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We succeeded in entering the third millennium, while we are more confident in ourselves."

H.H. Sheikh Khalifa Bin Zayed Al Nahyan
President of the United Arab Emirates

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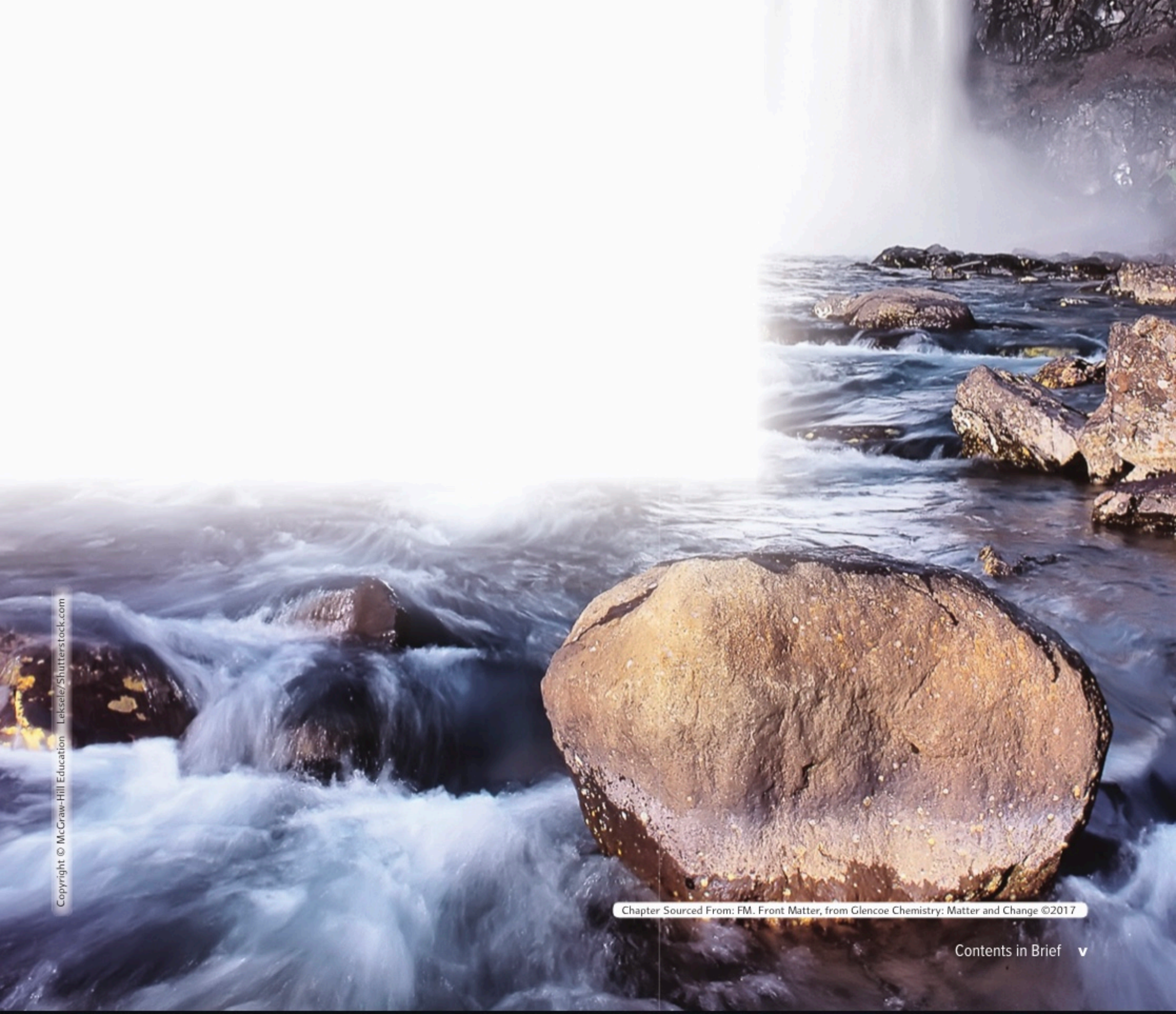
Student Resources



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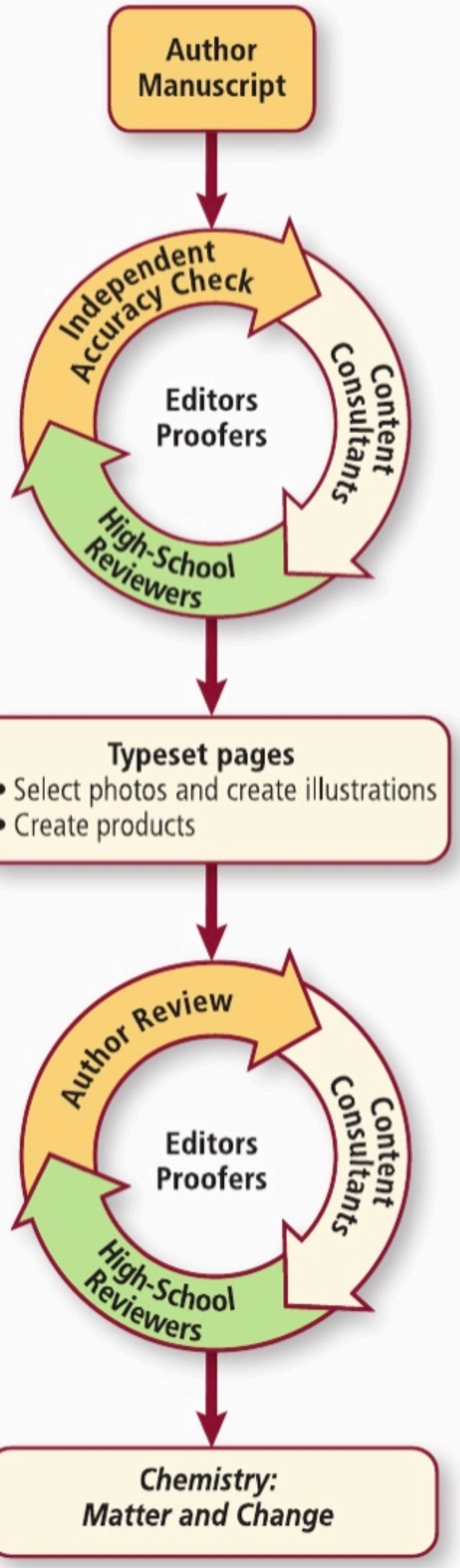

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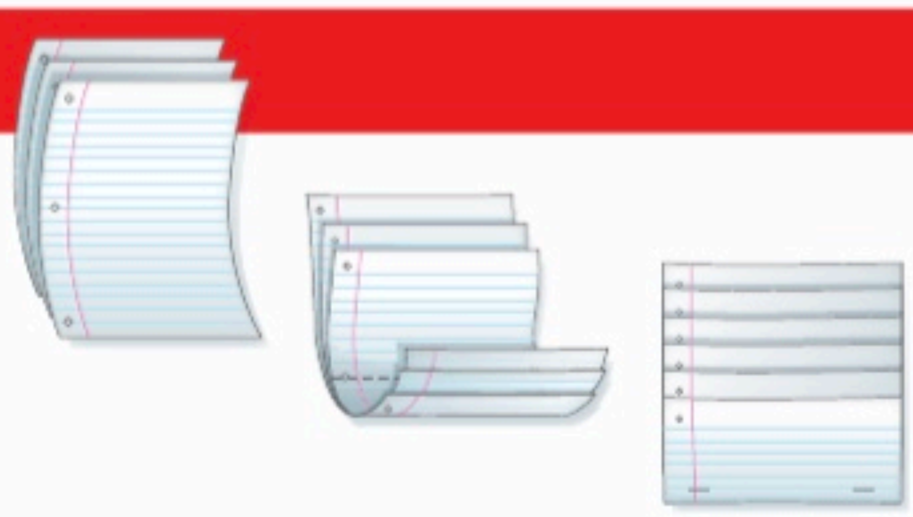
FOLDABLES® by Dinah Zike

Folding Instructions

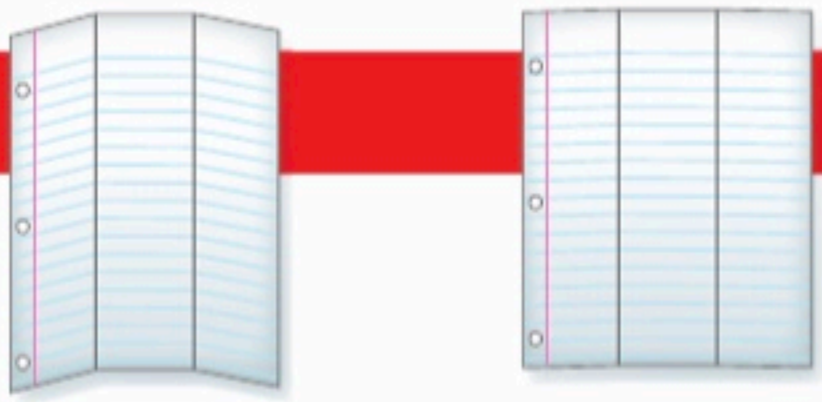
The following pages offer step-by-step instructions to make the Foldables study guides.

Layered-Look Book



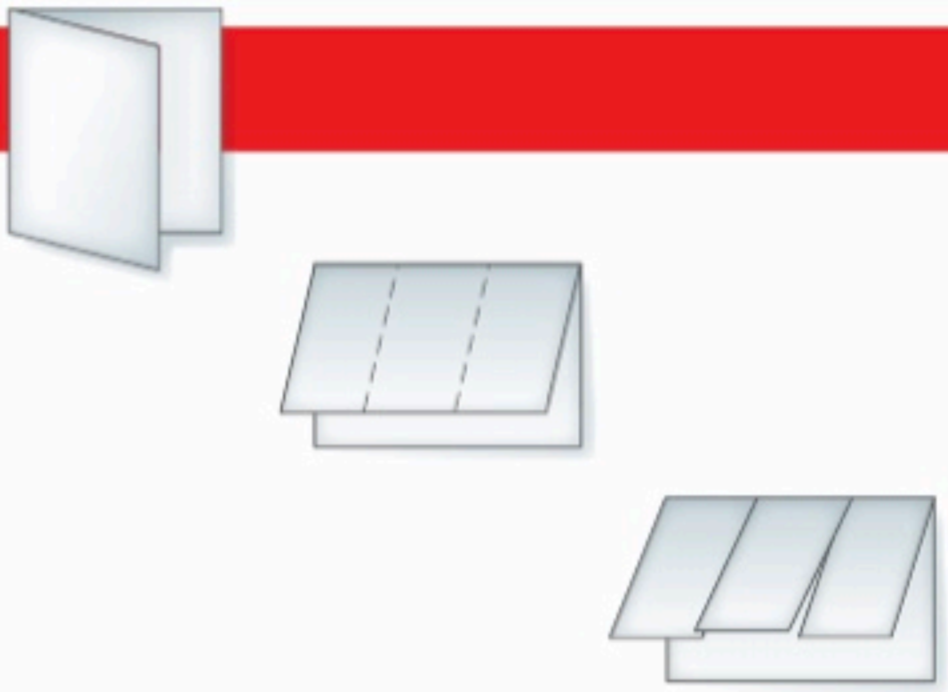
1. Collect three sheets of paper and layer them about 1 cm apart vertically. Keep the edges level.
2. Fold up the bottom edges of the paper to form 6 equal tabs.
3. Fold the papers and crease well to hold the tabs in place. Staple along the fold. Label each tab.

Trifold Book



1. Fold a vertical sheet of paper into thirds.
2. Unfold and label each row.

Three-Tab Book



1. Fold a horizontal sheet of paper from side to side. Make the front edge about 2 cm shorter than the back edge.
2. Turn length-wise and fold into thirds.
3. Unfold and cut only the top layer along both folds to make three tabs. Label each tab.

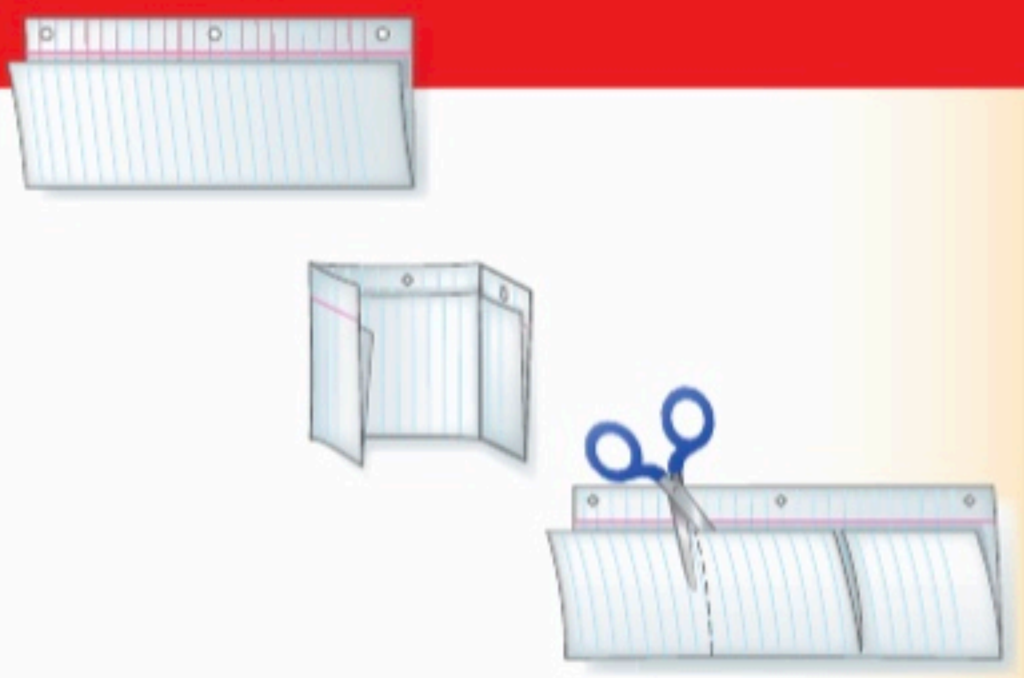
Two- and Four-Tab Books

1. Fold a sheet of paper in half.
2. Fold in half again. If making a four-tab book, then fold in half again to make three folds.
3. Unfold and cut only the top layer along the folds to make two or four tabs. Label each tab.

Shutter-Fold and Four-Door Books

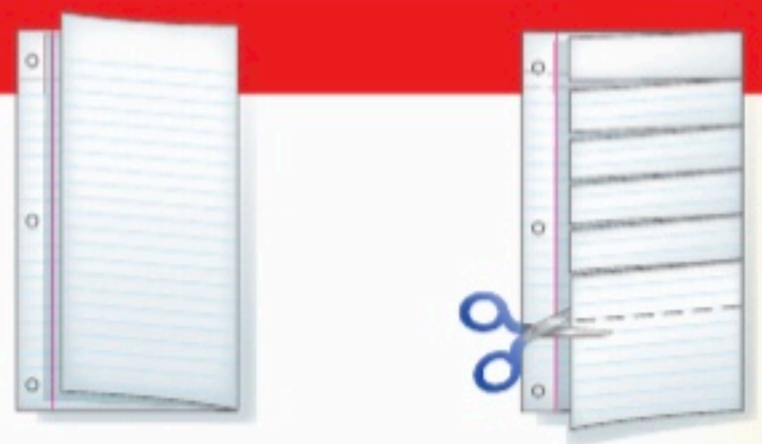
1. Find the middle of a horizontal sheet of paper. Fold both edges to the middle and crease the folds. Stop here if making a shutter-fold book. For a four-door book, complete the steps below.
2. Fold the folded paper in half, from top to bottom.
3. Unfold and cut along the fold lines to make four tabs. Label each tab.

Concept-Map Book



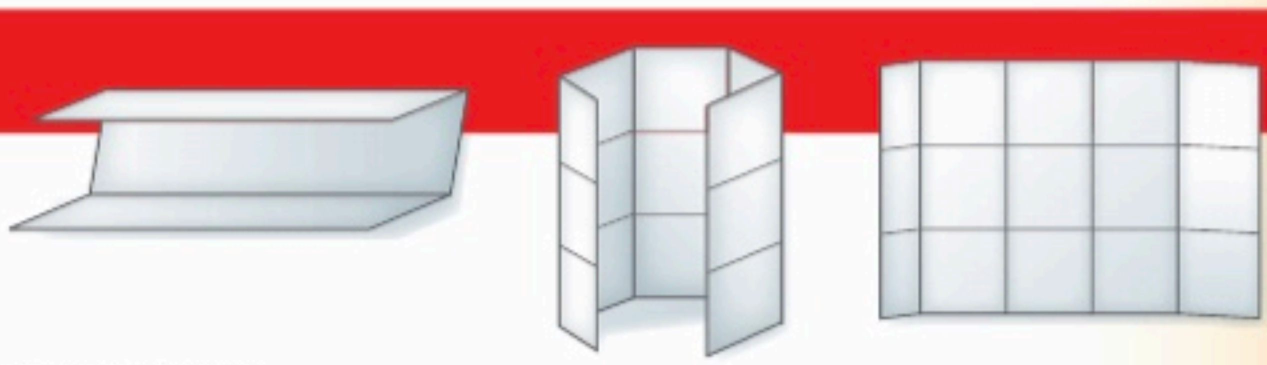
1. Fold a horizontal sheet of paper from top to bottom. Make the top edge about 2 cm shorter than the bottom edge.
2. Fold width-wise into thirds.
3. Unfold and cut only the top layer along both folds to make three tabs. Label the top and each tab.

Vocabulary Book



1. Fold a vertical sheet of notebook paper in half.
2. Cut along every third line of only the top layer to form tabs. Label each tab.

Folded Chart



1. Fold a sheet of paper length-wise into thirds.
2. Fold the paper width-wise into fifths.
3. Unfold, lay the paper length-wise, and draw lines along the folds. Label the table.

FOLDABLES®

by Dinah Zike

Pocket Book

1. Fold the bottom of a horizontal sheet of paper up about 3 cm.
2. If making a two-pocket book, fold in half. If making a three-pocket book, fold in thirds.
3. Unfold once and dot with glue or staple to make pockets. Label each pocket.

Bound Book

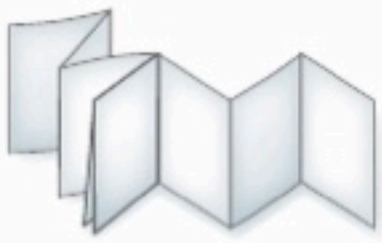
1. Fold several sheets of paper in half to find the middle. Hold all but one sheet together and make a 3-cm cut at the fold line on each side of the paper.
2. On the final page, cut along the fold line to within 3-cm of each edge.
3. Slip the first few sheets through the cut in the final sheet to make a multi-page book.

Top-Tab Book

1. Layer multiple sheets of paper so that about 2–3 cm of each can be seen.
2. Make a 2–3-cm horizontal cut through all pages a short distance (3 cm) from the top edge of the top sheet.
3. Make a vertical cut up from the bottom to meet the horizontal cut.
4. Place the sheets on top of an uncut sheet and align the tops and sides of all sheets. Label each tab.

Accordion Book

1. Fold a sheet of paper in half. Fold in half and in half again to form eight sections.
2. Cut along the long fold line, stopping before you reach the last two sections.
3. Refold the paper into an accordion book. You may want to glue the double pages together.



CHAPTER 8

Hydrocarbons

BIGIDEA Organic compounds called hydrocarbons differ by their types of bonds.

SECTIONS

1 Introduction to Hydrocarbons

2 Alkanes

3 Alkenes and Alkynes

4 Hydrocarbon Isomers

5 Aromatic Hydrocarbons

LaunchLAB

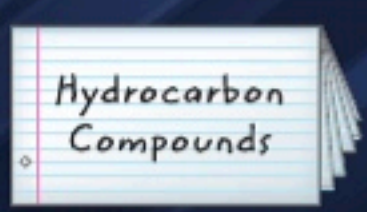
How can you model simple hydrocarbons?

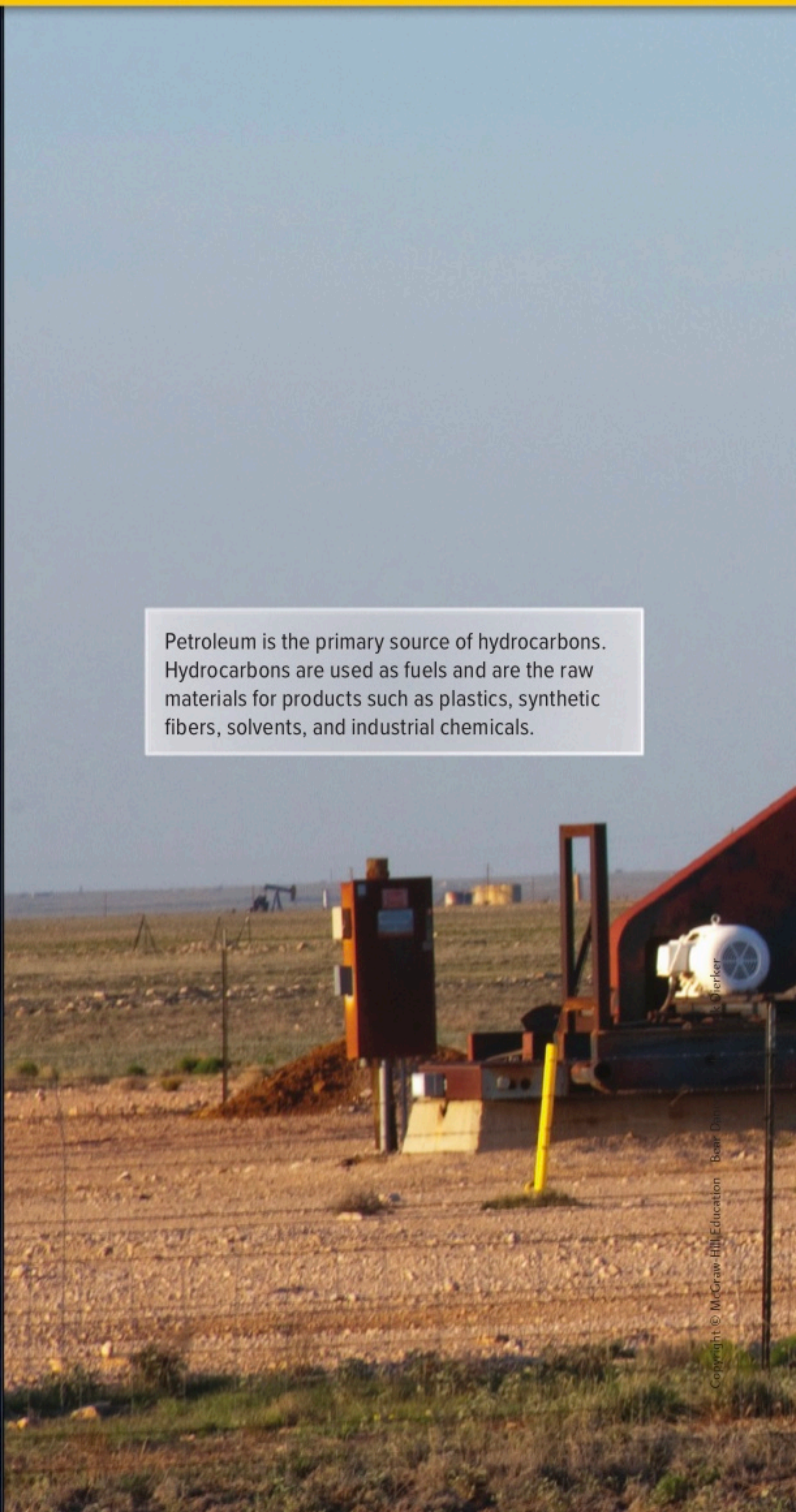
Hydrocarbons are made of hydrogen and carbon atoms. Recall that carbon has four valence electrons and it can form four covalent bonds. In this lab, you will build models of hydrocarbons with two, three, four, and five carbon atoms.

