. Graph the data in the table. Draw one best-fit line for alkanes and another best-fit line for alkenes. Include a legend. Set up your graph similar to the following.

Comparing Boiling Points of Alkanes and Alkenes



Analysis

3. State the relationship between the boiling point of a hydrocarbon and the number of carbon atoms within the molecule. Give an explanation for this relationship.
4. Predict which compound would have a higher boiling point—pentane or hexane. Give a reason for your choice.
5. Generally describe how the boiling points of alkanes compare with the boiling points of alkenes. Suggest an explanation.
6. Predict which compound would have a higher boiling point—pentane or 2-pentene. Give a reason for your choice.
7. Predict how the melting point of pentane would compare to the melting point of octane.
8. Predict how the melting point of octane would compare to the melting point of 2-octene.
9. Most saturated fats are solid at room temperature, whereas unsaturated fats are liquids (oils). Explain how this statement agrees with the data you analyzed.

The Melting Points and Boiling Points of Hydrocarbons

Generally speaking, the boiling points and melting points of hydrocarbons increase as the number of carbons in the molecule increases. There are two reasons for this:

- The attraction between molecules increases as the number of atoms within those molecule increases. If the attraction between molecules is strong, more energy (or heat) is required to break those attractions to cause a change in state.
- More energy is required to move something with greater mass. If the molecule is bigger, more energy (or heat) is required to make it move.

Therefore, a larger number of carbons in a molecule results in higher melting and boiling points for the compounds because of the stronger attractions between molecules and the greater mass. Smaller hydrocarbons, such as methane, $CH_4(g)$, and ethane, $C_2H_6(g)$, have weaker attractions between molecules and exist as gases at room temperature. Pentane, $C_5H_{12}(l)$, and octane, $C_8H_{18}(l)$, have more carbons, so these compounds tend to be liquids. Waxes tend to have 20 carbons or more in their molecules and are solid at room temperature.

Practice

31. Explain why pentane has a higher boiling point than butane.

32. Explain how a double bond affects the stability of a molecule.

33. For each group, order the compounds from highest boiling point to lowest boiling point.

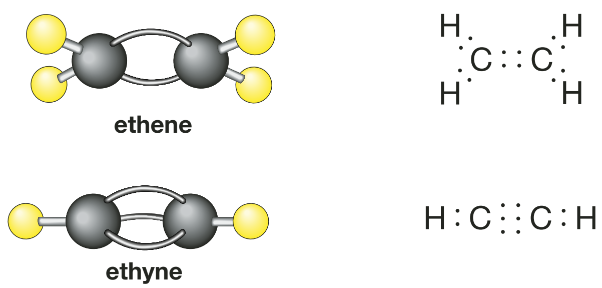
- **a.** pentane, propane, hexane
- **b.** 1-pentene, pentane, 1-butene
- **c.** 2-hexene, 2-heptene, 2-octene

The Reactivity of Hydrocarbons

The reactivity of hydrocarbons depends on other molecules around them. As a general rule, unsaturated hydrocarbons are more reactive than saturated hydrocarbons, due to the bond strain associated with the double or triple bond between carbons.

If you make a molecular model of a double bond or triple bond, you will notice some stress or tension in the bond. Recall that each spring in your model kit represents a pair of electrons shared by the two atoms with double and triple bonds. Carbon atoms joined by double and triple bonds have a greater number of electrons between the carbons than singly bonded carbons. The larger number of electrons results in a greater force of repulsion between them. As a result, hydrocarbons with double or triple bonds are more reactive than those with single bonds.

The Reactivity of Hydrocarbons



Recall that all electrons have a negative charge and, therefore, have a tendency to repel each other.

The close proximity of the electrons within double and triple bonds will increase the repulsion forces between the electrons. This repulsion force increases the stress within the bond and, therefore, increases the reactivity of the molecule.

The reactivity of unsaturated hydrocarbons is useful, especially when you look at industrial processes that use chemical reactions to produce different products. Many plastics and artificial rubbers are produced from chemical reactions involving unsaturated hydrocarbons. As you will see later, the breaking of double or triple bonds in short, unsaturated hydrocarbons can be used to form long carbon chains with single bonds.