FOLDABLES® Study Organizer

Hydrocarbon Compounds

Make a bound book. Label it as shown. Use it to help you organize information about hydrocarbon compounds.





Petroleum is the primary source of hydrocarbons. Hydrocarbons are used as fuels and are the raw materials for products such as plastics, synthetic fibers, solvents, and industrial chemicals.

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SECTION 1

Introduction to Hydrocarbons

MAINIDEA **Hydrocarbons are carbon-containing organic compounds that provide a source of energy and raw materials.**

Essential Questions

- What do the terms *organic compound* and *organic chemistry* mean?
- How are hydrocarbons and the models used to represent them identified?
- How are saturated and unsaturated hydrocarbons distinguished?
- Where are hydrocarbons obtained and how are they separated?

Review Vocabulary

microorganism: a tiny organism, such as a bacterium or a protozoan, that cannot be seen without a microscope

New Vocabulary

organic compound
hydrocarbon
saturated hydrocarbon
unsaturated hydrocarbon
fractional distillation
cracking

CHEM 4 YOU **If you have ridden in a car or a bus, you have used hydrocarbons. The gasoline and diesel fuel that are used in cars, trucks, and buses are hydrocarbons.**

Organic Compounds

Chemists in the early nineteenth century knew that living things, such as the plants and panda shown in **Figure 1,** produce an immense variety of carbon compounds. Chemists referred to these compounds as *organic* compounds because they were produced by living organisms.

Once Dalton's atomic theory was accepted in the early nineteenth century, chemists began to understand that compounds, including those made by living organisms, consisted of arrangements of atoms bonded together in certain combinations. They were able to synthesize many new and useful substances. However, scientists were not able to synthesize organic compounds. Many scientists incorrectly concluded that they were unable to synthesize organic compounds because of vitalism. According to vitalism, organisms possessed a mysterious "vital force," enabling them to assemble carbon compounds.

Disproving vitalism Friedrich Wöhler (1800–1882), a German chemist, was the first scientist to realize that he had produced an organic compound, called urea, by synthesis in a laboratory. Wöhler's experiment did not immediately disprove vitalism, but it prompted a chain of similar experiments by other European chemists. Eventually, the idea that the synthesis of organic compounds required a vital force was discredited and scientists realized they could synthesize organic compounds in the laboratory.

Figure 1 Living things contain, are made up of, and produce a variety of organic compounds.

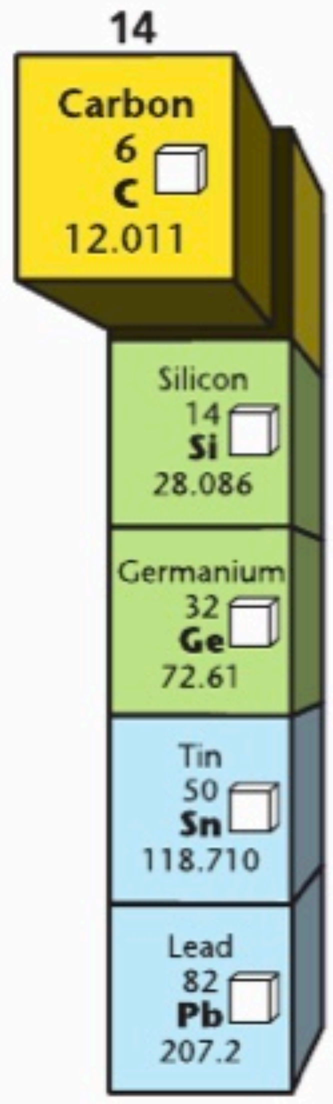
Identify ***two organic compounds that you have studied in a previous science course.***

Organic chemistry Today, the term **organic compound** is applied to all carbon-containing compounds with the primary exceptions of carbon oxides, carbides, and carbonates, which are considered inorganic. Because there are so many organic compounds, an entire branch of chemistry, called organic chemistry, is devoted to their study. Recall that carbon is an element in group 14 of the periodic table, as shown in **Figure 2.** With the electron configuration of $1s^2 2s^2 2p^2$, carbon nearly always shares its electrons and forms four covalent bonds. In organic compounds, carbon atoms are bonded to hydrogen atoms or atoms of other elements that are near carbon in the periodic table—especially nitrogen, oxygen, sulfur, phosphorus, and the halogens.

Most importantly, carbon atoms also bond to other carbon atoms and form chains from two to thousands of carbon atoms in length. Also, because carbon forms four bonds, it forms complex, branched-chain structures, ring structures, and even cagelike structures. With all of these bonding possibilities, chemists have identified millions of different organic compounds and are synthesizing more every day.

☑ READING CHECK **Explain** why carbon forms many compounds.

■ **Figure 2** Carbon is found in group 14 of the periodic table. It can bond to four other elements and form thousands of different compounds.



Hydrocarbons

The simplest organic compounds are **hydrocarbons,** which contain only the elements carbon and hydrogen. How many different compounds do you think two elements can form? You might guess that only a few compounds are possible. However, thousands of hydrocarbons are known, each containing only the elements carbon and hydrogen. The simplest hydrocarbon molecule, CH_4, consists of a carbon atom bonded to four hydrogen atoms. This substance, called methane, is an excellent fuel and is the main component of natural gas, as shown in **Figure 3.**

☑ READING CHECK **Name** two uses of methane or natural gas in your home or community.

■ **Figure 3** Methane—a hydrocarbon found in natural gas—is the simplest hydrocarbon.

Identify ***In addition to hydrogen, what other elements readily bond with carbon?***

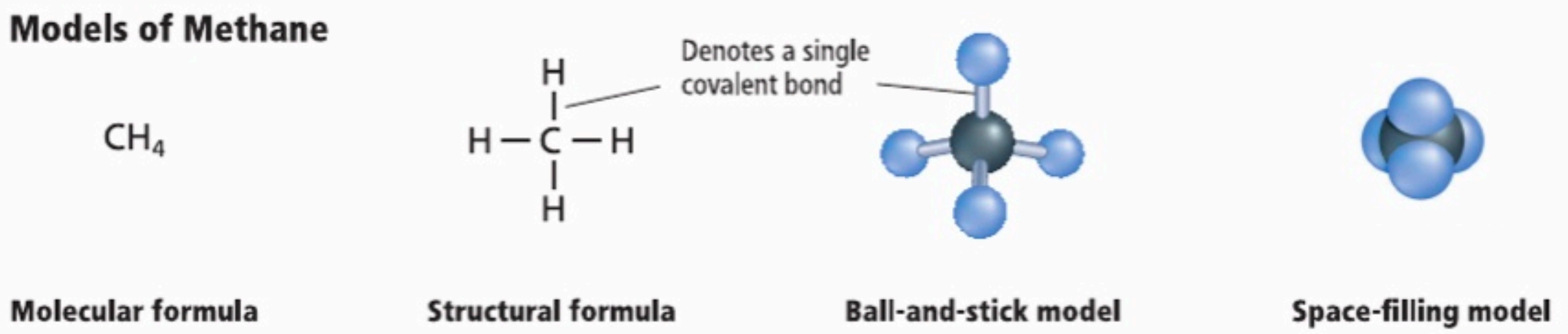
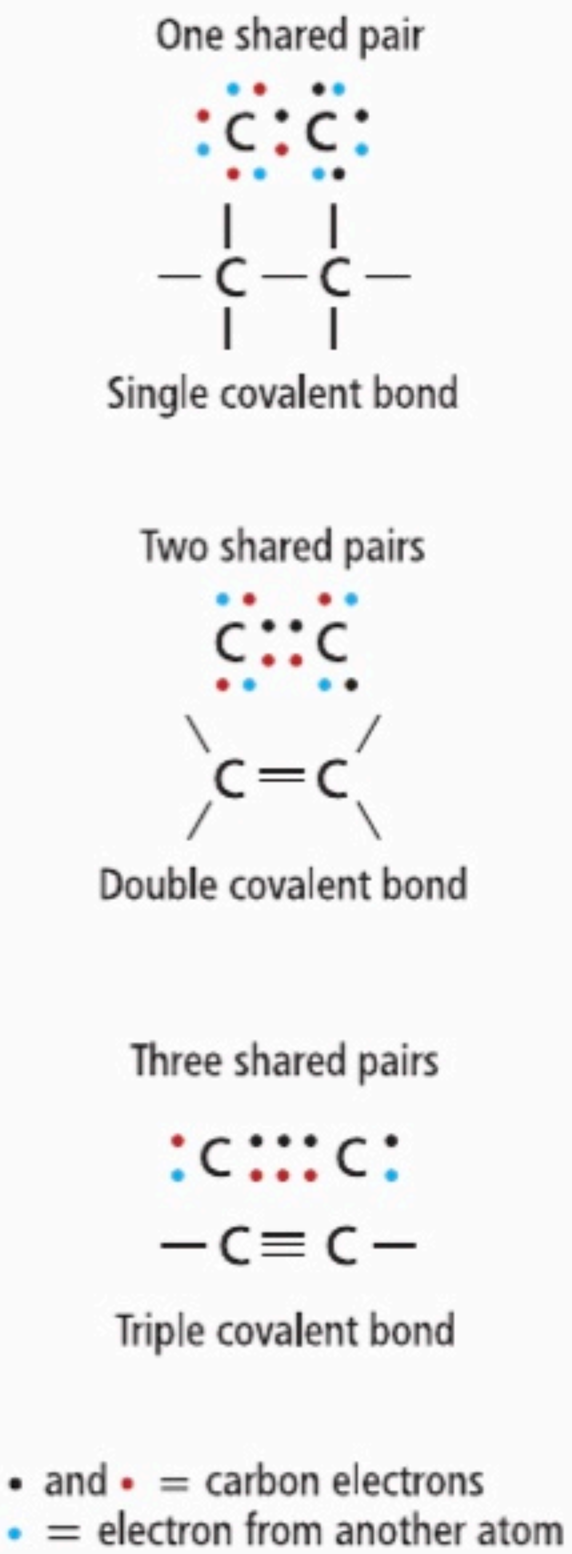


Figure 4 Chemists use four different models to represent a methane (CH_4) molecule. See the Reference Tables in the Student Resources for a key to atom color conventions.

Models and hydrocarbons Chemists represent organic molecules in a variety of ways. **Figure 4** shows four different ways to represent a methane molecule. Covalent bonds are represented by a single straight line, which denotes two shared electrons. Most often, chemists use the type of model that best shows the information they want to highlight. As shown in **Figure 4,** molecular formulas give no information about the geometry of the molecule. A structural formula shows the general arrangement of atoms in the molecule but not the exact, three-dimensional geometry. The ball-and-stick model demonstrates the geometry of the molecule clearly, but the space-filling model gives a more realistic picture of what a molecule would look like if you could see it. Keep in mind as you look at the models that the atoms are held closely together by electron-sharing bonds.

Figure 5 Carbon can bond to other carbon atoms in double and triple bonds. These Lewis structures and structural formulas show two ways to denote double and triple bonds.



Multiple carbon-carbon bonds Carbon atoms can bond to each other not only by single covalent bonds but also by double and triple covalent bonds, as shown in **Figure 5.** Recall that in a double bond, atoms share two pairs of electrons; in a triple bond, they share three pairs of electrons.

In the nineteenth century, before chemists understood bonding and the structure of organic substances, they experimented with hydrocarbons obtained from heating animal fats and plant oils. They classified these hydrocarbons according to a chemical test in which they mixed each hydrocarbon with bromine and then measured how much reacted with the hydrocarbon. Some hydrocarbons would react with a small amount of bromine, some would react with more, and some would not react with any amount of bromine. Chemists called the hydrocarbons that reacted with bromine unsaturated hydrocarbons in the same sense that an unsaturated aqueous solution can dissolve more solute. Hydrocarbons that did not react with bromine were said to be saturated.

Present-day chemists can now explain the experimental results obtained 170 years ago. Hydrocarbons that reacted with bromine had double or triple covalent bonds. Those compounds that did not react with bromine had only single covalent bonds. Today, a hydrocarbon having only single bonds is defined as a **saturated hydrocarbon.** A hydrocarbon that has at least one double or triple bond between carbon atoms is an **unsaturated hydrocarbon.** You will learn more about these different types of hydrocarbons later in this chapter.

READING CHECK **Explain** the origin of the terms *saturated* and *unsaturated hydrocarbons.*

Refining Hydrocarbons

Today, many hydrocarbons are obtained from a fossil fuel called petroleum. Petroleum formed from the remains of microorganisms that lived in Earth's oceans millions of years ago. Over time, the remains formed thick layers of mudlike deposits on the ocean floor. Heat from Earth's interior and the tremendous pressure of overlying sediments transformed this mud into oil-rich shale and natural gas. In certain kinds of geological formations, the petroleum ran out of the shale and collected in pools deep in Earth's crust. Natural gas, which formed at the same time and in the same way as petroleum, is usually found with petroleum deposits. Natural gas is composed primarily of methane, but it also contains small amounts of other hydrocarbons that have from two to five carbon atoms.

Fractional distillation Unlike natural gas, petroleum is a complex mixture containing more than a thousand different compounds. For this reason, raw petroleum, sometimes called crude oil, has little practical use. Petroleum is much more useful to humans when it is separated into simpler components or fractions. Separation is carried out in a process called **fractional distillation**, also called fractionation, which involves boiling the petroleum and collecting components or fractions as they condense at different temperatures. Fractional distillation is done in a fractionating tower similar to the one shown in **Figure 6.**

The temperature inside the fractionating tower is controlled so that it remains near 400°C at the bottom, where the petroleum is boiling, and gradually decreases toward the top. The condensation temperatures (boiling points) generally decrease as molecular mass decreases. Therefore, as the vapors travel up through the column, the hydrocarbons condense and are drawn off, as shown in **Figure 6.**

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Deposit

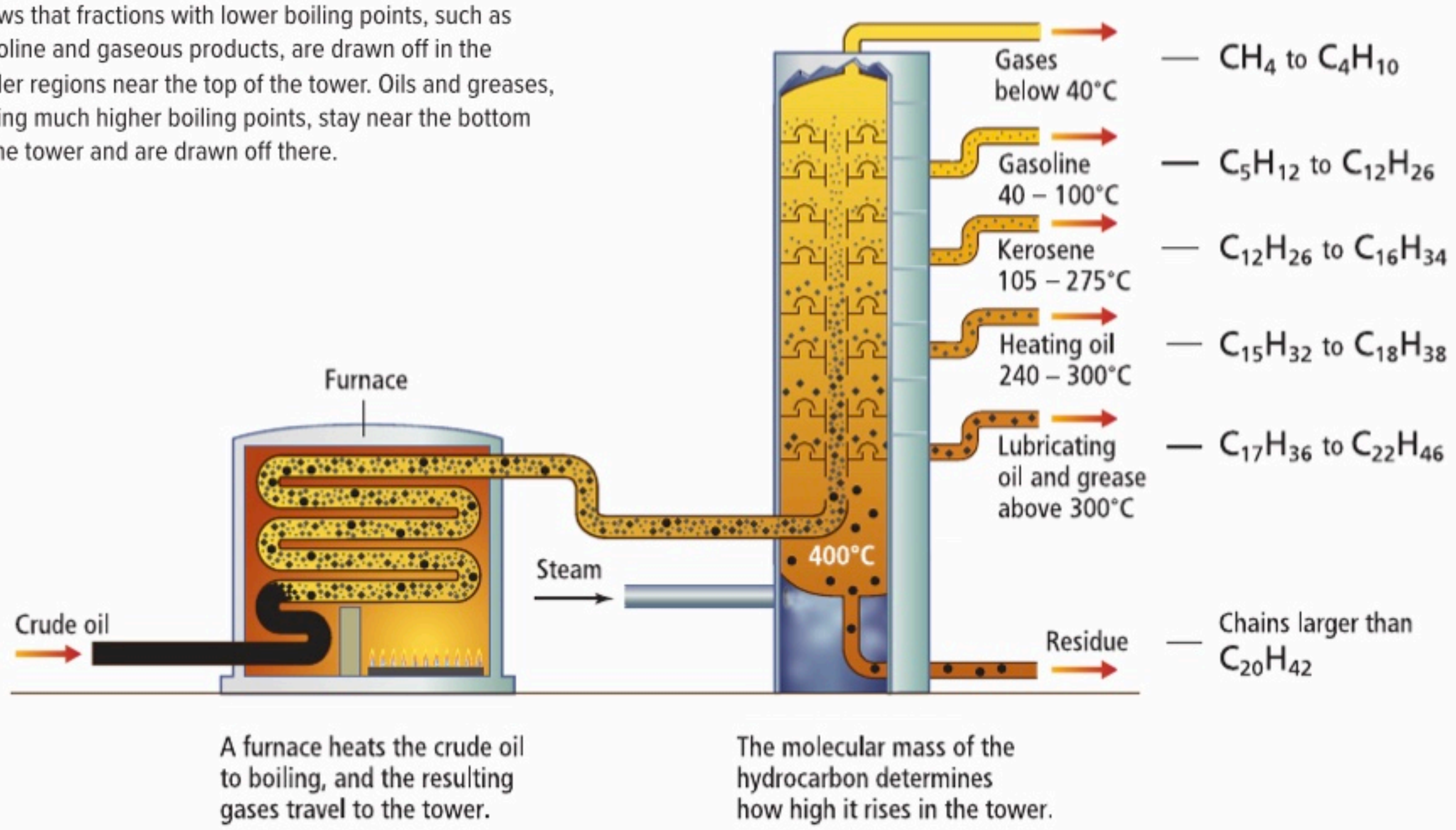
Science usage: a natural collection of oil or ore

There was a rich deposit of copper in the mountain.

Common usage: money placed in a bank account or the act of placing money in a bank account

The store owner placed his deposit in the after-hours slot at the bank.

Figure 6 This diagram of a fractionating tower shows that fractions with lower boiling points, such as gasoline and gaseous products, are drawn off in the cooler regions near the top of the tower. Oils and greases, having much higher boiling points, stay near the bottom of the tower and are drawn off there.



■ **Figure 7** Fractional distillation towers separate large quantities of petroleum into usable components. Thousands of products we use in our homes, for transportation, and in industry result from petroleum refining.

Infer ***What types of emissions must be controlled by refineries to protect the environment?***

Figure 6 also gives the names of the typical fractions separated from petroleum, along with their boiling points, hydrocarbon size ranges, and common uses. You might recognize some of the fractions because you use them every day. Unfortunately, fractional distillation towers, shown in **Figure 7,** do not yield fractions in the same proportions that they are needed. For example, distillation seldom yields the amount of gasoline desired. However, it yields more of the heavier oils than the market demands.

Many years ago, petroleum chemists and engineers developed a process to help match the supply with the demand. This process in which heavier fractions are converted to gasoline by breaking their large molecules into smaller molecules is called **cracking.** Cracking is done in the absence of oxygen and in the presence of a catalyst. In addition to breaking heavier hydrocarbons into molecules of the size range needed for gasoline, cracking also produces starting materials for the synthesis of many different products, including plastic products, films, and synthetic fabrics.

READING CHECK **Describe** the process in which large-chain hydrocarbons are broken into more-desirable smaller-chain hydrocarbons.

Rating gasoline None of the petroleum fractions is a pure substance. As shown in **Figure 6,** gasoline is not a pure substance, but rather a mixture of hydrocarbons. Most molecules with single covalent bonds in gasoline have 5 to 12 carbon atoms. However, the gasoline pumped into cars today is different from the gasoline used in automobiles in the early 1900s. The gasoline fraction that is distilled from petroleum is modified by adjusting its composition and adding substances to improve its performance in today's automobile engines and to reduce pollution from car exhaust.

It is critical that the gasoline-air mixture in the cylinder of an automobile engine ignite at exactly the right instant and burn evenly. If it ignites too early or too late, much energy will be wasted, fuel efficiency will drop, and the engine will wear out prematurely. Most straight-chain hydrocarbons burn unevenly and tend to ignite from heat and pressure before the piston is in the proper position and the spark plug fires. This early ignition causes a rattling or pinging noise called knocking.

CAREERS IN CHEMISTRY

Petroleum Technician This science technician uses instruments to measure and record physical and geological information about oil or gas wells. For example, a petroleum technician might test a geological sample to determine its petroleum content and its mineral or element composition.

■ **Figure 8** Octane ratings are used to give the antiknock rating of fuel. Mid-grade gasoline for cars has an octane rating of about 89. Aviation fuel has an octane rating of about 100. Racing fuel has an octane rating of about 110.

In the late 1920s, an antiknock, or octane rating, system for gasoline was established, resulting in the octane ratings posted on gasoline pumps like those shown in **Figure 8.** Mid-grade gasoline today has a rating of about 89, whereas premium gasoline has ratings of 91 or higher. Several factors determine which octane rating a car needs, including how much the piston compresses the air-fuel mixture and the altitude at which the car is driven.

Connection to Earth Science Since ancient times, people have found petroleum seeping from cracks in rocks. Historical records show that petroleum has been used for more than 5000 years. In the nineteenth century, as the United States entered the machine age and its population increased, the demand for petroleum products, namely kerosene for lighting and lubricants for machines, increased. In an attempt to find a reliable petroleum supply, Edwin Drake drilled the first oil well in the United States in Pennsylvania, in 1859. The oil industry flourished for a time, but when Thomas Edison introduced the electric light in 1882, investors feared that the industry was doomed. However, the invention of the automobile in the 1890s revived the industry on a massive scale.

SECTION 1 REVIEW

Section Summary

- Organic compounds contain carbon, which is able to form straight chains and branched chains.
- Hydrocarbons are organic substances composed of carbon and hydrogen.
- The major sources of hydrocarbons are petroleum and natural gas.
- Petroleum can be separated into components by the process of fractional distillation.

1. MAINIDEA **Identify** three applications of hydrocarbons as a source of energy and raw materials.
2. **Name** an organic compound and explain what an organic chemist studies.
3. **Identify** what each of the four molecular models highlights about a molecule.
4. **Compare and contrast** saturated and unsaturated hydrocarbons.
5. **Describe** the process of fractional distillation.
6. **Infer** Some shortening products are described as “hydrogenated vegetable oil,” which are oils that reacted with hydrogen in the presence of a catalyst. Form a hypothesis to explain why hydrogen reacted with the oils.
7. **Interpret Data** Refer to **Figure 6.** What property of hydrocarbon molecules correlates to the viscosity of a particular fraction when it is cooled to room temperature?

SECTION 2 Alkanes

MAINIDEA **Alkanes are hydrocarbons that contain only single bonds.**

Essential Questions

- How are alkanes named when given their structures?
- How are alkane structures drawn when given their names?
- What are the properties of alkanes?

Review Vocabulary

IUPAC (International Union of Pure and Applied Chemistry): an international group that aids communication between chemists by setting rules and standards in areas such as chemical nomenclature, terminology, and standardized methods

New Vocabulary

alkane
homologous series
parent chain
substituent group
cyclic hydrocarbon
cycloalkane

CHEM 4 YOU **Have you ever used a Bunsen burner or an outdoor gas grill? If so, you have used an alkane. Natural gas and propane are the two most common gases used in these applications, and both are alkanes.**

Straight-Chain Alkanes

Methane is the smallest member of a series of hydrocarbons known as alkanes. It is used as a fuel in homes and science labs and is a product of many biological processes. **Alkanes** are hydrocarbons that have only single bonds between atoms. Look in Section 1 to review the various models of methane. The models for ethane (C_2H_6), the second member of the alkane series, are shown in **Table 1.** Ethane consists of two carbon atoms bonded together with a single bond and six hydrogen atoms sharing the remaining valence electrons of the carbon atoms.

The third member of the alkane series, propane, has three carbon atoms and eight hydrogen atoms, giving it the molecular formula C_3H_8. The next member, butane, has four carbon atoms and the formula C_4H_{10}. Compare the structures of ethane, propane, and butane in **Table 1.**

Propane, also known as LP (liquefied propane) gas, is sold as a fuel for cooking and heating. Butane is used as fuel in small lighters and in some torches. It is also used in the manufacture of synthetic rubber.

Table 1 Simple Alkanes

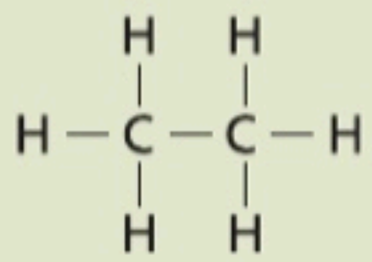
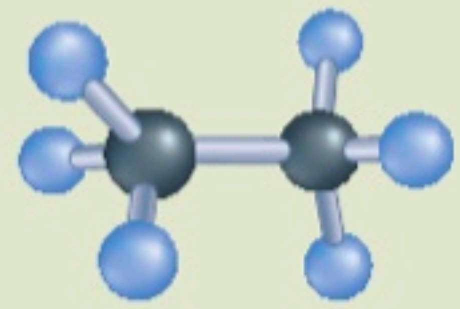
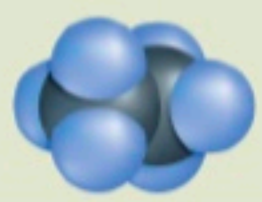
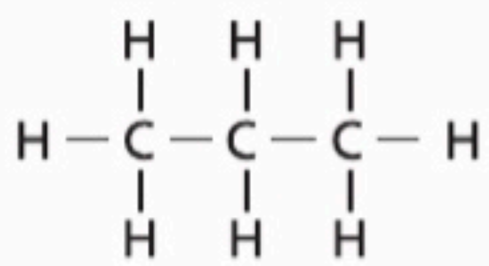
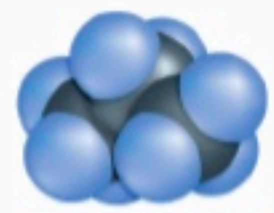
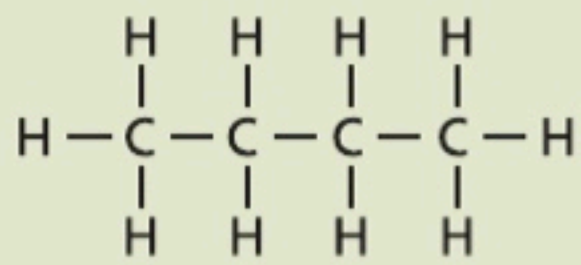
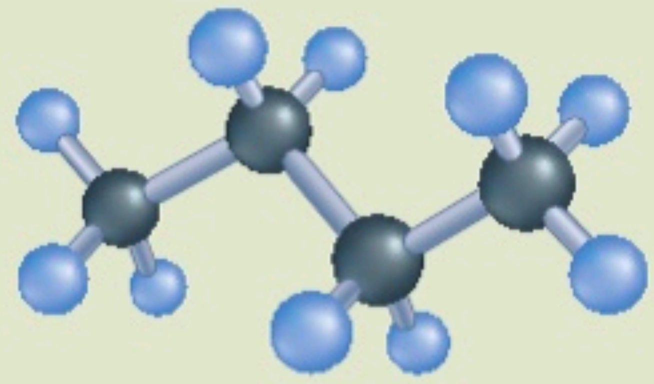
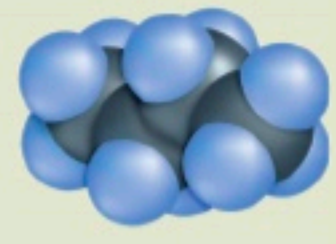
Molecular Formula	Structural Formula	Ball-and-Stick Model	Space-Filling Model
Ethane (C_2H_6)			
Propane (C_3H_8)			
Butane (C_4H_{10})			

Table 2 First Ten of the Alkane Series

Name	Molecular Formula	Condensed Structural Formula
Methane	CH_4	CH_4
Ethane	C_2H_6	CH_3CH_3
Propane	C_3H_8	$CH_3CH_2CH_3$
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$
Heptane	C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
Octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$
Nonane	C_9H_{20}	$CH_3(CH_2)_7CH_3$
Decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$

Naming straight-chain alkanes By now, you have likely noticed that names of alkanes end in *-ane.* Also, alkanes with five or more carbons in a chain have names that use a prefix derived from the Greek or Latin word for the number of carbons in each chain. For example, *pent*ane has five carbons just as a *pent*agon has five sides, and *oct*ane has eight carbons just as an *oct*opus has eight tentacles. Because methane, ethane, propane, and butane were named before alkane structures were known, their names do not have numerical prefixes. **Table 2** shows the names and structures of the first ten alkanes. Notice the underlined prefix representing the number of carbon atoms in the molecule.

In **Table 2,** you can see that the structural formulas are written in a different way from those in **Table 1.** These formulas, called condensed structural formulas, save space by not showing how the hydrogen atoms branch off from the carbon atoms. Condensed formulas can be written in several ways. In **Table 2,** the lines between carbon atoms have been eliminated to save space.

In **Table 2,** you can see that $–CH_2–$ is a repeating unit in the chain of carbon atoms. Note, for example, that pentane has one more $–CH_2–$ unit than butane. You can further condense structural formulas by writing the $–CH_2–$ unit in parentheses followed by a subscript to show the number of units, as is done with octane, nonane, and decane.

A series of compounds that differ from one another by a repeating unit is called a **homologous series.** A homologous series has a fixed numerical relationship among the numbers of atoms. For alkanes, the relationship between the numbers of carbon and hydrogen atoms can be expressed as C_nH_{2n+2}, where n is equal to the number of carbon atoms in the alkane. Given the number of carbon atoms in an alkane, you can write the molecular formula for any alkane. For example, heptane has seven carbon atoms, so its formula is $C_7H_{2(7)+2}$, or C_7H_{16}.

VOCABULARY
WORD ORIGIN
Homologous
comes from the Greek word *homologos* meaning *agreeing*

READING CHECK **Write** the molecular formula for an alkane that has 13 carbon atoms in its molecular structure.

Branched-Chain Alkanes

The alkanes discussed so far in this chapter are called straight-chain alkanes because the carbon atoms are bonded to each other in a single line. Now look at the two structures in **Figure 9.** If you count the carbon and hydrogen atoms, you will discover that both structures have the same molecular formula, C_4H_{10}. Do the structures in **Figure 9** represent the same substance?

If you think that the structures represent two different substances, you are correct. The structure on the left represents butane, and the structure on the right represents a branched-chain alkane known as isobutane–a substance whose chemical and physical properties are different from those of butane. Carbon atoms can bond to one, two, three, or even four other carbon atoms. This property makes possible a variety of branched-chain alkanes.

Recall that butane is used in lighters and in torches. Isobutane is used as both an environmentally-safe refrigerant and a propellant in products such as shaving gel, as shown in **Figure 9.** In addition to these applications, both butane and isobutane are used as raw materials for many chemical processes.

READING CHECK **Describe** the difference in the molecular structures of butane and isobutane.

Alkyl groups You have seen that both a straight-chain and a branched-chain alkane can have the same molecular formula. This fact illustrates a basic principle of organic chemistry: the order and arrangement of atoms in an organic molecule determine its identity. Therefore, the name of an organic compound must also accurately describe the molecular structure of the compound.

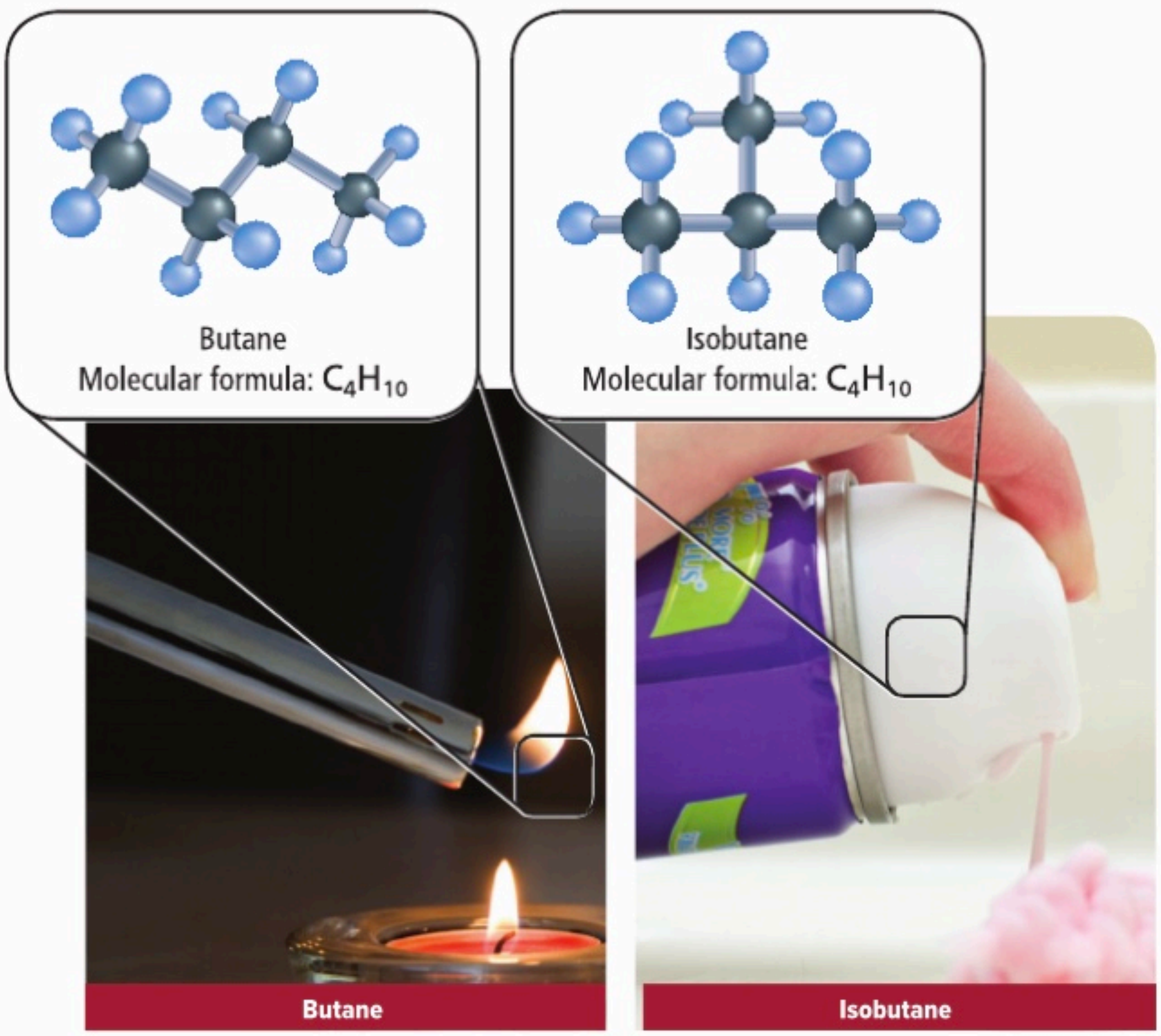
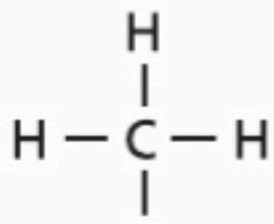
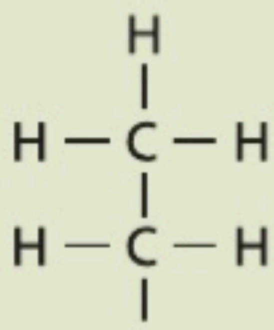
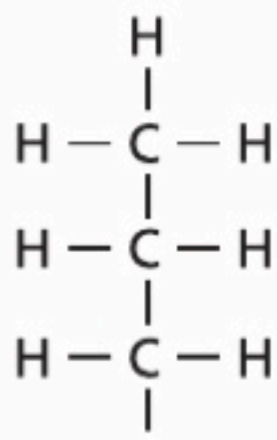
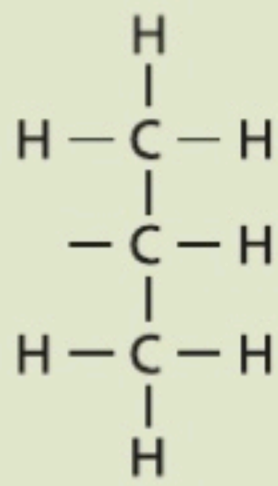
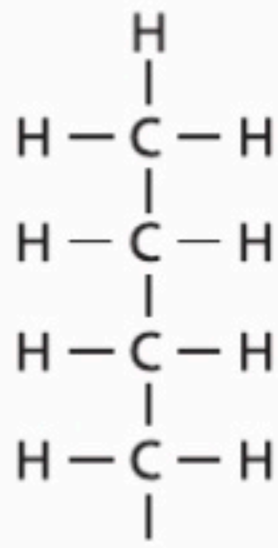


Figure 9 Butane is a fuel used in lighters. Isobutane is used as a propellant in products such as shaving gel.

Table 3 Common Alkyl Groups

Name	Methyl	Ethyl	Propyl	Isopropyl	Butyl
Condensed structural formula	CH_3—	CH_3CH_2—	$CH_3CH_2CH_2$—	$CH_3\underset{\vert}{C}HCH_3$	$CH_3CH_2CH_2CH_2$—
Structural formula					

When naming branched-chain alkanes, the longest continuous chain of carbon atoms is called the **parent chain**. All side branches are called **substituent groups** because they appear to substitute for a hydrogen atom in the straight chain. Each alkane-based substituent group branching from the parent chain is named for the straight-chain alkane that has the same number of carbon atoms as the substituent. The ending *-ane* is replaced with the letters *-yl*. An alkane-based substituent group is called an alkyl group. Several alkyl groups are shown in **Table 3.**

VOCABULARY

ACADEMIC VOCABULARY

Substitute
a person or thing that takes the place of another
A substitute teacher taught chemistry class yesterday.

Naming branched-chain alkanes To name organic structures, chemists use the following systematic rules approved by the International Union of Pure and Applied Chemistry (IUPAC).

Step 1. *Count the number of carbon atoms in the longest continuous chain.* Use the name of the straight-chain alkane with that number of carbons as the name of the parent chain of the structure.

Step 2. *Number each carbon in the parent chain.* Locate the end carbon closest to a substituent group. Label that carbon *Position 1.* This step gives all the substituent groups the lowest position numbers possible.

Step 3. *Name each alkyl group substituent.* Place the name of the group before the name of the parent chain.

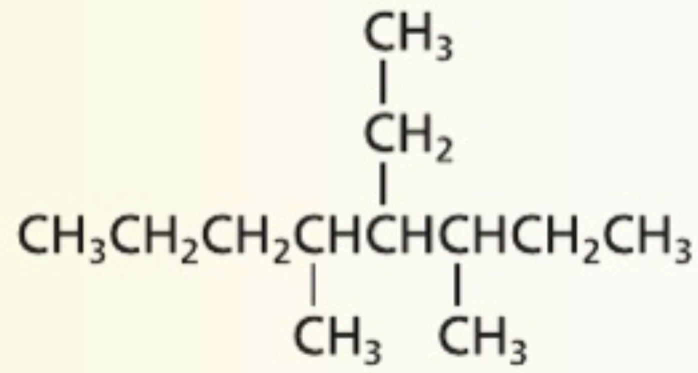
Step 4. *If the same alkyl group occurs more than once as a branch on the parent structure, use a prefix* (di-, tri-, tetra-, *and so on*) *before its name to indicate how many times it appears.* Then, use the number of the carbon to which each is attached to indicate its position.

Step 5. *When different alkyl groups are attached to the same parent structure, place their names in alphabetical order.* Do not consider the prefixes (*di-*, *tri-*, and so on) when determining alphabetical order.

Step 6. *Write the entire name, using hyphens to separate numbers from words and commas to separate numbers.* Do not add a space between the substituent name and the name of the parent chain.

EXAMPLE 1

NAMING BRANCHED-CHAIN ALKANES
Name the alkane shown.



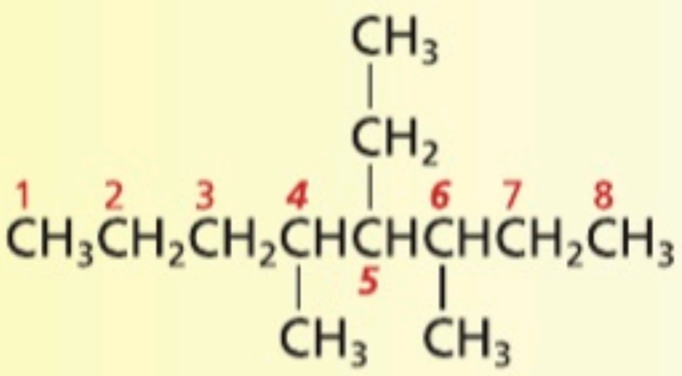
1 ANALYZE THE PROBLEM

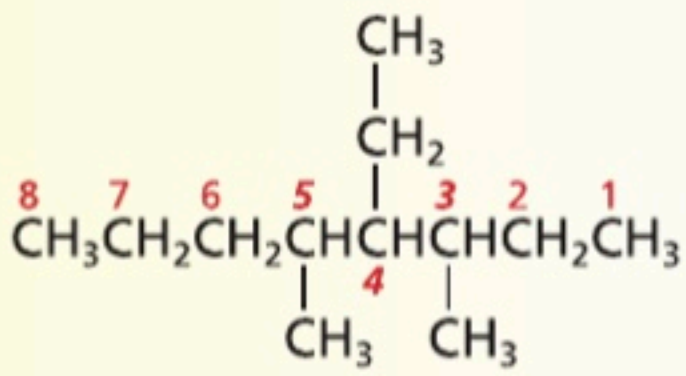
You are given a structure. To determine the name of the parent chain and the names and locations of branches, follow the IUPAC rules.

2 SOLVE FOR THE UNKNOWN

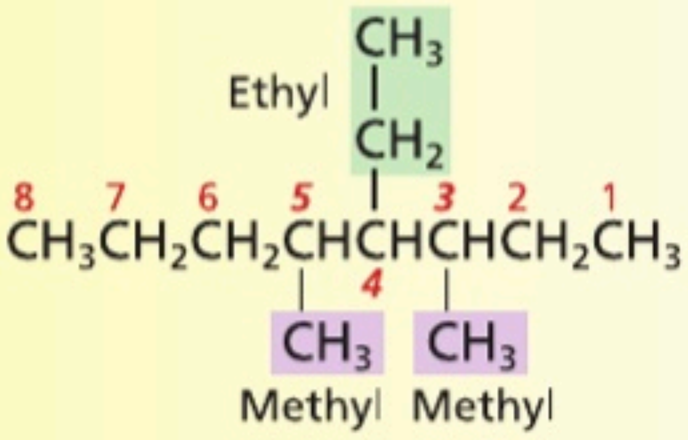
Step 1. *Count the number of carbon atoms in the longest continuous chain.* Because structural formulas can be written with chains oriented in various ways, you need to be careful in finding the longest continuous carbon chain. In this case, it is easy. The longest chain has eight carbon atoms, so the parent name is *octane.*

Step 2. *Number each carbon in the parent chain.* Number the chain in both directions, as shown below. Numbering from the left puts the alkyl groups at Positions 4, 5, and 6. Numbering from the right puts alkyl groups at Positions 3, 4, and 5. Because 3, 4, and 5 are the lowest position numbers, they will be used in the name.

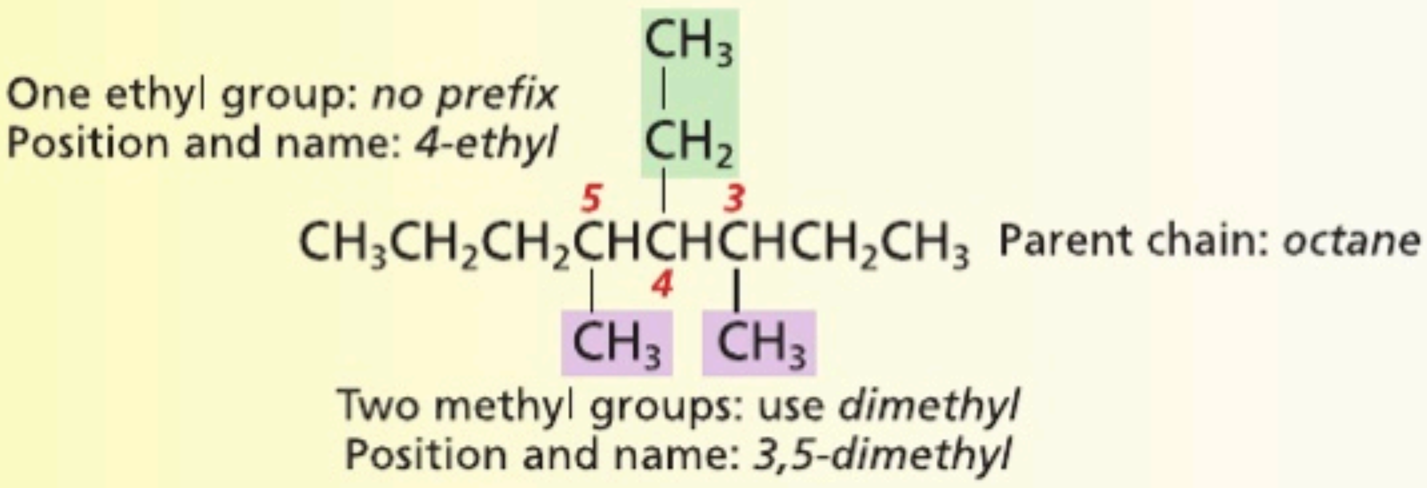




Step 3. *Name each alkyl group substituent.* Identify and name the alkyl groups branching from the parent chain. There are one-carbon methyl groups at Positions 3 and 5, and a two-carbon ethyl group at Position 4.



Step 4. *If the same alkyl group occurs more than once as a branch on the parent structure, use a prefix* (di-, tri-, tetra-, *and so on) before its name to indicate how many times it appears.* Look for and count the alkyl groups that occur more than once. Determine the prefix to use to show the number of times each group appears. In this example, the prefix *di-* will be added to the name *methyl* because two methyl groups are present. No prefix is needed for the one ethyl group. Then show the position of each group with the appropriate number.



Step 5. *Whenever different alkyl groups are attached to the same parent structure, place their names in alphabetical order.* Place the names of the alkyl branches in alphabetical order, ignoring the prefixes. Alphabetical order puts the name ethyl before dimethyl.