Practice

34. For each group, order the compounds from most reactive to least reactive.
   a. 2-hexene, 2-hexyne, hexane
   b. propane, ethene, 2-butyne
   c. 3-octyne, heptane, 2-hexene

The Origins of Industrially Produced Trans Fatty Acids

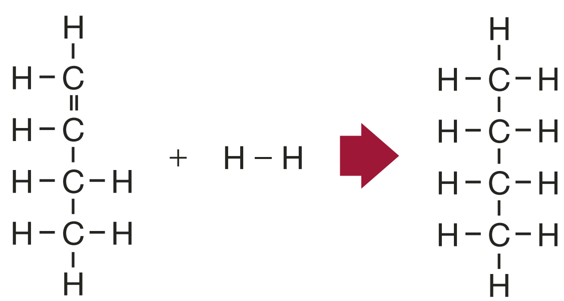
Since butter tends to be expensive and vegetable oils less expensive, it seems to be a good idea to make a spreadable fat from vegetable oil. However, it was not easy to manufacture a new fat that was soft enough to be spread smoothly on a piece of bread. Early attempts produced a product that was too hard. Eventually, food scientists developed a process that could produce an artificial fat from vegetable oil.

Figure A3.11: Industrially produced toppings should be able to spread as smoothly as butter.

Margarine is made by bubbling hydrogen gas through hot vegetable oil under pressure in a special metal vat. The result is that the carbon double bond is broken and is replaced with two single bonds to hydrogen atoms. Since two more hydrogen atoms can be added to the molecule for every double bond that is broken, the process is called **hydrogenation**.

hydrogenation: a reaction that converts carbon-carbon double and triple bonds in unsaturated compounds into carbon-carbon single bonds of saturated compounds

A Hydrogenation Reaction



If the hydrogenation is complete, then all the double bonds have been broken. The result is a fat that is so hard that it cannot be spread like butter. To solve this problem, the oil is only partially hydrogenated. This produces a soft, spreadable fat called margarine. The high temperatures needed for the partial hydrogenation process seem to have an unintended effect on some of the unsaturated molecules that remain in the vegetable oils. See if you can spot the difference in Figure A3.12.

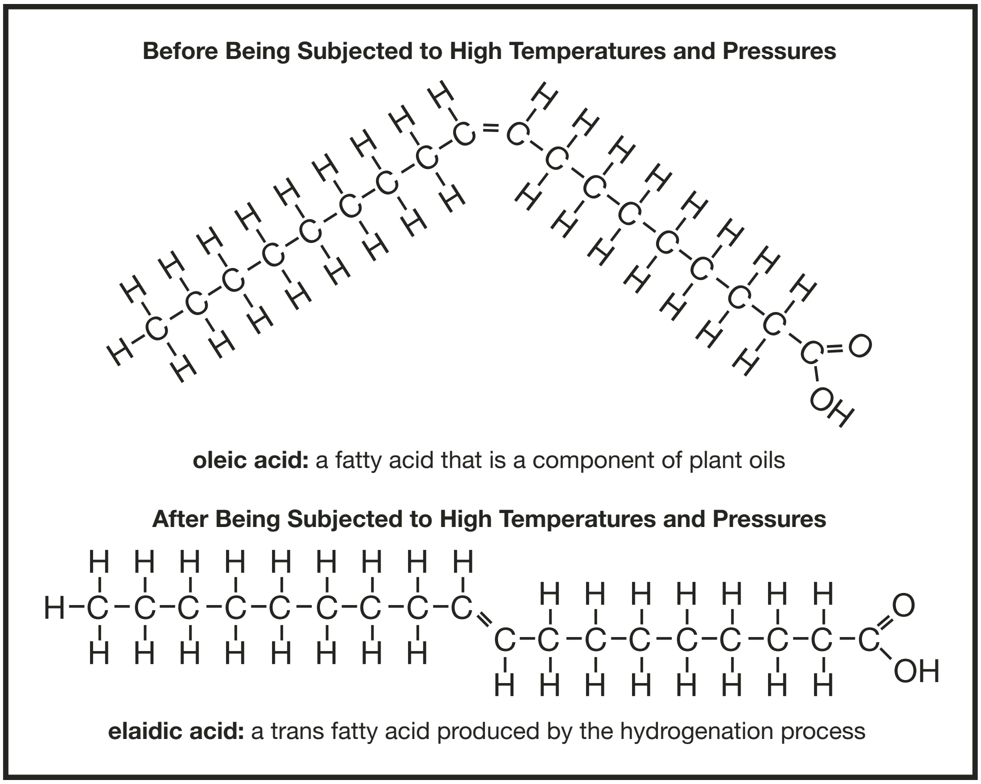


Figure A3.12: Can you spot the difference in the bonding within these two fatty acids that causes the difference in shape?