Step 6. *Write the entire name, using hyphens to separate numbers from words and commas to separate numbers.* Write the name of the structure, using hyphens and commas as needed. The name should be written as *4-ethyl-3,5-dimethyloctane.*

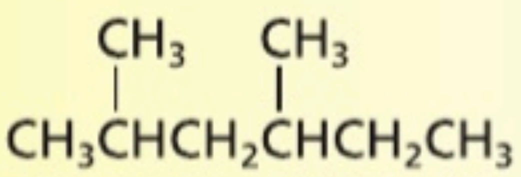
3 EVALUATE THE ANSWER

The longest continuous carbon chain has been found and numbered correctly. All branches have been designated with correct prefixes and alkyl group names. Alphabetical order and punctuation are correct.

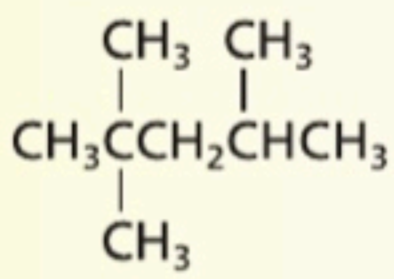
APPLICATIONS

8. Use the IUPAC rules to name the following structures.

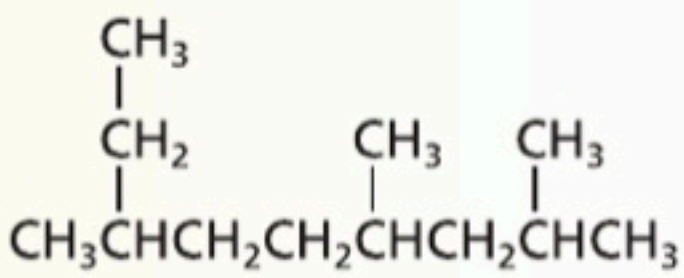
a.



b.



c.



9. Challenge Draw the structures of the following branched-chain alkanes.

a. 2,3-dimethyl-5-propyldecane

b. 3,4,5-triethyloctane

Cycloalkanes

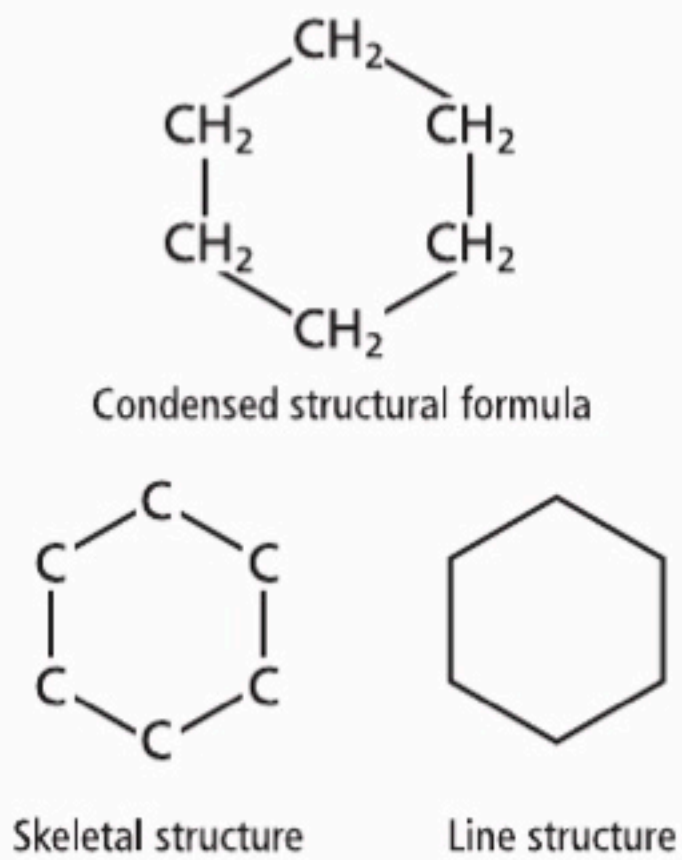
One of the reasons that such a variety of organic compounds exists is that carbon atoms can form ring structures. An organic compound that contains a hydrocarbon ring is called a **cyclic hydrocarbon.** To indicate that a hydrocarbon has a ring structure, the prefix *cyclo-* is used with the hydrocarbon name. Thus, cyclic hydrocarbons that contain only single bonds are called **cycloalkanes.**

Cycloalkanes can have rings with three, four, five, six, or even more carbon atoms. The name for the six-carbon cycloalkane is *cyclohexane.* Cyclohexane, which is obtained from petroleum, is used in paint and varnish removers and for extracting essential oils to make perfume. Note that cyclohexane (C_6H_{12}) has two fewer hydrogen atoms than straight-chain hexane (C_6H_{14}) because a valence electron from each of two carbon atoms is now forming a carbon-carbon bond rather than a carbon-hydrogen bond.

READING CHECK Evaluate If the prefix *cyclo-* is present in the name of an alkane, what do you know about the alkane?

As shown in **Figure 10,** cyclic hydrocarbons such as cyclohexane are represented by condensed, skeletal, and line structures. Line structures show only the carbon-carbon bonds with carbon atoms understood to be at each vertex of the structure. Hydrogen atoms are assumed to occupy the remaining bonding positions unless substituents are present. Hydrogens are also not shown in skeletal structures.

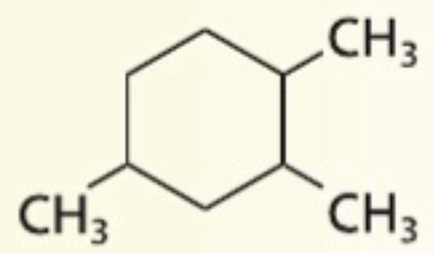
Figure 10 Cyclohexane can be represented in several ways.



Naming substituted cycloalkanes Like other alkanes, cycloalkanes can have substituent groups. Substituted cycloalkanes are named by following the same IUPAC rules used for straight-chain alkanes, but with a few modifications. With cycloalkanes, there is no need to find the longest chain because the ring is always considered to be the parent chain. Because a cyclic structure has no ends, numbering is started on the carbon that is bonded to the substituent group. When there are two or more substituents, the carbons are numbered around the ring in a way that gives the lowest-possible set of numbers for the substituents. If only one group is attached to the ring, no number is necessary. The following Example Problem illustrates the naming process for cycloalkanes.

EXAMPLE 2

NAMING CYCLOALKANES
Name the cycloalkane shown.



1 ANALYZE THE PROBLEM

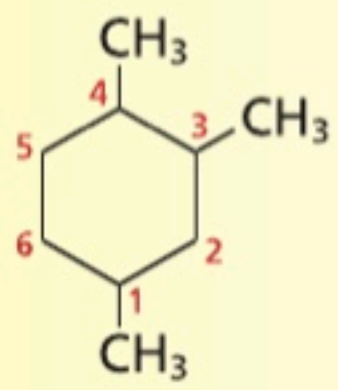
You are given a structure. To determine the parent cyclic structure and the location of branches, follow the IUPAC rules.

2 SOLVE FOR THE UNKNOWN

Step 1. Count the carbons in the ring, and use the name of the parent cyclic hydrocarbon. In this case, the ring has six carbons, so the parent name is *cyclohexane.*

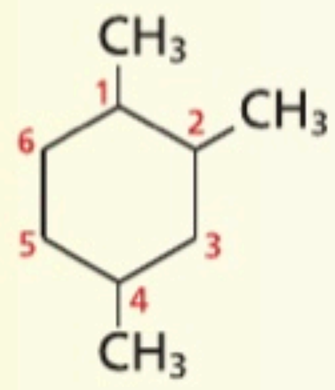
Step 2. Number the ring, starting from one of the CH_3— branches. Find the numbering that gives the lowest possible set of numbers for the branches. Here are two ways of numbering the ring.

A



1,3,4

B



1,2,4

Numbering from the carbon atom at the bottom of the ring puts the CH_3— groups at Positions 1, 3, and 4 in Structure A. Numbering from the carbon at the top of the ring gives Positions 1, 2, and 4. All other numbering schemes place the CH_3— groups at higher position numbers. Thus, 1, 2, and 4 are the lowest possible position numbers and will be used in the name.

Step 3. Name the substituents. All three are the same—carbon methyl groups.

Step 4. Add the prefix to show the number of groups present. Three methyl groups are present, so you add the prefix *tri-* to the name *methyl* to make *trimethyl.*

Step 5. Alphabetical order can be ignored because only one type of group is present.

Step 6. Put the name together using the name of the parent cycloalkane. Use commas between separate numbers, and hyphens between numbers and words. Write the name as *1,2,4-trimethylcyclohexane.*

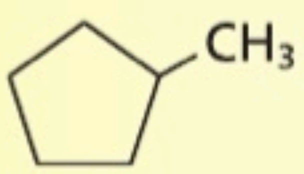
3 EVALUATE THE ANSWER

The parent-ring structure is numbered to give the branches the lowest possible set of numbers. The prefix *tri-* indicates that three methyl groups are present. No alphabetization is necessary because all branches are methyl groups.

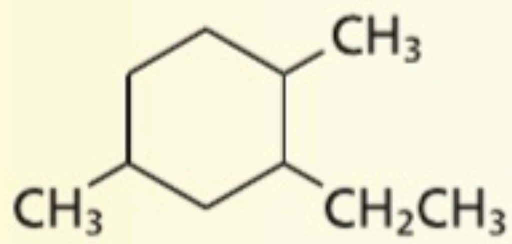
APPLICATIONS

10. Use IUPAC rules to name the following structures.

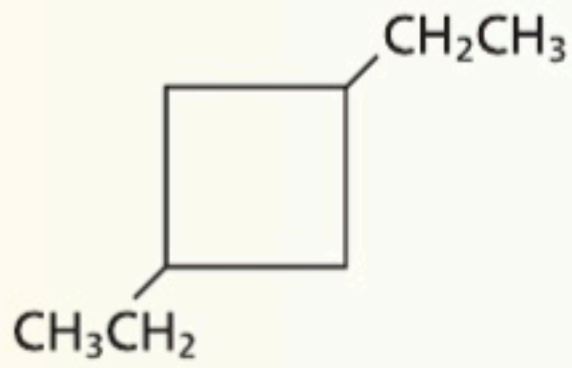
a.



b.



c.



11. Challenge Draw the structures of the following cycloalkanes.

a. 1-ethyl-3-propylcyclopentane

b. 1,2,2,4-tetramethylcyclohexane

Properties of Alkanes

You have learned that the structure of a molecule affects its properties. For example, the O–H bonds in a water molecule are polar, and because the H–O–H molecule has a bent geometry, the molecule itself is polar. Thus, water molecules can form hydrogen bonds with each other. As a result, the boiling and melting points of water are much higher than those of other substances having similar molecular mass and size.

What properties would you predict for alkanes? All of the bonds in alkanes are between either a carbon atom and a hydrogen atom or between two carbon atoms. A bond between two identical atoms, such as carbon, can never be polar. Also, the C–H bonds have only a small electronegativity difference and are nonpolar. Because all of the bonds in alkanes are nonpolar, alkane molecules are nonpolar, which makes them good solvents for other nonpolar substances, as shown in **Figure 11.**

Figure 11 Many solvents—used as thinners for paints, coatings, waxes, photocopier toners, adhesives, and printer press inks—contain alkanes and cycloalkanes.

Table 4 Comparing Physical Properties		
Substance and formula	**Water (H_2O)**	**Methane (CH_4)**
Molecular mass	18 amu	16 amu
State at room temperature	liquid	gas
Boiling point	100°C	−162°C
Melting point	0°C	−182°C

Physical properties of alkanes How do the properties of a polar and nonpolar compound compare? Refer to **Table 4,** and note that the molecular mass of methane (16 amu) is close to the molecular mass of water (18 amu). Also, water and methane molecules are similar in size. However, when you compare the melting and boiling points of methane to those of water, you can see evidence that the molecules differ in some significant way. These temperatures differ greatly because methane molecules have little intermolecular attraction compared to water molecules. This difference in attraction can be explained by the fact that methane molecules are nonpolar and do not form hydrogen bonds with each other, whereas water molecules are polar and freely form hydrogen bonds.

The difference in polarity and hydrogen bonding also explains the immiscibility of alkanes and other hydrocarbons with water. If you try to dissolve alkanes, such as lubricating oils, in water, the two liquids separate almost immediately into two phases. This separation happens because the attractive forces between alkane molecules are stronger than the attractive forces between the alkane and water molecules. Therefore, alkanes are more soluble in solvents composed of nonpolar molecules like themselves than in water, a polar solvent.

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Chemical properties of alkanes The main chemical property of alkanes is their low reactivity. Recall that many chemical reactions occur when a reactant with a full electric charge, such as an ion, or with a partial charge, such as a polar molecule, is attracted to another reactant with the opposite charge. Molecules such as alkanes, in which atoms are connected by nonpolar bonds, have no charge. As a result, they have little attraction for ions or polar molecules. The low reactivity of alkanes can also be attributed to the relatively strong C–C and C–H bonds.

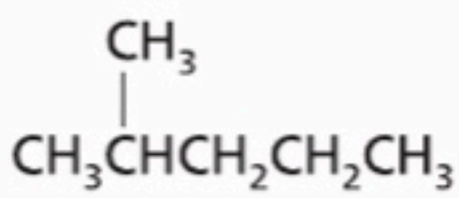
SECTION 2 REVIEW

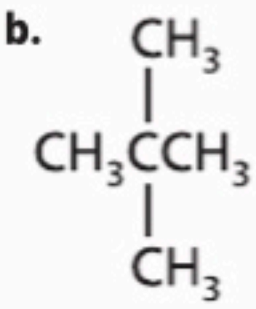
Section Summary

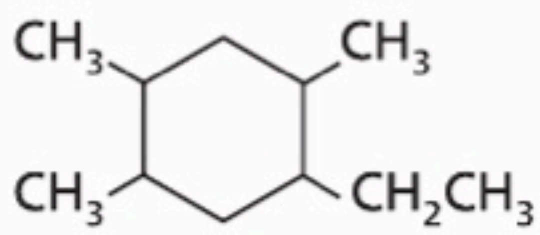
- Alkanes contain only single bonds between carbon atoms.
- Alkanes and other organic compounds are best represented by structural formulas and can be named using systematic rules determined by the International Union of Pure and Applied Chemistry (IUPAC).
- Alkanes that contain hydrocarbon rings are called cyclic alkanes.

12. MAIN Idea **Describe** the main structural characteristics of alkane molecules.

13. **Name** the following structures using IUPAC rules.

a.


b.


c.


14. **Describe** the general properties of alkanes.

15. **Draw** the molecular structure for each of the following.
   a. 3,4-diethylheptane
   b. 4-isopropyl-3-methyldecane
   c. 1-ethyl-4-methylcyclohexane
   d. 1,2-dimethylcyclopropane

16. **Interpret Chemical Structures** Why is the name 3-butylpentane incorrect? Based on this name, write the structural formula for the compound. What is the correct IUPAC name for 3-butylpentane?

SECTION 3

Alkenes and Alkynes

MAINIDEA **Alkenes are hydrocarbons that contain at least one double bond, and alkynes are hydrocarbons that contain at least one triple bond.**

Essential Questions

- How do the properties of alkenes and alkynes compare with those of alkanes?
- How are the molecular structures of alkenes and alkynes described?
- How are alkenes and alkynes named when given their structures?
- How are alkenes and alkynes drawn when given their names?

Review Vocabulary

hormone: chemical produced in one part of an organism and transported to another part, where it causes a physiological change

New Vocabulary

alkene
alkyne

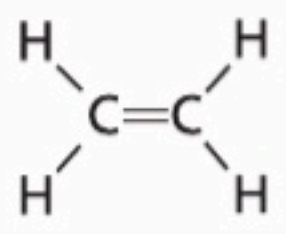
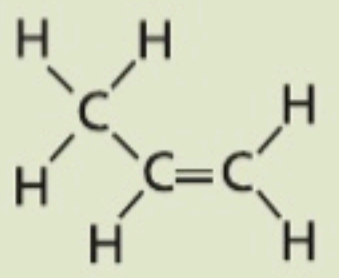
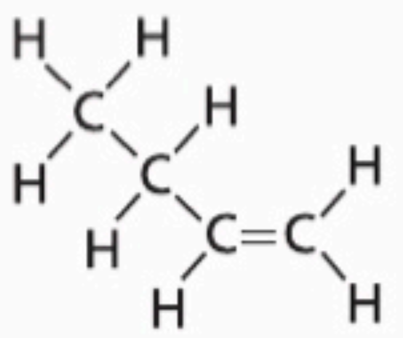
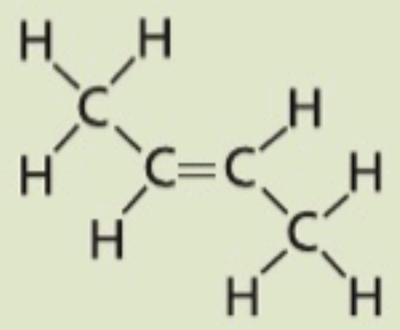
CHEM 4 YOU **Plants produce ethene as a natural ripening hormone. For efficiency in harvesting and transporting produce to market, fruits and vegetables are often picked while unripe and are exposed to ethene so they will ripen at the same time.**

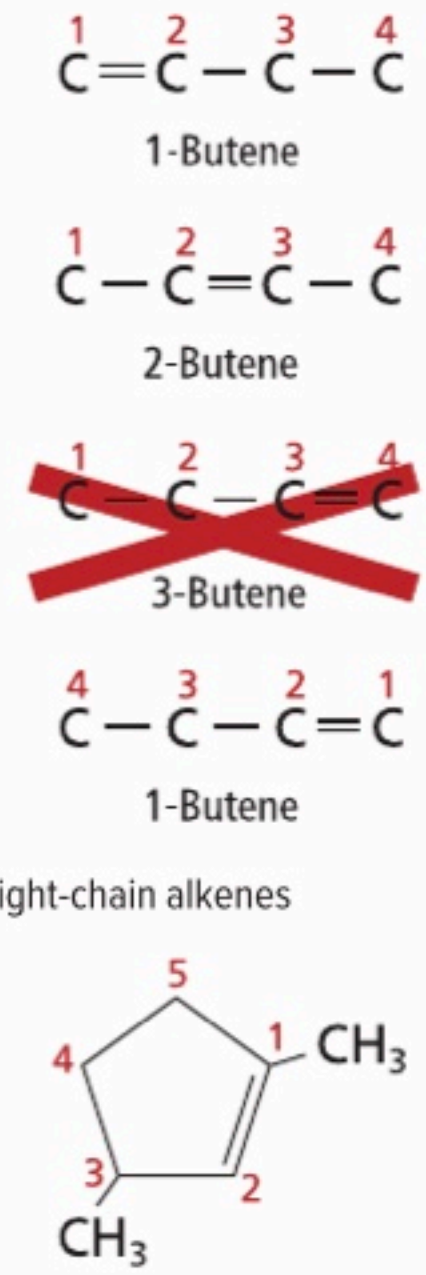
Alkenes

Recall that alkanes are saturated hydrocarbons because they contain only single covalent bonds between carbon atoms, and that unsaturated hydrocarbons have at least one double or triple bond between carbon atoms. Unsaturated hydrocarbons that contain one or more double covalent bonds between carbon atoms in a chain are called **alkenes.** Because an alkene must have a double bond between carbon atoms, there is no 1-carbon alkene. The simplest alkene has two carbon atoms double bonded to each other. The remaining four electrons—two from each carbon atom—are shared with four hydrogen atoms to give the molecule ethene (C_2H_4).

Alkenes with only one double bond constitute a homologous series. Recall from the previous section that a homologous series has a fixed numerical relationship among the numbers of atoms. If you study the molecular formulas for the substances shown in **Table 5,** you will see that each has twice as many hydrogen atoms as carbon atoms. The general formula for the series is C_nH_{2n}. Each alkene has two fewer hydrogen atoms than the corresponding alkane because two electrons now form the second covalent bond and are no longer available for bonding to hydrogen atoms. What are the molecular formulas for 6-carbon and 9-carbon alkenes?

Table 5 Examples of Alkenes

Name	Ethene	Propene	1-Butene	2-Butene
Molecular formula	C_2H_4	C_3H_6	C_4H_8	C_4H_8
Structural formula				
Condensed structural formula	$CH_2{=}CH_2$	$CH_3CH{=}CH_2$	$CH_3CH_2CH{=}CH_2$	$CH_3CH{=}CHCH_3$



a. Straight-chain alkenes

b. Cyclic alkenes

■ **Figure 12** When naming either branched or straight-chain alkenes, they must be numbered using IUPAC rules.

Naming alkenes Alkenes are named in much the same way as alkanes. Their names are formed by changing the *-ane* ending of the corresponding alkane to *-ene*. An alkane with two carbons is named et*hane*, and an alkene with two carbons is named et*hene*. Likewise, a three-carbon alkene is named propene. Ethene and propene have older, more common names: *ethylene* and *propylene*, respectively.

To name alkenes with four or more carbons in the chain, it is necessary to specify the location of the double bond, as shown in **Figure 12a.** This is done by numbering the carbons in the parent chain, starting at the end of the chain that will give the first carbon in the double bond the lowest number. Then, use only that number in the name.

Note that the third structure is not "3-butene" because it is identical to the first structure, 1-butene. It is important to recognize that 1-butene and 2-butene are two different substances, each with its own properties.

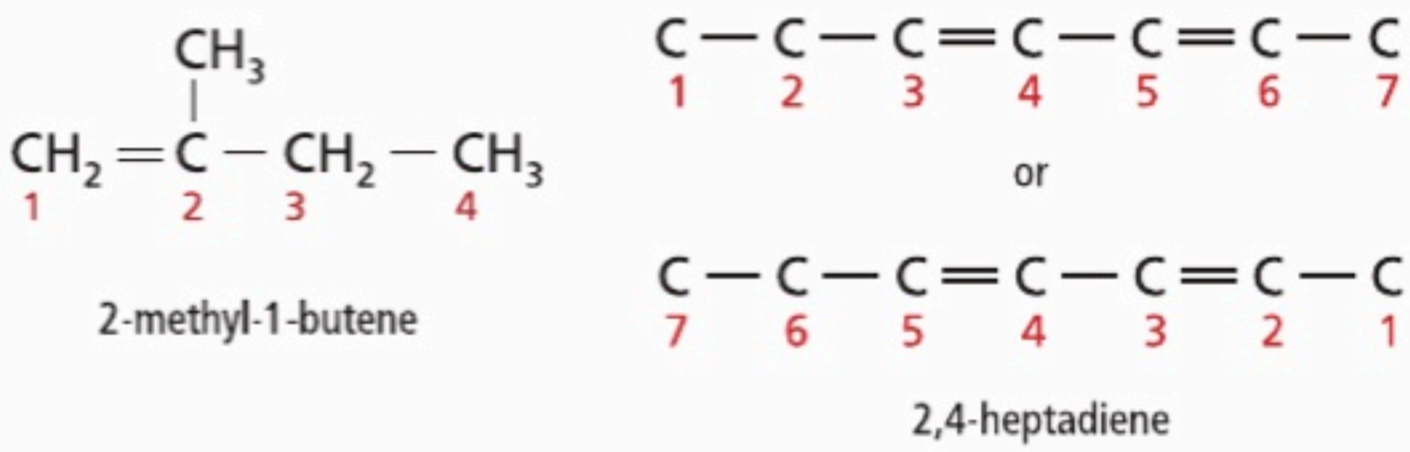
Cyclic alkenes are named in much the same way as cyclic alkanes; however, carbon number 1 must be one of the carbons connected by the double bond. In **Figure 12b,** note the numbering in the compound. The name of this compound is 1,3-dimethylcyclopentene.

☑ **READING CHECK** **Infer** why it is necessary to identify where the double bond is located in the name of an alkene.

Naming branched-chain alkenes When naming branched-chain alkenes, follow the IUPAC rules for naming branched-chain alkanes, but with two exceptions. First, in alkenes, the parent chain is always the longest chain that contains the double bond, whether or not it is the longest chain of carbon atoms. Second, the position of the double bond, not the branches, determines how the chain is numbered. A number specifies the location of the double bond, just as it does in straight-chain alkenes. Note that there are two 4-carbon chains in the molecule shown in **Figure 13a,** but only the one with the double bond is used as a basis for naming. This branched-chain alkene is 2-methyl-1-butene.

Some unsaturated hydrocarbons contain more than one double (or triple) bond. The number of double bonds in such molecules is shown by using a prefix (*di-*, *tri-*, *tetra-*, and so on) before the suffix *-ene*. The positions of the bonds are numbered in a way that gives the lowest set of numbers. Which numbering system would you use in the example in **Figure 13b?** Because the molecule has a seven-carbon chain, you would use the prefix *hepta-*. Because it has two double bonds, you would use the prefix *di-* before *-ene*, giving the name *heptadiene*. Adding the numbers 2 and 4 to designate the positions of the double bonds gives the name *2,4-heptadiene*.

■ **Figure 13** The positions of the double bonds in alkenes are numbered in a way that gives the lowest set of numbers. This is true of both branched and straight-chain alkenes.

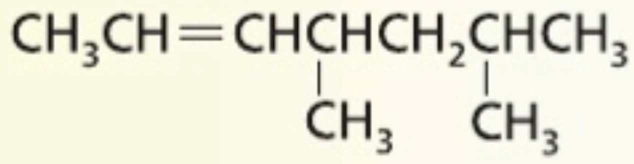


a. Single double bond

b. Two double bonds

EXAMPLE 3

NAMING BRANCHED-CHAIN ALKENES Name the alkene shown.

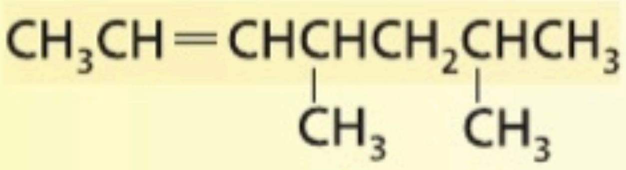


1 ANALYZE THE PROBLEM

You are given a branched-chain alkene that contains one double bond and two alkyl groups. Follow the IUPAC rules to name the organic compound.

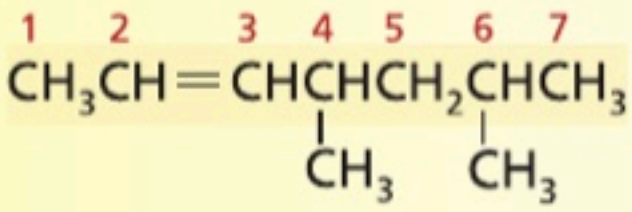
2 SOLVE FOR THE UNKNOWN

Step 1. The longest continuous-carbon chain that includes the double bond contains seven carbons. The 7-carbon alkane is heptane, but the name is changed to heptene because a double bond is present.



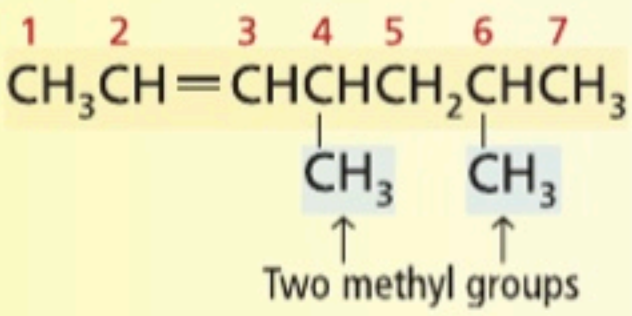
***Heptene* parent chain**

Step 2. Number the chain to give the lowest number to the double bond.



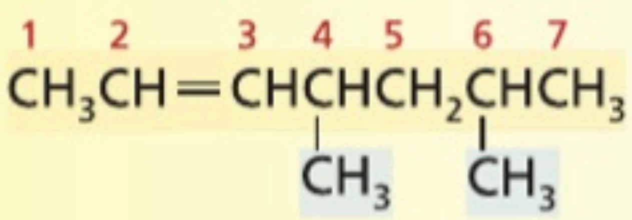
***2-Heptene* parent chain**

Step 3. Name each substituent.



Each substituent is a methyl group.

Step 4. Determine how many of each substituent is present, and assign the correct prefix to represent that number. Then, include the position numbers to get the complete prefix.



***2-Heptene* parent chain**

Two methyl groups at Positions 4 and 6

Prefix is 4,6-*dimethyl*

Step 5. The names of substituents do not have to be alphabetized because they are the same. Apply the complete prefix to the name of the parent alkene chain. Use commas between numbers, and hyphens between numbers and words. Write the name 4,6-*dimethyl-2-heptene.*

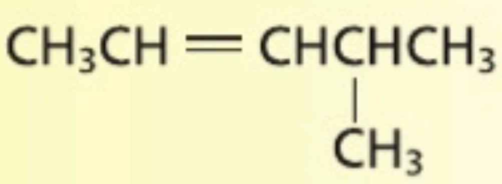
3 EVALUATE THE ANSWER

The longest carbon chain includes the double bond, and the position of the double bond has the lowest possible number. Correct prefixes and alkyl group names designate the branches.

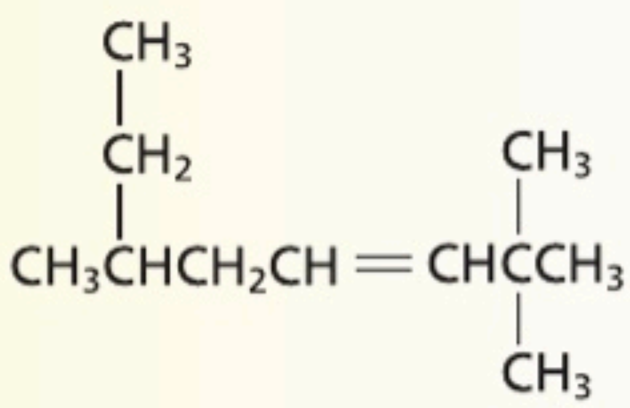
APPLICATIONS

17. Use the IUPAC rules to name the following structures.

a.



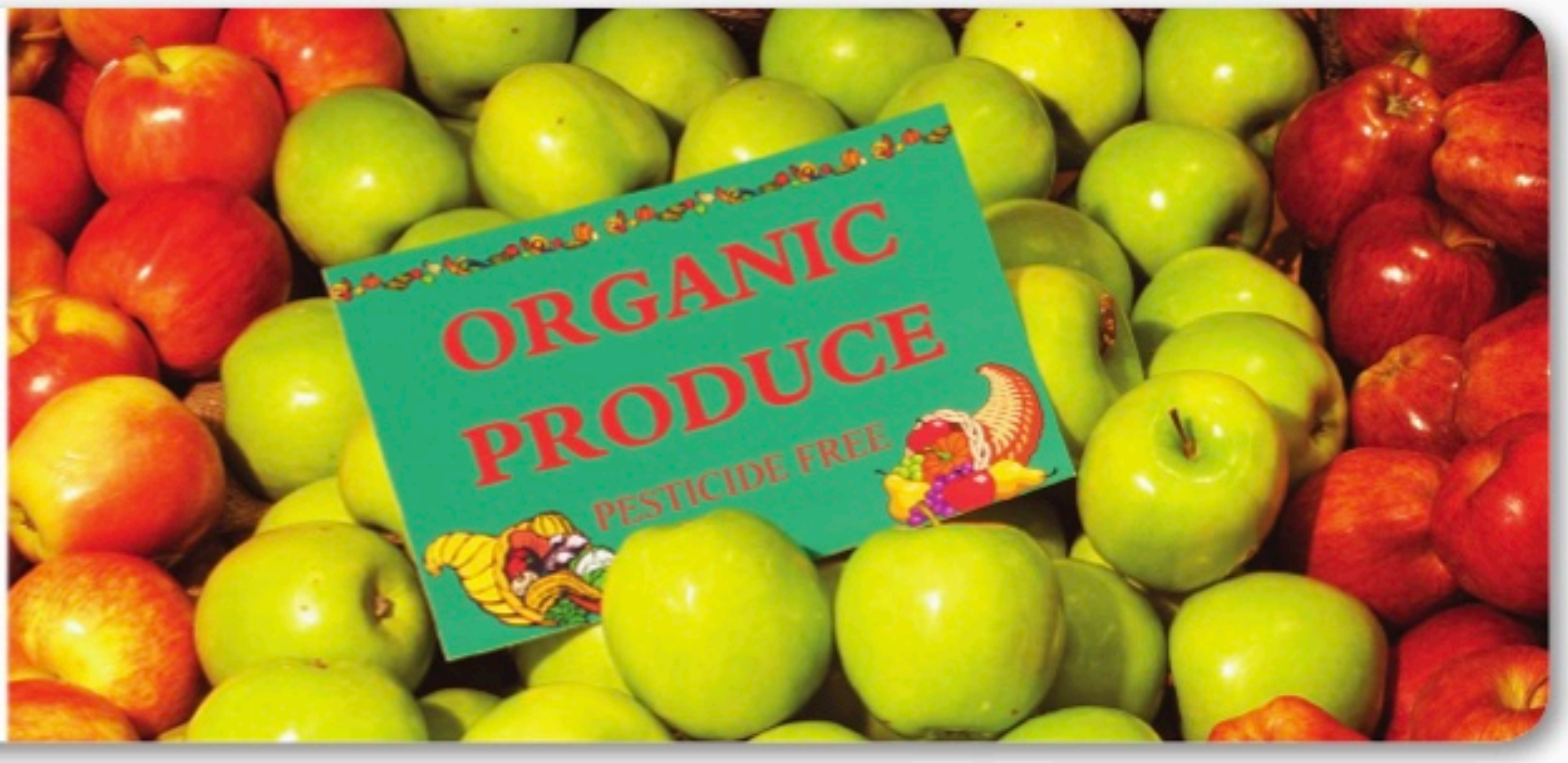
b.



18. Challenge Draw the structure of 1,3-pentadiene.

■ **Figure 14** The use of ethene to ripen produce allows growers to harvest fruits and vegetables before they ripen.

Explain ***why this is a benefit to growers.***



Properties and uses of alkenes Like alkanes, alkenes are nonpolar and therefore have low solubility in water as well as relatively low melting and boiling points. However, alkenes are more reactive than alkanes because the second covalent bond increases the electron density between two carbon atoms, providing a good site for chemical reactivity. Reactants that attract electrons can pull the electrons away from the double bond.

Several alkenes occur naturally in living organisms. For example, ethene is a hormone produced naturally by plants. It causes fruit to ripen and plays a part in causing leaves to fall from deciduous trees in preparation for winter. The fruits shown in **Figure 14** and other produce sold in grocery stores ripen artificially when they are exposed to ethene. Ethene is also the starting material for the synthesis of the plastic polyethylene, which is used to manufacture many products, including plastic bags, rope, and milk jugs. Other alkenes are responsible for the scents of lemons, limes, and pine trees.

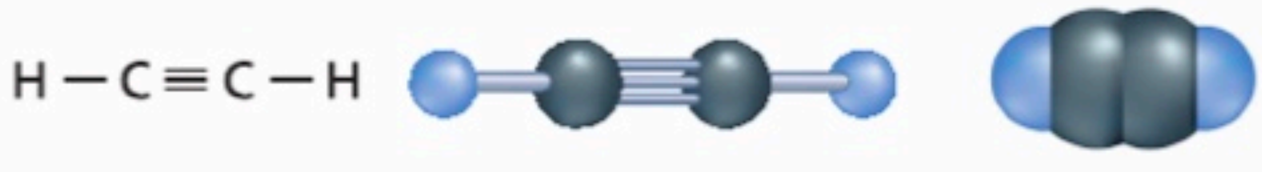
Alkynes

Unsaturated hydrocarbons that contain one or more triple bonds between carbon atoms in a chain are called **alkynes.** Triple bonds involve the sharing of three pairs of electrons. The simplest and most commonly used alkyne is ethyne (C_2H_2), which is widely known by its common name *acetylene*. Study the models of ethyne in **Figure 15.**

Naming alkynes Straight-chain alkynes and branched-chain alkynes are named in the same way as alkenes. The only difference is that the name of the parent chain ends in *-yne* rather than *-ene*. Study the examples in **Table 6.** Alkynes with one triple covalent bond form a homologous series with the general formula C_nH_{2n-2}.

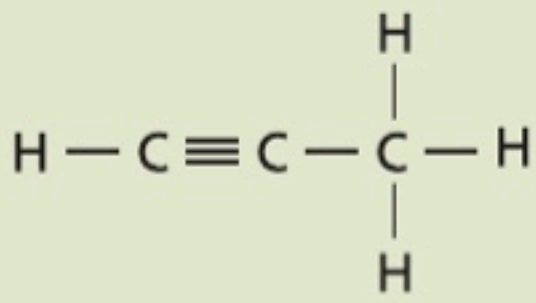
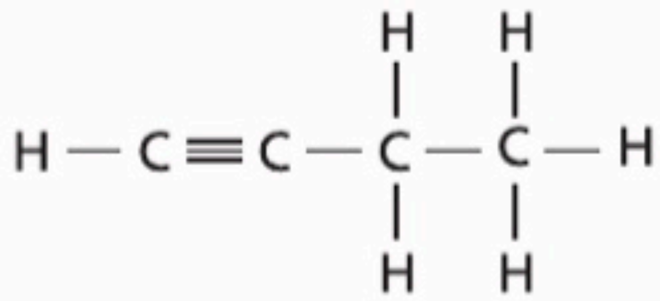
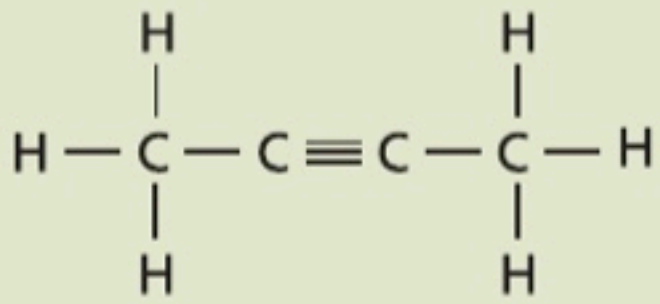
☑ **READING CHECK** **Infer,** by looking at the bonds in ethyne, why it is highly reactive with oxygen.

■ **Figure 15** These three molecular models represent ethyne.



Models of ethyne (acetylene)

Table 6 Examples of Alkynes

Name	Molecular Formula	Structural Formula	Condensed Structural Formula
Ethyne	C_2H_2	$H-C \equiv C-H$	$CH \equiv CH$
Propyne	C_3H_4		$CH \equiv CCH_3$
1-Butyne	C_4H_6		$CH \equiv CCH_2CH_3$
2-Butyne	C_4H_6		$CH_3C \equiv CCH_3$

MiniLab

Synthesize and Observe Ethyne

Why is ethyne used in welding torches?

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Use a **rubber band** to attach a **wood splint** to one end of a **ruler** that is about 40 cm long, so that about 10 cm of the splint extends beyond the ruler.
3. Place 120 mL **water** in a **150-mL beaker,** and add 5 mL **dishwashing detergent.** Mix thoroughly.
4. Use **forceps** to pick up a pea-sized lump of **calcium carbide** (CaC_2). Do not touch the CaC_2 with your fingers. **WARNING:** ***CaC_2 is corrosive; if CaC_2 dust touches your skin, wash it away immediately with a lot of water.*** Place the lump of CaC_2 in the beaker of detergent solution.
5. Use a **match** to light the splint while holding the ruler at the opposite end. Immediately bring the burning splint to the bubbles that have formed from the reaction in the beaker. Extinguish the splint after observing the reaction.
6. Use a **stirring rod** to dislodge a few large bubbles of ethyne. Do they float or sink in air?
7. Rinse the beaker thoroughly, then add 25 mL **distilled water** and a drop of **phenolphthalein solution.** Use forceps to place a small piece of CaC_2 in the solution. Observe the results.

Analysis

1. **Infer** What can you infer about the density of ethyne compared to the density of air?
2. **Predict** The reaction of calcium carbide with water yields two products. One is ethyne gas (C_2H_2). What is the other product? Write a balanced chemical equation for the reaction.

■ **Figure 16** Ethyne, or acetylene, reacts with oxygen in the chemical reaction $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$, which produces enough heat to weld metals.

Properties and uses of alkynes Alkynes have physical and chemical properties similar to those of alkenes. Alkynes undergo many of the reactions alkenes undergo. However, alkynes are generally more reactive than alkenes because the triple bonds of alkynes have even greater electron density than the double bonds of alkenes. This cluster of electrons is effective at inducing dipoles in nearby molecules, causing them to become unevenly charged and thus reactive.

Ethyne–known commonly as acetylene–is a by-product of oil refining and is also made in large quantities by the reaction of calcium carbide (CaC_2) with water. When supplied with enough oxygen, ethyne burns with an intensely hot flame that can reach temperatures as high as 3000°C. Acetylene torches are commonly used in welding, as shown in **Figure 16.** Because the triple bond makes alkynes reactive, simple alkynes like ethyne are used as starting materials in the manufacture of plastics and other organic chemicals used in industry.

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SECTION 3 REVIEW

Section Summary

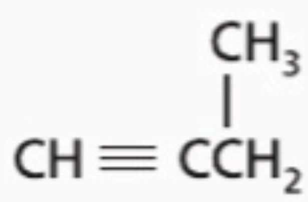
- Alkenes and alkynes are hydrocarbons that contain at least one double or triple bond, respectively.
- Alkenes and alkynes are nonpolar compounds with greater reactivity than alkanes but with other properties similar to those of alkanes.

19. MAINIDEA Describe how the molecular structures of alkenes and alkynes differ from the structure of alkanes.

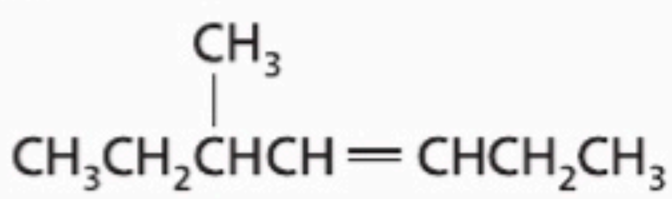
20. Identify how the chemical properties of alkenes and alkynes differ from those of alkanes.

21. Name the structures shown using IUPAC rules.

a.



b.



22. Draw the molecular structure of 4-methyl-1,3-pentadiene and 2,3-dimethyl-2-butene.

23. Infer how the boiling and freezing points of alkynes compare with those of alkanes with the same number of carbon atoms. Explain your reasoning, then research data to see if it supports your idea.

24. Predict What geometric arrangement would you expect from the bonds surrounding the carbon atom in alkanes, alkenes, and alkynes? (*Hint: VSEPR theory can be used to predict the shape.*)

SECTION 4

Hydrocarbon Isomers

MAINIDEA **Some hydrocarbons have the same molecular formula but have different molecular structures.**

Essential Questions

- How can the two main categories of isomers—structural isomers and stereoisomers—be distinguished?
- How are *cis*- and *trans*- geometric isomers different?
- What is the structural variation in molecules that results in optical isomers?

Review Vocabulary

electromagnetic radiation: transverse waves that carry energy through empty space

New Vocabulary

isomer
structural isomer
stereoisomer
geometric isomer
chirality
asymmetric carbon
optical isomer
optical rotation

CHEM 4 YOU **Have you ever met a pair of identical twins? Identical twins have the same genetic makeup, yet they are two separate individuals with different personalities. Isomers are similar to twins—they have the same molecular formula, but different molecular structures and properties.**

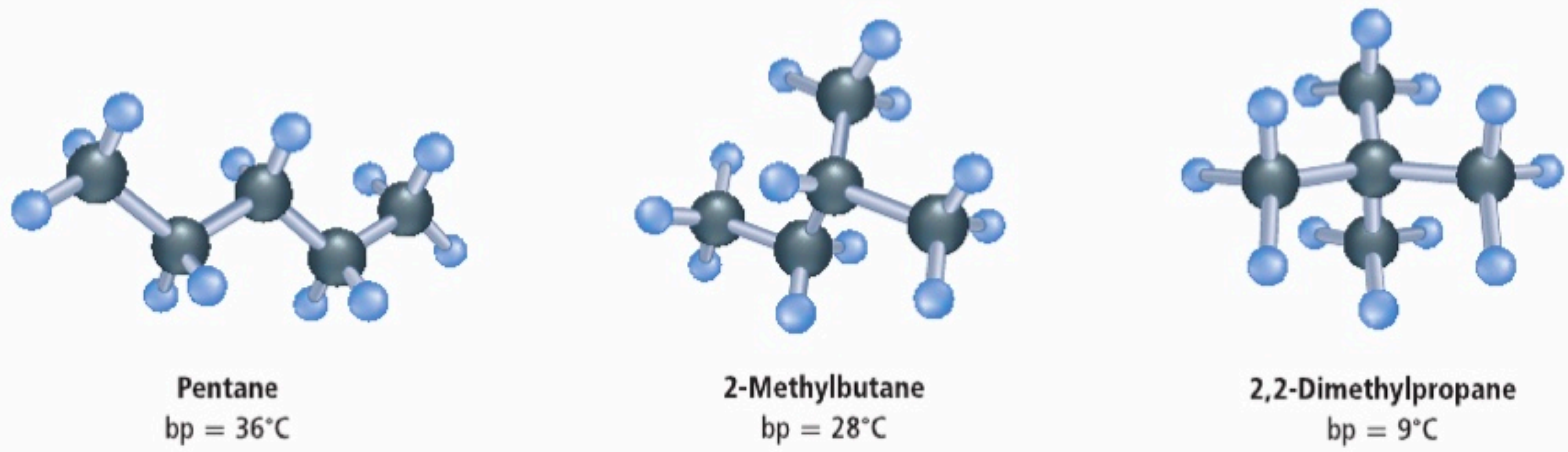
Structural Isomers

Examine the models of three alkanes in **Figure 17** to determine how they are similar and how they are different. All three have 5 carbon atoms and 12 hydrogen atoms, so they have the molecular formula C_5H_{12}. However, as you can see, these models represent three different arrangements of atoms and three different compounds–pentane, 2-methylbutane, and 2,2-dimethylpropane. These three compounds are isomers. **Isomers** are two or more compounds that have the same molecular formula but different molecular structures. Note that cyclopentane and pentane are not isomers because cyclopentane's molecular formula is C_5H_{10}.

There are two main classes of isomers. **Figure 17** shows compounds that are examples of structural isomers. **Structural isomers** have the same chemical formula, but their atoms are bonded in different arrangements. Structural isomers have different chemical and physical properties despite having the same formula. This observation supports one of the main principles of chemistry: The structure of a substance determines its properties. How does the trend in boiling points of C_5H_{12} isomers relate to their molecular structures?