Although it may be obvious that the molecule after being subjected to high temperatures and pressures is no longer bent, it is not as obvious why this occurred. Look at the position of the hydrogen atoms on either side of the double bond. In the original oleic acid molecule, the hydrogen atoms are on the same side of the double bond, providing a gap so the molecule can bend. In the elaidic acid molecule, the hydrogen atoms are on either side of the double bond, making the molecule more symmetrical so the carbon chain remains straight. The position of the two hydrogen atoms is what makes the elaidic acid molecule an **industrially produced trans fatty acid**. The word *trans* means “across” in Latin. Trans fatty acids produced by this process can combine with other fatty acids to make an **industrially produced trans fat**. You might be surprised to know that this industrial hydrogenation process generates a family of trans fatty acids that are completely different than what tends to be produced naturally by plants and animals.

industrially produced trans fatty acid: a synthetic molecule that has the hydrogen atoms on either side of the double bond, resulting in a straighter carbon chain

industrially produced trans fat: a fat molecule produced by partial hydrogenation that contains at least one trans fatty acid chain

COMPARING MOLECULES

Most Fatty Acids Produced Naturally by Plants and Animals	Industrially Produced Trans fatty Acids Manufactured Through Hydrogenation
• Hydrogen atoms are always on the same side of the double bond, resulting in bent molecules. • The double bond occurs after carbon 3, 6, or 9 when counting from the omega end. This accounts for omega-3, omega-6, and omega-9 fatty acids. • The number of carbon atoms in the fatty acid chain is always an even number.	• Hydrogen atoms are on opposite sides of the double bond, resulting in straight molecules. • The double bond can occur after almost any carbon in the chain, but especially after carbons 8, 9, 10, 11, 12, and 13. • The number of carbon atoms in the fatty acid chain could be an odd or even number.

Biochemists and nutritionists are concerned because the molecules of trans fatty acids are so different from the natural fatty acids that our bodies need to stay healthy. Nobody knows all the effects that these substances will have on the human body.

One known property is linked to the fact that trans fatty acids have a straight chain of carbon atoms. This means that these molecules have some properties in common with saturated fatty acids found in butter, cheese, beef, and coconut oil. Because these molecules tend to be solid at room temperature, they have a greater likelihood of clogging up your arteries. Eating foods rich in saturated fats or trans fats should be avoided for the same reason that bacon fat shouldn't be poured down the drain: it will "clog up the pipes." Deposits that develop inside arteries that lead to the heart and brain can cause heart attacks and strokes. Another component of food that also contributes to the buildup of fat deposits in blood vessels is **dietary cholesterol**.

dietary cholesterol: a substance found in food from animal sources

Studies from all over the world are indicating that industrially produced trans fats pose an even greater risk for heart disease than saturated fats. A study in Denmark indicates that, gram for gram, industrially produced trans fats contribute to a more than ten times greater risk of developing heart disease than do naturally produced saturated fats.

Practice

35. Consider Figure A3.12 on page 134. Explain why oleic acid is an oil at room temperature with a melting point of 4°C, whereas elaidic acid is a solid at room temperature with a melting point of 46.5°C.

36. A theme you will encounter throughout Science 20 is how technological solutions to societal problems often create new, unintended problems. Concisely describe how the industrial production of cholesterol-free, spreadable fats (like margarine) illustrates this theme.

37. Consider the statement, "Dietary cholesterol is found in butter but not in margarine."

- **a.** Explain this statement.
- **b.** Does this statement automatically mean that margarine is a healthier food choice?

38. Although the human body has no need for industrially produced trans fats, food manufacturers began to deliberately add trans fats to foods in the 1980s. Use the Internet to determine why this was done.

Making Healthy Food Choices

Fats and oils are a major source of energy for the body. These substances play key roles in the operation of the nervous system and in other essential body functions. However, it is important to choose foods that have moderate amounts of unsaturated fatty acids, such as the monounsaturated fatty acids found in olive oil or the omega-3 fatty acids found in fish oils and flax seeds.