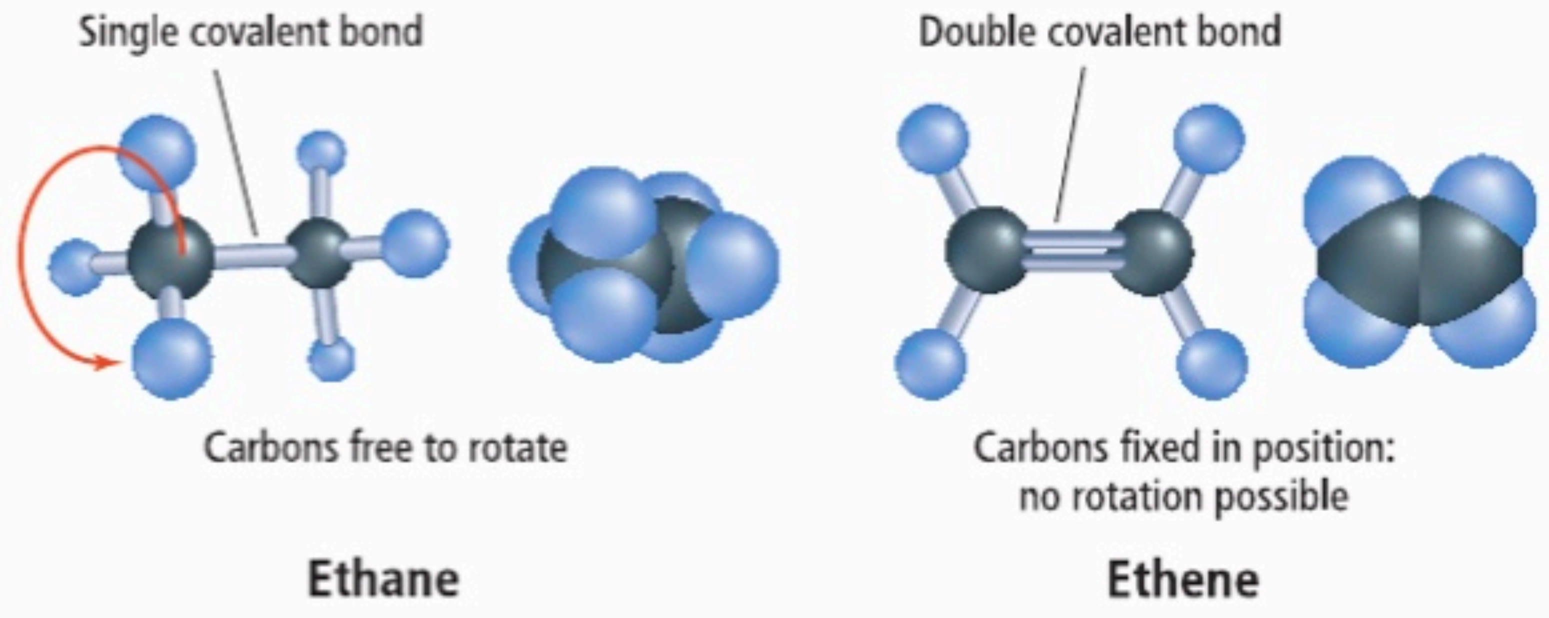
As the number of carbons in a hydrocarbon increases, the number of possible structural isomers increases. For example, there are nine alkanes with the molecular formula C_7H_{16}. There are more than 300,000 structural isomers with the formula $C_{20}H_{42}$.

Figure 17 These compounds with the same molecular formula, C_5H_{12}, are structural isomers. Note how their boiling points differ.



■ **Figure 18** The single-bonded carbons in ethane are free to rotate around the bond. The double-bonded carbons in ethene resist being rotated.

Explain ***How do you think this difference in ability to rotate would affect atoms or groups of atoms bonded to single-bonded and double-bonded carbon atoms?***



Stereoisomers

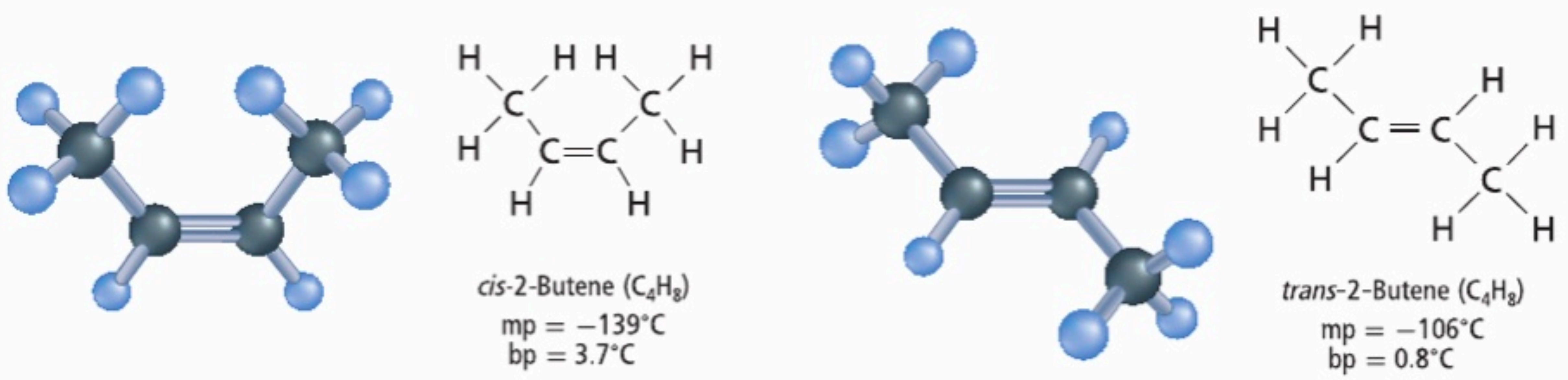
The second class of isomers involves a more subtle difference in bonding. **Stereoisomers** are isomers in which all atoms are bonded in the same order but are arranged differently in space. There are two types of stereoisomers. One type occurs in alkenes, which contain double bonds. Two carbon atoms with a single bond between them can rotate freely in relationship to each other. However, when a second covalent bond is present, the carbons can no longer rotate; they are locked in place, as shown in **Figure 18.**

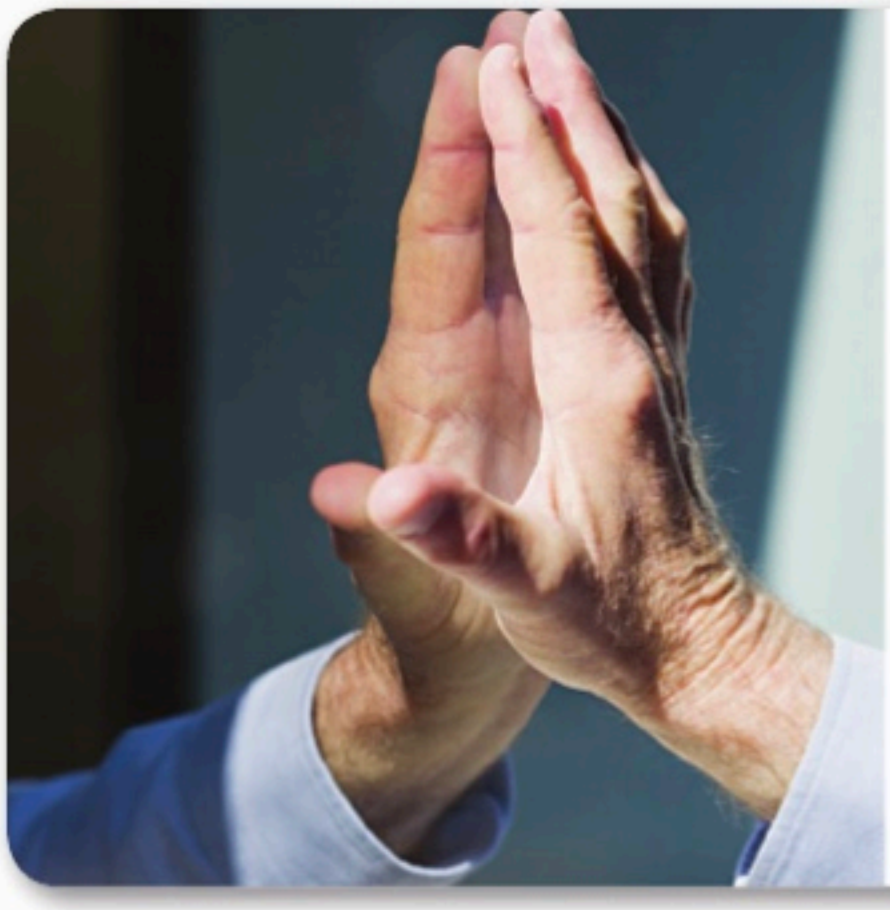
Compare the two possible structures of 2-butene shown in **Figure 19.** The arrangement in which the two methyl groups are on the same side of the molecule is indicated by the prefix *cis*-. The arrangement in which the two methyl groups are on opposite sides of the molecule is indicated by the prefix *trans*-. These terms derive from Latin: *cis* means *on the same side*, and *trans* means *across from*. Because the double-bonded carbon atoms cannot rotate, the *cis*- form cannot easily change into the *trans*- form.

Isomers resulting from different arrangements of groups around a double bond are called **geometric isomers.** Note how the difference in geometry affects the isomers' physical properties, such as melting point and boiling point. Geometric isomers differ in some chemical properties as well. If the compound is biologically active, such as a drug, the *cis*- and *trans*- isomers usually have very different effects.

☑ **READING CHECK** **Explain** how structural and geometric isomers differ.

■ **Figure 19** These isomers of 2-butene differ in the arrangement in space of the two methyl groups at the ends. The double-bonded carbon atoms cannot rotate with respect to each other, so the methyl groups are fixed in one of these two arrangements.





■ **Figure 20** The reflection of your right hand looks the same as your left hand. However, you cannot place your hands palms down with one on top of the other and have matching parts lie on top of each other.

RealWorld CHEMISTRY

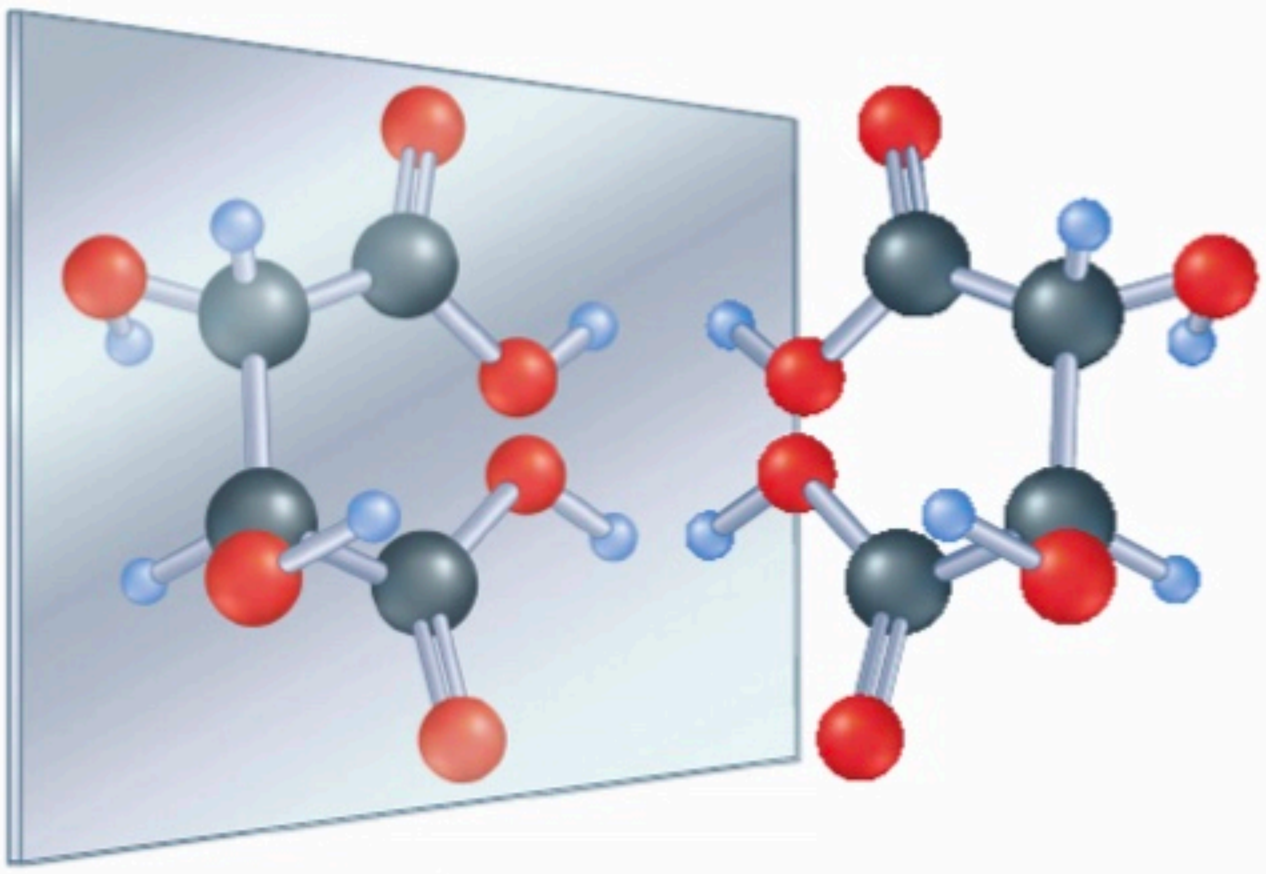
Trans fats

ISOMERS IN THE DIET Fats with *trans* isomers are called *trans* fats. Many pre-packaged foods are made with *trans* fats because they have a longer shelf life. Evidence suggests that *trans* fat increases the unhealthy form of cholesterol and decreases the healthy form, which increases the chance of heart disease.

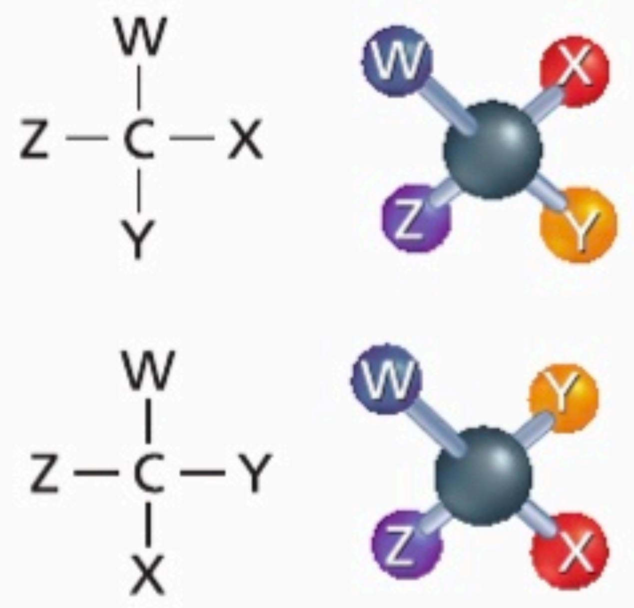
Chirality

Connection to Biology In 1848, the young French chemist Louis Pasteur (1822–1895) reported his discovery that crystals of the organic compound tartaric acid, existed in two shapes that were mirror images of each other. Because a person's hands are like mirror images, as shown in **Figure 20,** the crystals were called the right-handed and left-handed forms. The two forms of tartaric acid had the same chemical properties, melting point, density, and solubility in water, but only the left-handed form was produced by fermentation. In addition, bacteria were able to multiply only when they were fed the left-handed form as a nutrient.

The two crystalline forms of tartaric acid exist in the two arrangements as shown in **Figure 21.** Today, these two forms are called d-tartaric acid and l-tartaric acid. The letters d and l stand for the Latin prefixes *dextro-*, which means *to the right*, and *levo-*, which means *to the left*. The property in which a molecule exists in a right- and left-handed form is called **chirality.** Many of the substances found in living organisms, such as the amino acids that make up proteins, have this chirality. In general, living organisms make use of only one chiral form of a substance because only this form fits the active site of an enzyme.



■ **Figure 21** These models represent the two forms of tartaric acid that Pasteur studied. If the model of right-handed tartaric acid (d-tartaric acid) is reflected in a mirror, its image is a model of left-handed tartaric acid (l-tartaric acid).



■ **Figure 22** These models represent two different molecules. Groups X and Y have switched places.

Optical Isomers

In the 1860s, chemists realized that chirality occurs whenever a compound contains an asymmetric carbon. An **asymmetric carbon** is a carbon atom that has four different atoms or groups of atoms attached to it. The four groups can always be arranged in two different ways. Suppose that groups W, X, Y, and Z are attached to the same carbon atom in the two arrangements shown in **Figure 22.** Note that the structures differ in that groups X and Y have been exchanged. You cannot rotate the two arrangements in any way that will make them identical to each other.

Now suppose that you build models of these two structures. Is there any way you could turn one structure so that it looks the same as the other? (Whether letters appear forward or backward does not matter.) You would discover that there is no way to accomplish the task without removing X and Y from the carbon atom and switching their positions. Therefore, the molecules are different even though they look very much alike.

Isomers that result from different arrangements of four different groups around the same carbon atom represent another class of stereoisomers called optical isomers. **Optical isomers** have the same physical and chemical properties, except in chemical reactions where chirality is important, such as enzyme-catalyzed reactions in biological systems. Human cells, for example, incorporate only l-amino acids into proteins. Only the l-form of ascorbic acid is active as vitamin C. The chirality of a drug molecule can also be important. For example, only one isomer of some drugs is effective and the other isomer can be harmful.

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Data Analysis LAB

Based on Real Data*

Interpret Data

What are the rates of oxidation of dichloroethene isomers? *Pseudomonas butanovora* is a bacterium that uses some alkanes, alcohols, and organic acids as sources of carbon and energy. This bacteria was tested as an agent to rid groundwater of dichloroethene (DCE) contaminants. Mixtures containing various reducing agents and butane monooxygenase in *Pseudomonas butanovora* oxidized isomers of DCE.

Data and Observations

The table shows the rate of oxidation of each compound in butane-grown *P. butanovora.*

Rates of Oxidation

	Initial Rate of Oxidation (nmol min^{-1} mg $protein^{-1}$)	
Reducing Agent	**1,2-cis DCE**	**1,2-trans DCE**
Buffer	0.9 (1.0)	1.6 (1.0)
Butyrate	6.8 (7.6)	2.0 (1.3)
Propionate	5.9 (6.6)	0.4 (0.3)
Acetate	8.5 (9.4)	3.8 (2.8)
Formate	1.4 (1.6)	1.2 (0.7)
Lactate	11 (12.2)	4.5 (2.8)

Values in parentheses represent the increase (*n*-fold) above the buffer rate.

Think Critically

1. **Compare** Which reducing agent was most useful in oxidizing each isomer?
2. **Conclude** Which isomer oxidized the slowest?

Data obtained from: Doughty, D.M. et al. 2005. Effects of dichloroethene isomers on the induction and activity of butane monooxygenase in the alkane-oxidizing Bacterium *"Pseudomonas butanovora." Applied Environmental Microbiology.* October: 6054–6059.

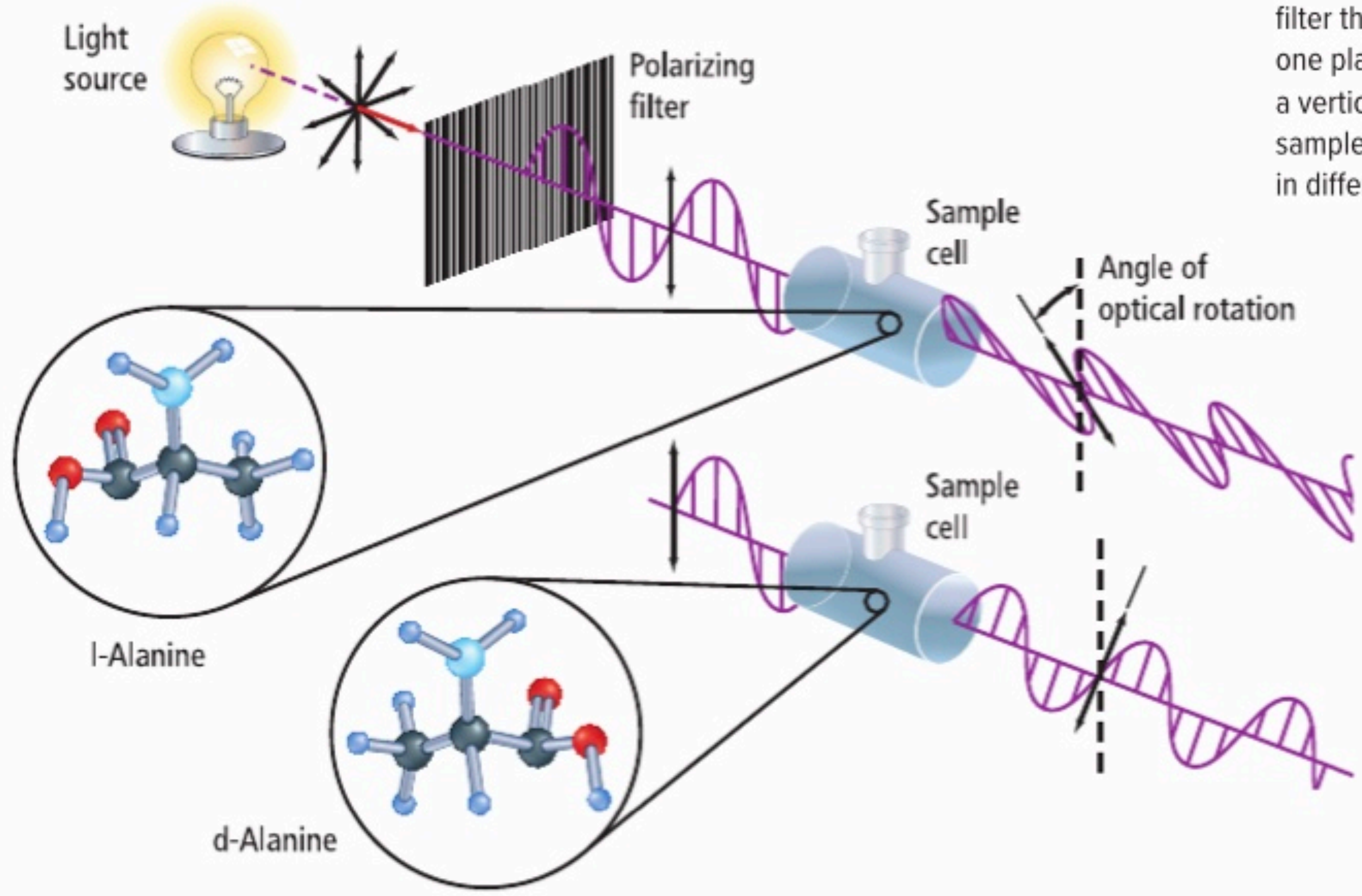


Figure 23 Polarized light can be produced by passing ordinary light through a filter that transmits light waves that lie in only one plane. Here, the filtered light waves are in a vertical plane before they pass through the sample cells. The two isomers rotate the light in different directions.

Optical rotation Mirror-image isomers are called optical isomers because they affect light passing through them. Normally, the light waves in a beam from the Sun or a lightbulb move in all possible planes. However, light can be filtered or reflected in such a way that the resulting waves all lie in the same plane. This type of light is called polarized light.

When polarized light passes through a solution containing an optical isomer, the plane of polarization is rotated to the right (clockwise, when looking toward the light source) by a d-isomer or to the left (counterclockwise) by an l-isomer, producing an effect called **optical rotation.** This effect is shown in **Figure 23.**

One optical isomer that you might have used is l-menthol. This natural isomer has a strong, minty flavor, and a cooling odor and taste. The mirror-image isomer, d-menthol, does not have the same cooling effect as l-menthol.

SECTION 4 REVIEW

Section Summary

- Isomers are two or more compounds with the same molecular formula but different molecular structures.
- Structural isomers differ in the order in which atoms are bonded to each other.
- Stereoisomers have all atoms bonded in the same order but arranged differently in space.

25. MAINIDEA Draw all of the structural isomers possible for the alkane with the molecular formula C_6H_{14}. Show only the carbon chains.

26. Explain the difference between structural isomers and stereoisomers.

27. Draw the structures of *cis*-3-hexene and *trans*-3-hexene.

28. Infer why living organisms can make use of one only chiral form of a substance.

29. Evaluate A certain reaction yields 80% *trans*-2-pentene and 20% cis-2-pentene. Draw the structures of these two geometric isomers, and develop a hypothesis to explain why the isomers form in the proportions cited.

30. Formulate Models Starting with a single carbon atom, draw two different optical isomers by attaching the following atoms or groups to the carbon: $-H$, $-CH_3$, $-CH_2CH_3$, and $-CH_2CH_2CH_3$.

SECTION 5

Aromatic Hydrocarbons

MAINIDEA **Aromatic hydrocarbons are unusually stable compounds with ring structures in which electrons are shared by many atoms.**

Essential Questions

- How do the properties of aromatic and aliphatic hydrocarbons compare and contrast?
- What is a carcinogen and what are some examples?

Review Vocabulary

hybrid orbitals: equivalent atomic orbitals that form during bonding by the rearrangement of valence electrons

New Vocabulary

aromatic compound
aliphatic compound

CHEM 4 YOU **What do bright, colorful fabrics, asphalt roofing shingles, and essential oils for perfumes have in common? They all contain aromatic hydrocarbons.**

The Structure of Benzene

Natural dyes, like those found in the fabrics in **Figure 24,** and essential oils for perfumes contain six-carbon ring structures. Compounds with these structures have been used for centuries. By the middle of the nineteenth century, chemists had a basic understanding of the structures of hydrocarbons with single, double, and triple covalent bonds. However, certain hydrocarbon ring structures remained a mystery.

The simplest example of this class of hydrocarbon is benzene, which the English physicist Michael Faraday (1791–1867) first isolated in 1825 from the gases given off when either whale oil or coal was heated. Although chemists had determined that benzene's molecular formula was C_6H_6, it was hard for them to determine what sort of hydrocarbon structure would give such a formula. After all, the formula of the saturated hydrocarbon with six carbon atoms, hexane, was C_6H_{14}. Because the benzene molecule had so few hydrogen atoms, chemists reasoned that it must be unsaturated; that is, it must have several double or triple bonds, or a combination of both. They proposed many different structures, including this one suggested in 1860.

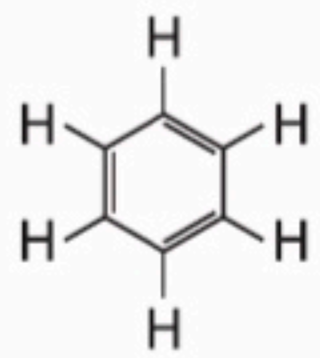
$$CH_2=C=CH-CH=C=CH_2$$

Although this structure has a molecular formula of C_6H_6, such a hydrocarbon would be unstable and extremely reactive because of its many double bonds. However, benzene was fairly unreactive, and it did not react in the ways that alkenes and alkynes usually react. For that reason, chemists reasoned that structures such as the one shown above must be incorrect.

Figure 24 Dyes used to produce brightly-colored fabrics have been used for centuries.

Explain ***What do many natural dyes and essential oils for perfumes have in common?***

Kekulé's dream In 1865, the German chemist Friedrich August Kekulé (1829–1896) proposed a different kind of structure for benzene–a hexagon of carbon atoms with alternating single and double bonds. How does the molecular formula of this structure compare with that of benzene?



Kekulé claimed that benzene's structure came to him in a dream while he dozed in front of a fireplace in Ghent, Belgium. He said that he had dreamed of the Ouroboros, an ancient Egyptian emblem of a snake devouring its own tail, and that had made him think of a ring-shaped structure. The flat, hexagonal structure Kekulé proposed explained some of the properties of benzene, but it did not explain benzene's lack of reactivity.

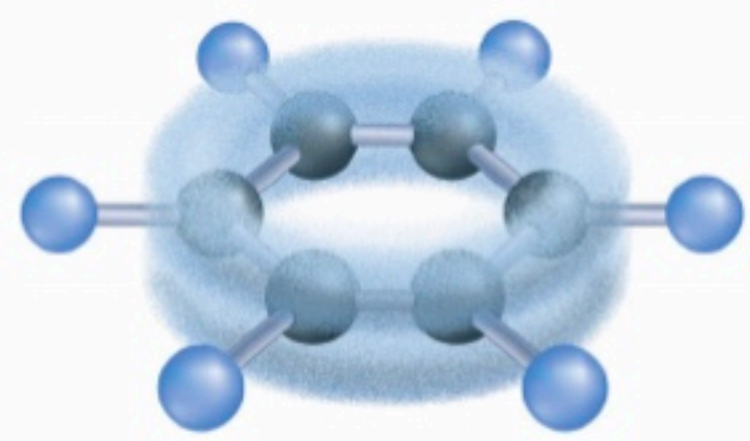


Figure 25 Benzene's bonding electrons spread evenly in a double-donut shape around the ring instead of remaining near individual atoms.

A modern model of benzene Since the time of Kekulé's proposal, research has confirmed that benzene's molecular structure is indeed hexagonal. However, benzene's unreactivity could not be explained until the 1930s, when Linus Pauling proposed the theory of hybrid orbitals. When applied to benzene, this theory predicts that the pairs of electrons that form the second bond of each of benzene's double bonds are not localized between only two specific carbon atoms as they are in alkenes. Instead, the electron pairs are delocalized, which means they are shared among all six carbons in the ring. **Figure 25** shows that this delocalization makes the benzene molecule chemically stable because electrons shared by six carbon nuclei are harder to pull away than electrons held by only two nuclei. The six hydrogen atoms are usually not shown, but it is important to remember that they are there. In this representation, the circle in the middle of the hexagon symbolizes the cloud formed by the three pairs of electrons.

Aromatic Compounds

Organic compounds that contain benzene rings as part of their structures are called **aromatic compounds.** The term *aromatic* was originally used because many of the benzene-related compounds known in the nineteenth century were found in pleasant-smelling oils that came from spices, fruits, and other plant parts. Hydrocarbons such as the alkanes, alkenes, and alkynes are called **aliphatic compounds** to distinguish them from aromatic compounds. The term *aliphatic* comes from the Greek word for *fat,* which is *aleiphatos.* Early chemists obtained aliphatic compounds by heating animal fats. What are some examples of animal fats that might contain aliphatic compounds?

☑ READING CHECK **Infer** why the terms *aromatic compound* and *aliphatic compound* continue to be used by chemists today.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

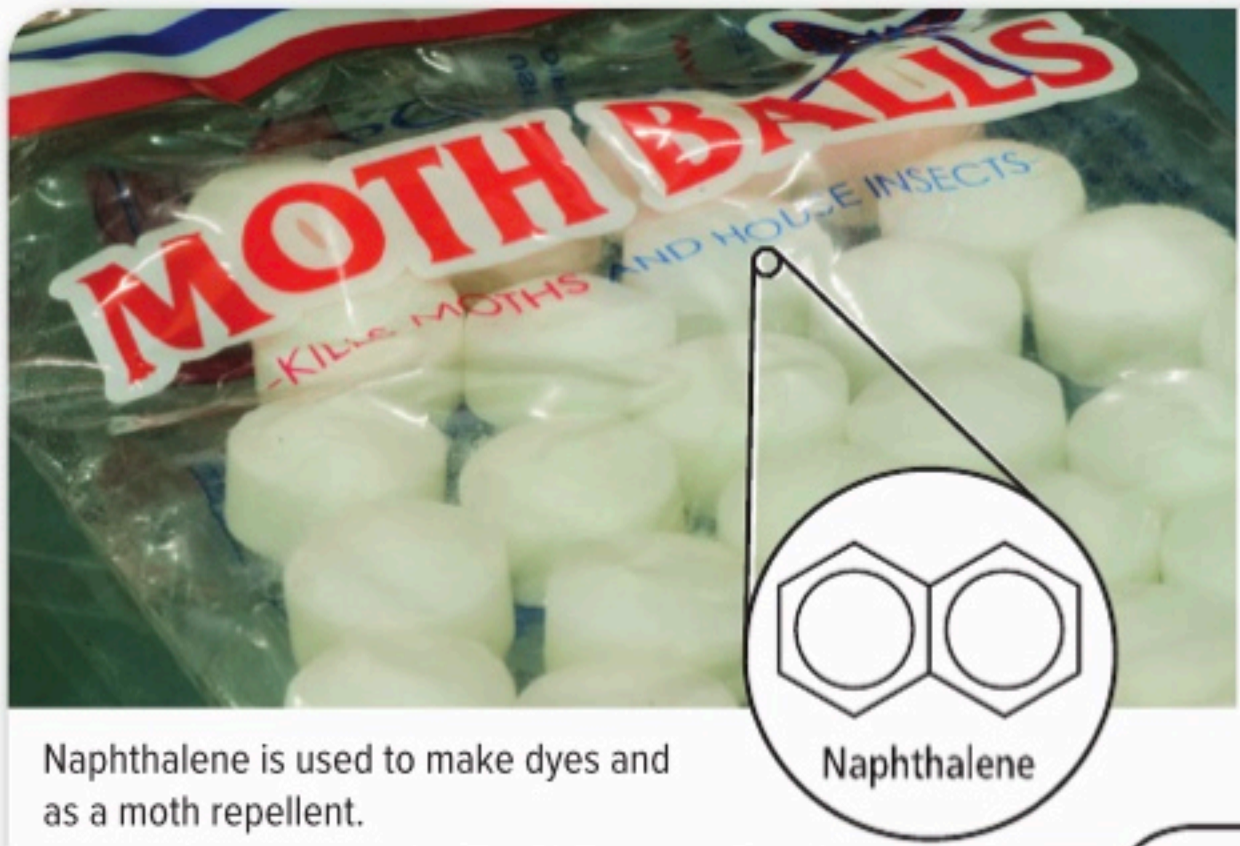
Aromatic

Science usage: an organic compound with increased chemical stability due to the delocalization of electrons

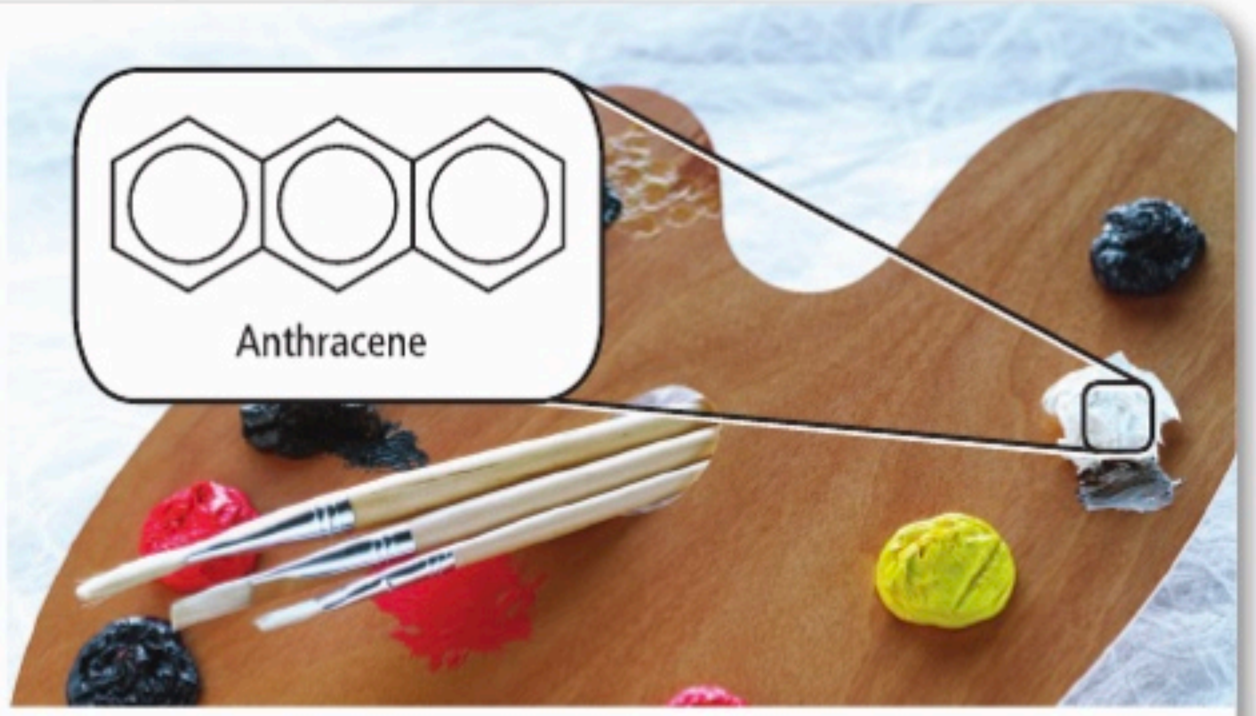
Benzene is an aromatic compound.

Common usage: having a strong odor or smell

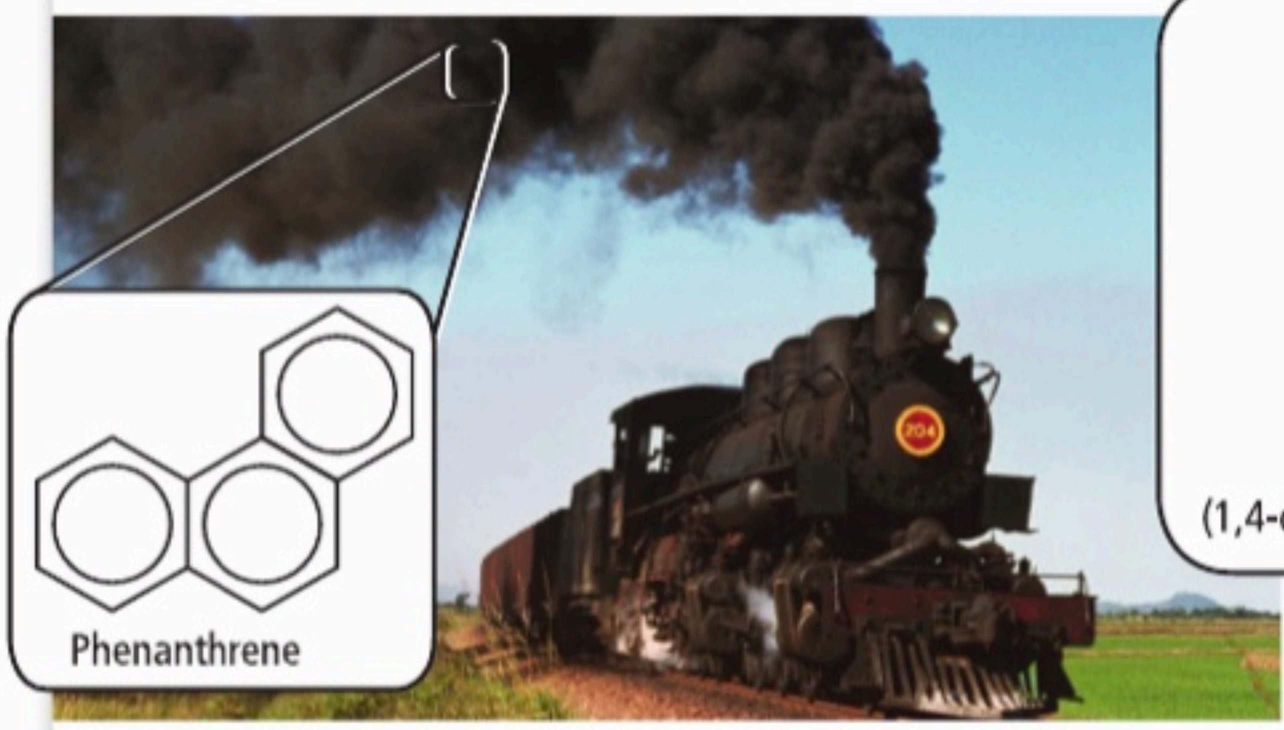
The perfume was very aromatic.



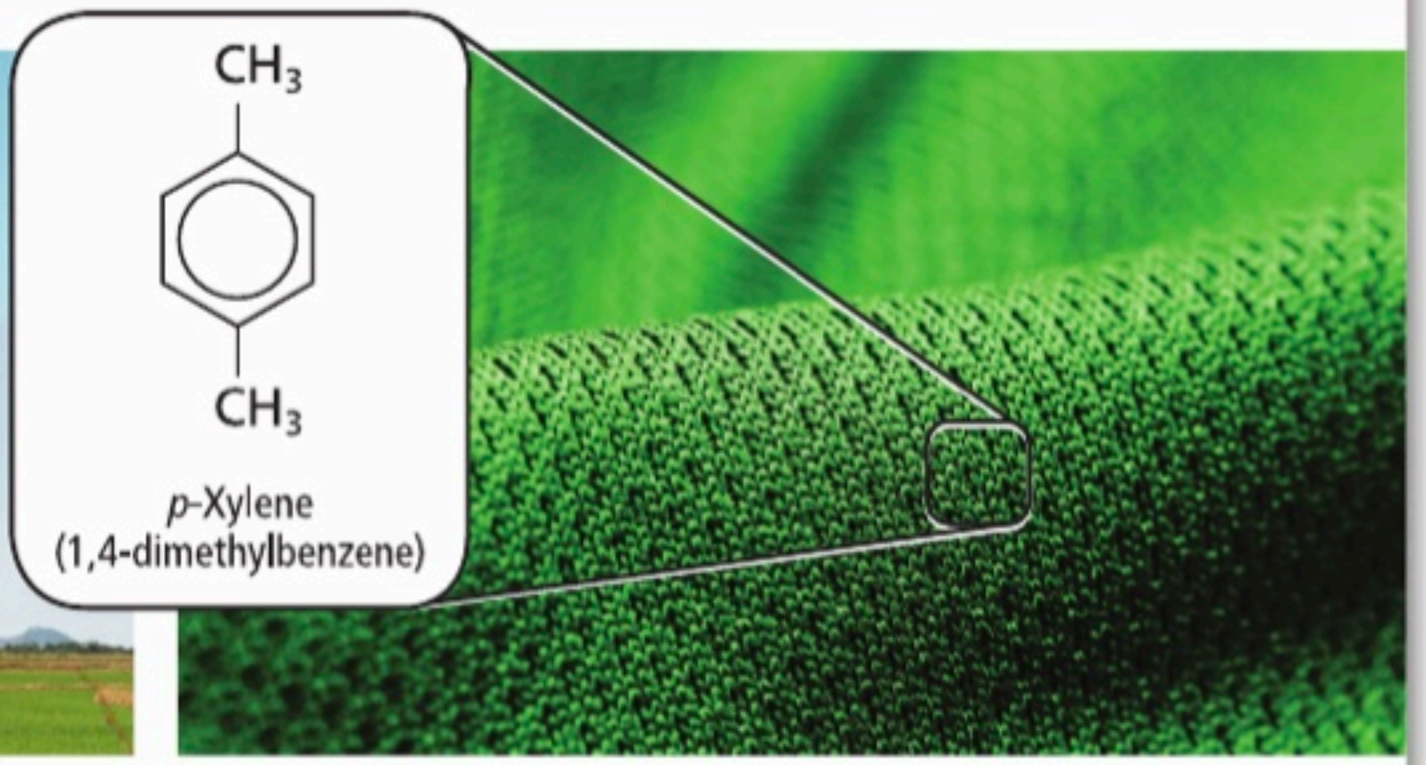
Naphthalene is used to make dyes and as a moth repellent.



Anthracene is used to produce dyes and pigments.



Phenanthrene is present in the atmosphere due to the incomplete combustion of hydrocarbons.



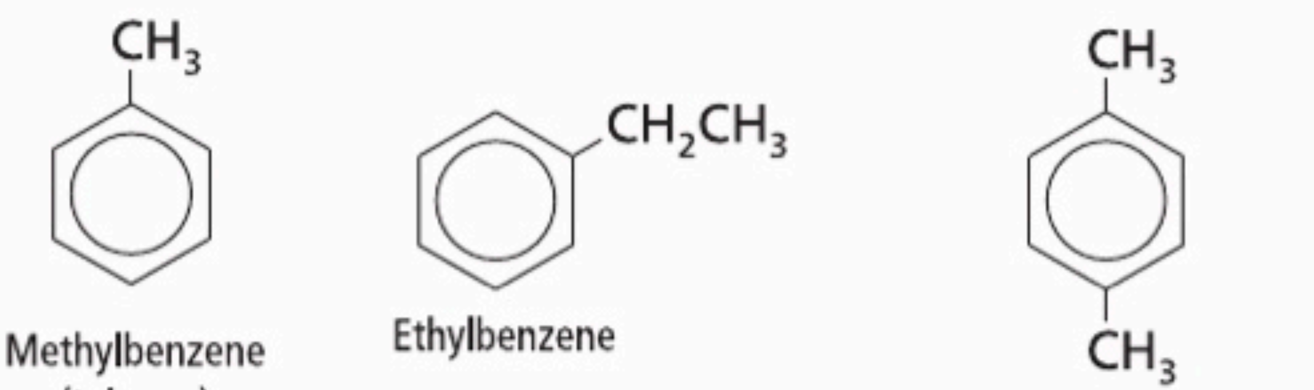
Xylene is used to make polyester fibers and fabrics.

Figure 26 Aromatic hydrocarbons are found in the environment due to the incomplete combustion of hydrocarbons and are used to make a variety of products.

Structures of some aromatic compounds are shown in **Figure 26.** Note that naphthalene has a structure that looks like two benzene rings arranged side by side. Naphthalene is an example of a fused-ring system, in which an organic compound has two or more cyclic structures with a common side. As in benzene, electrons are shared by the carbon atoms that make up the ring systems.

Naming substituted aromatic compounds Like other hydrocarbons, aromatic compounds can have different groups attached to their carbon atoms. For example, methylbenzene, also known as toluene, consists of a methyl group attached to a benzene ring in place of one hydrogen atom. Whenever you see something attached to an aromatic ring system, remember that the hydrogen atom is no longer there.

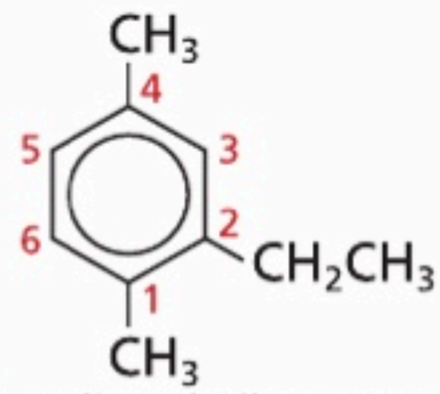
Substituted benzene compounds are named in the same way as cyclic alkanes. For example, ethylbenzene has a 2-carbon ethyl group attached, and 1,4-dimethylbenzene, also known as *para*-xylene, has two methyl groups attached at positions 1 and 4.



Methylbenzene (toluene) | Ethylbenzene | 1,4-Dimethylbenzene (*para*-xylene)

Just as with substituted cycloalkanes, substituted benzene rings are numbered in a way that gives the lowest-possible numbers for the substituents, as shown in **Figure 27.** Numbering the ring as shown gives the numbers 1, 2, and 4 for the substituent positions. Because *ethyl* comes before *methyl* in the alphabet, it is written first in the name: 2-ethyl-1,4-dimethylbenzene.