Saturated fats, industrially produced trans fats, and dietary cholesterol are all substances that can significantly increase your risk of heart disease. It is best to choose foods that have the lowest amounts of these substances.

3.2 Summary

In this lesson you discovered that carbon atoms have the ability to form double and triple bonds. The molecules that contain only single carbon-carbon bonds are called saturated compounds; molecules that contain double or triple carbon-carbon bonds are called unsaturated compounds. Unsaturated compounds can be further subdivided into compounds with double carbon-carbon bonds, called alkenes, and compounds with triple carbon-carbon bonds, called alkynes. Scientists and industries have created a system to name unsaturated compounds.

In terms of properties, as you increase the number of carbons within a carbon chain, the compound's melting point and boiling point also increases. Since double and triple carbon-carbon bonds experience bond strain, these bonds are less stable than single bonds. This is why unsaturated compounds are more chemically reactive than saturated compounds.

It is important to choose foods that contain the least amount of saturated fats, industrially produced trans fatty acids, and cholesterol. People who eat foods that contain high amounts of these substances have been shown to have a significantly high risk for heart disease.

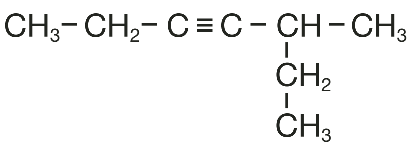
3.2 Questions

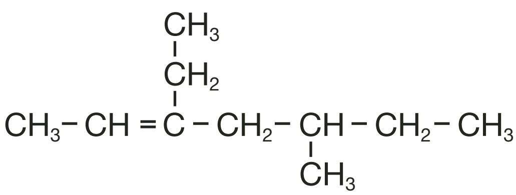
Knowledge

1. Define and provide an example for the following terms.
   - **a.** saturated compound
   - **b.** unsaturated compound
   - **c.** alkane
   - **d.** alkene
   - **e.** alkyne
2. Describe how the number of carbon atoms within a compound affects the melting point and boiling point of that compound.
3. Why are alkenes more reactive than alkanes?
4. Why are alkynes more reactive than alkenes?

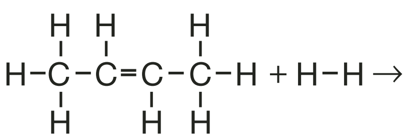
Applying Concepts

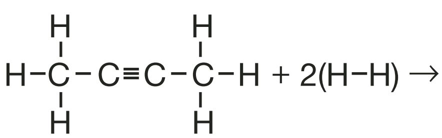
5. Name the following compounds.

a. 

b. 

6. Looking at physical properties, explain why it is more convenient to use octane as a fuel for cars than methane or ethane.
7. Provide a condensed structural diagram for each compound.
   - **a.** 2,3-dimethyl-1-pentene
   - **b.** 3-ethyl-4-methyl-1-pentyne
   - **c.** 3-methyl-3-octene
   - **d.** 4-ethyl-2,3-dimethyl-3-hexene
8. Complete each reaction by drawing the complete structural diagram of the product.

a. 

b. 

9. Refer to your answer to question 8. Identify which type of reaction is illustrated by all of these reactions.
10. The following nutrition facts describe the contents of butter, margarine sold in tubs, and margarine sold in rectangular blocks.

NUTRITION FACTS FOR BUTTER
(per serving, 14 g)

Energy	100 cal (419 kJ)
Total fat	11 g
Saturated fat	7 g
Trans fat	0 g
Cholesterol	30 g

NUTRITION FACTS FOR TUB MARGARINE
(per serving, 14 g)

Energy	60 cal (251 kJ)
Total fat	7 g
Saturated fat	1 g
Trans fat	0 g
Cholesterol	0 g

NUTRITION FACTS FOR BLOCK MARGARINE
(per serving, 14 g)

Energy	100 cal (419 kJ)
Total fat	11 g
Saturated fat	2 g
Trans fat	3 g
Cholesterol	0 g

Which of these three foods would be the healthiest choice if you wanted to reduce the risks associated with heart disease? Concisely support your answer.

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Legend: t = top, m = middle, b = bottom, l = left, r = right

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