READING CHECK **Explain** what the circle means inside the six-membered ring structure in **Figure 27.**

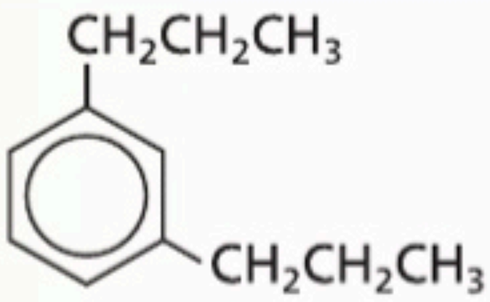


2-Ethyl-1,4-dimethylbenzene

Figure 27 Substituted benzene rings are named in the same way as cyclic alkanes.

EXAMPLE 4

NAMING AROMATIC COMPOUNDS Name the aromatic compound shown.

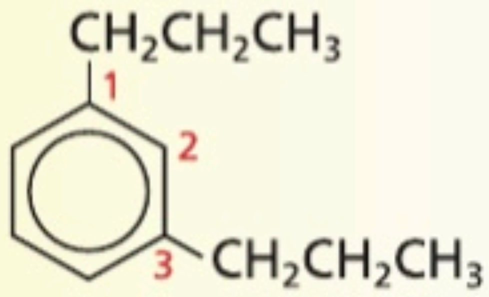


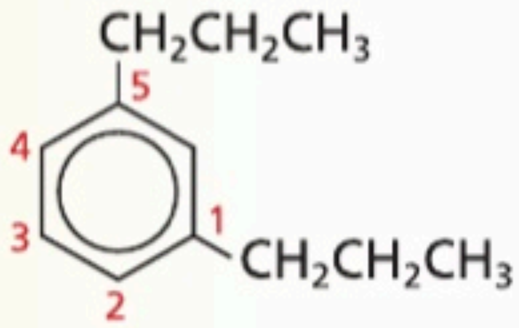
1 ANALYZE THE PROBLEM

You are given an aromatic compound. Follow the rules to name the aromatic compound.

2 SOLVE FOR THE UNKNOWN

Step 1. Number the carbon atoms to give the lowest numbers possible.





As you can see, the numbers 1 and 3 are lower than the numbers 1 and 5. So the numbers used to name the hydrocarbon should be 1 and 3.

Step 2. Determine the name of the substituents. If the same substituent appears more than once, add the prefix to show the number of groups present.

Step 3. Put the name together. Alphabetize the substituent names, and use commas between numbers and hyphens between numbers and words. Write the name as 1,3-dipropylbenzene.

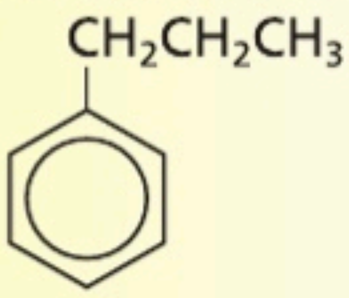
3 EVALUATE THE ANSWER

The benzene ring is numbered to give the branches the lowest possible set of numbers. The names of the substituent groups are correctly identified.

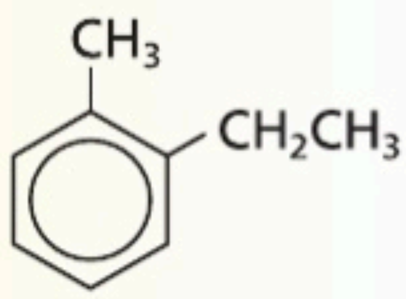
APPLICATIONS

31. Name the following structures.

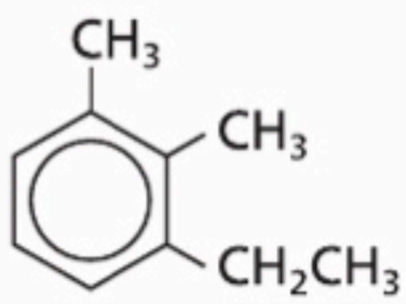
a.



b.

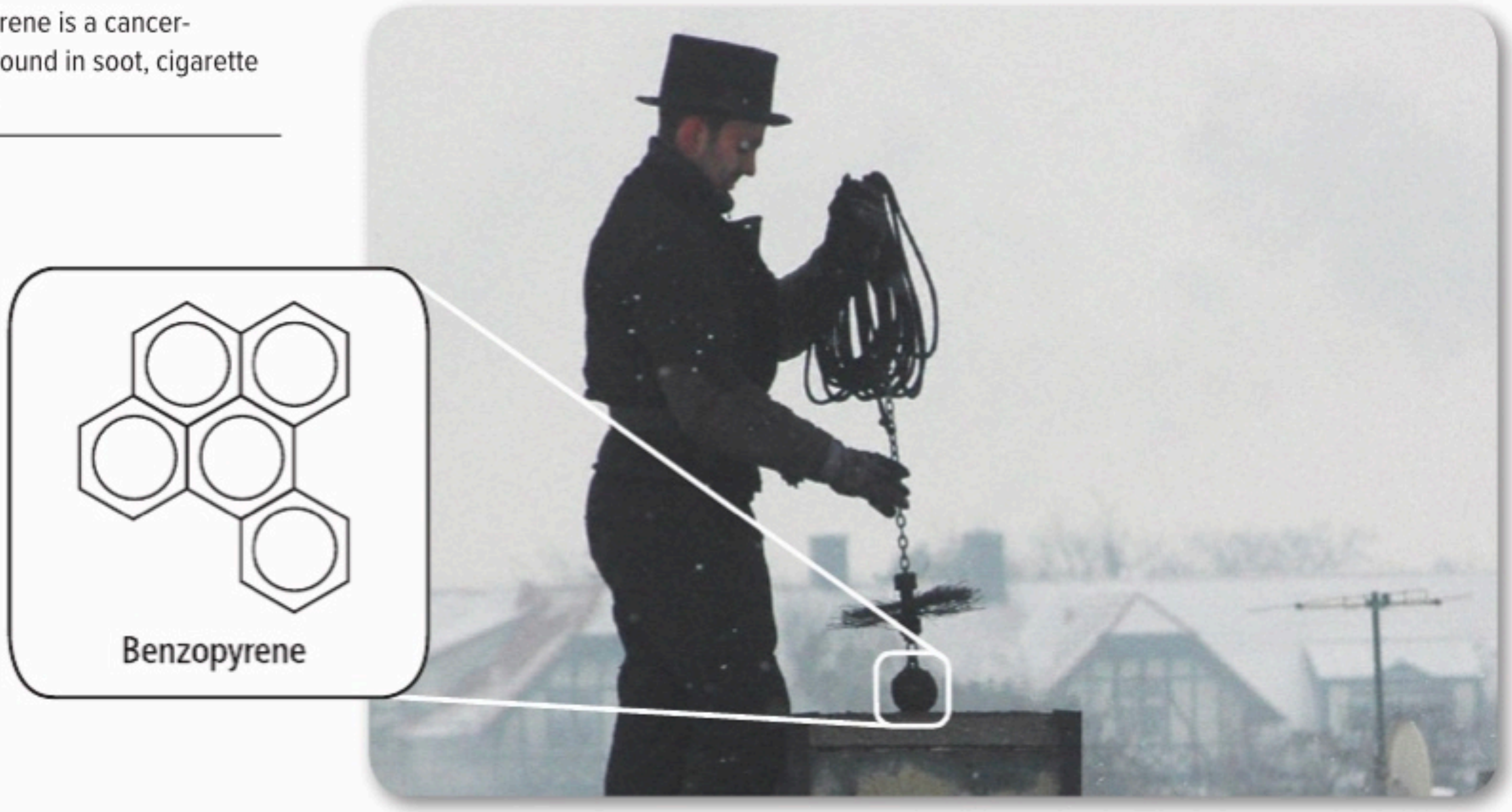


c.



32. Challenge Draw the structure of 1,4-dimethylbenzene.

Figure 28 Benzopyrene is a cancer-causing chemical that is found in soot, cigarette smoke, and car exhaust.



Carcinogens Many aromatic compounds, particularly benzene, toluene, and xylene, were once commonly used as industrial and laboratory solvents. However, tests have shown that the use of such compounds should be limited because they can affect the health of people who are exposed to them regularly. Health risks linked to aromatic compounds include respiratory ailments, liver problems, and damage to the nervous system. Beyond these hazards, some aromatic compounds are carcinogens, which are substances that can cause cancer.

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The first known carcinogen was an aromatic substance discovered around the turn of the twentieth century in chimney soot. Chimney sweeps in Great Britain were known to have abnormally high rates of cancer. Scientists discovered that the cause of the cancer was the aromatic compound benzopyrene, shown in **Figure 28.** This compound is a by-product of the burning of complex mixtures of organic substances, such as wood and coal. Some aromatic compounds found in gasoline are also known to be carcinogenic.

SECTION 5 REVIEW

Section Summary

- Aromatic hydrocarbons contain benzene rings as part of their molecular structures.
- The electrons in aromatic hydrocarbons are shared evenly over the entire benzene ring.

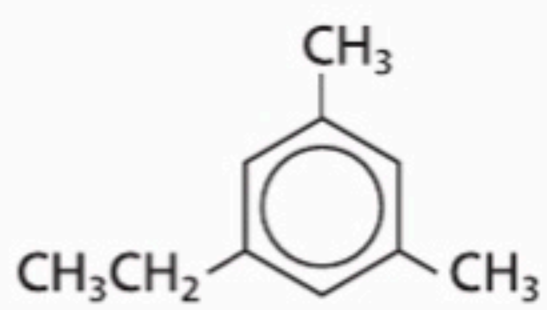
33. MAINIDEA Explain benzene's structure and how it makes the molecule unusually stable.

34. Explain how aromatic hydrocarbons differ from aliphatic hydrocarbons.

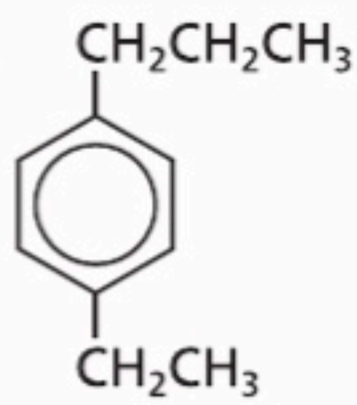
35. Describe the properties of benzene that made chemists think it was not an alkene with several double bonds.

36. Name the following structures.

a.



b.



37. Explain why the connection between benzopyrene and cancer was significant.

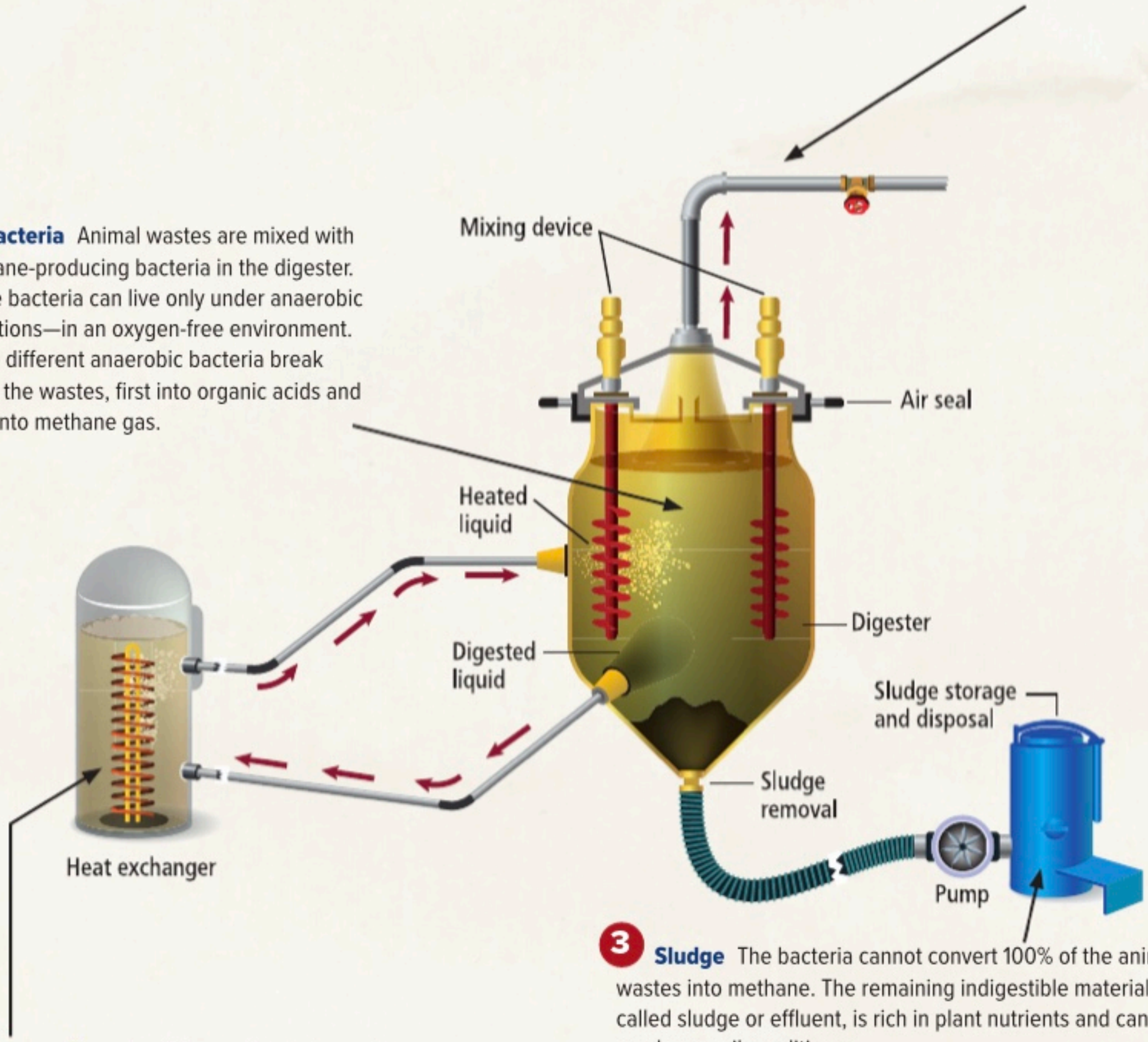
HOW IT works

POOCH TO POWER: How a Methane Digester Works

Officials in San Francisco are hoping the city's pet owners will contribute their animals' wastes to a pilot project that will convert organic matter into usable energy. A methane digester converts the wastes into biogas—a mixture of methane and carbon dioxide. Burning the methane provides energy for the city.

4 Gas Methane gas is collected, compressed, and either used immediately or stored. The methane can be used to heat homes or to generate electricity.

1 Bacteria Animal wastes are mixed with methane-producing bacteria in the digester. These bacteria can live only under anaerobic conditions—in an oxygen-free environment. Three different anaerobic bacteria break down the wastes, first into organic acids and then into methane gas.



3 Sludge The bacteria cannot convert 100% of the animal wastes into methane. The remaining indigestible material, called sludge or effluent, is rich in plant nutrients and can be used as a soil conditioner.

2 Temperature As with any chemical reaction, temperature affects methane production. Like the bacteria in our own bodies, the bacteria in the digester are most efficient between 35°C and 37°C. An external heat exchanger, combined with insulation around the digester chamber, help to keep the temperature constant and within the optimal range.

WRITING IN Chemistry

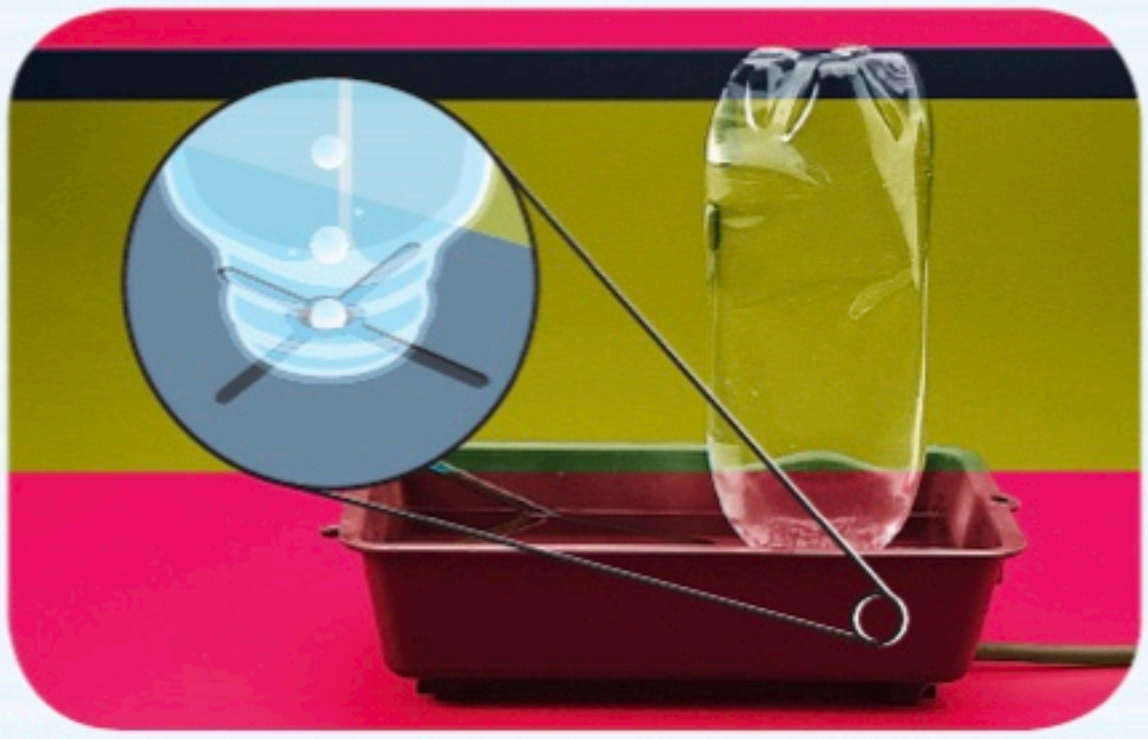
Compare Research and create a pamphlet comparing the advantages of biogas production to other forms of waste disposal for agribusinesses, such as dairies and beef, and poultry producers.

ChemLAB

Forensics: Analyze Hydrocarbon Burner Gases

Background: A valve needs to be replaced in the science lab. The custodian says the gas used in the lab is propane, and the chemistry teacher says it is natural gas (methane). Use scientific methods to settle this dispute.

Question: *What type of alkane gas is used in the science laboratory?*



Materials

barometer	pneumatic trough
thermometer	100-mL graduated cylinder
1-L or 2-L plastic soda bottle with cap	balance (0.01g)
burner tubing	paper towels

Safety Precautions

Procedure

1. Discuss the safety concerns of this lab before work begins.
2. Connect the burner tubing from the gas supply to the inlet of the pneumatic trough. Fill the trough with tap water. Open the gas valve slightly, and let a small amount of gas into the tank to flush the air out of the tubing.
3. Measure the mass of the dry plastic bottle and cap. Record the mass, barometric pressure, and air temperature.
4. Fill the bottle to overflowing with tap water, and screw on the cap. If some air bubbles remain, tap the bottle gently on the desktop until all the air has risen to the top. Add more water, and recap the bottle.
5. Place the thermometer in the trough. Invert the capped bottle into the pneumatic trough, and remove the cap while keeping the mouth of the bottle under water. Hold the mouth of the bottle directly over the inlet opening of the trough.
6. Slowly open the gas valve, and allow gas to enter the inverted bottle until all of the water has been displaced. Close the gas valve immediately. Record the temperature of the water.
7. While the bottle is still inverted, screw on the cap. Remove the bottle from the water, and dry the outside of the bottle.
8. Measure and record the mass of the bottle containing the burner gas.
9. Place the bottle in a fume hood, turn on the exhaust fan, and remove the cap. Compress the bottle several times to expel most of the gas. Refill the bottle to overflowing with water, and determine the volume of the bottle by pouring the water into a graduated cylinder. Record the volume of the bottle.
10. **Cleanup and Disposal** Clean your workspace as directed.

Analyze and Conclude

1. **Solve** The density of air at 1 atm and 20°C is 1.205 g/L. Use the volume of the bottle to compute the mass of the air the bottle contains. Use gas laws to compute the density of air at the temperature and pressure of your laboratory.
2. **Calculate** the mass of the empty bottle. Calculate the mass of the collected gas. Use the volume of gas, water temperature, and barometric pressure along with the ideal gas law to calculate the number of moles of gas collected. Use the mass of gas and the number of moles to calculate the molar mass of the gas.
3. **Conclude** How does your experimental molar mass compare with the molar masses of methane, ethane, and propane? Infer which gases are in the burner gas in your lab.
4. **Error Analysis** Suggest possible sources of error in the experiment.

INQUIRY EXTENSION

Design an Experiment to test how one variable, such as temperature or atmospheric pressure, affects your results.

CHAPTER 8 STUDY GUIDE

BIGIDEA **Organic compounds called hydrocarbons differ by their types of bonds.**

SECTION 1 Introduction to Hydrocarbons

MAINIDEA Hydrocarbons are carbon-containing organic compounds that provide a source of energy and raw materials.

- Organic compounds contain the element carbon, which is able to form straight chains and branched chains.
- Hydrocarbons are organic substances composed of carbon and hydrogen.
- The major sources of hydrocarbons are petroleum and natural gas.
- Petroleum can be separated into components by the process of fractional distillation.

VOCABULARY

- **organic compound**
- **hydrocarbon**
- **saturated hydrocarbon**
- **unsaturated hydrocarbon**
- **fractional distillation**
- **cracking**

SECTION 2 Alkanes

MAINIDEA Alkanes are hydrocarbons that contain only single bonds.

- Alkanes contain only single bonds between carbon atoms.
- Alkanes and other organic compounds are best represented by structural formulas and can be named using systematic rules determined by the International Union of Pure and Applied Chemistry (IUPAC).
- Alkanes that contain hydrocarbon rings are called cyclic alkanes.

VOCABULARY

- **alkane**
- **homologous series**
- **parent chain**
- **substituent group**
- **cyclic hydrocarbon**
- **cycloalkane**

SECTION 3 Alkenes and Alkynes

MAINIDEA Alkenes are hydrocarbons that contain at least one double bond, and alkynes are hydrocarbons that contain at least one triple bond.

- Alkenes and alkynes are hydrocarbons that contain at least one double or triple bond, respectively.
- Alkenes and alkynes are nonpolar compounds with greater reactivity than alkanes but with other properties similar to those of alkanes.

VOCABULARY

- **alkene**
- **alkyne**

SECTION 4 Hydrocarbon Isomers

MAINIDEA Some hydrocarbons have the same molecular formula but have different molecular structures.

- Isomers are two or more compounds with the same molecular formula but different molecular structures.
- Structural isomers differ in the order in which atoms are bonded to each other.
- Stereoisomers have all atoms bonded in the same order but arranged differently in space.

VOCABULARY

- **isomer**
- **structural isomer**
- **stereoisomer**
- **geometric isomer**
- **chirality**
- **asymmetric carbon**
- **optical isomer**
- **optical rotation**

SECTION 5 Aromatic Hydrocarbons

MAINIDEA Aromatic hydrocarbons are unusually stable compounds with ring structures in which electrons are shared by many atoms.

- Aromatic hydrocarbons contain benzene rings as part of their molecular structures.
- The electrons in aromatic hydrocarbons are shared evenly over the entire benzene ring.

VOCABULARY

- **aromatic compound**
- **aliphatic compound**

CHAPTER 8 ASSESSMENT

SECTION 1

Mastering Concepts

38. **Organic Chemistry** Why did WÖhler's discovery lead to the development of the field of organic chemistry?

39. What is the main characteristic of an organic compound?

40. What characteristic of carbon accounts for the large variety of organic compounds?

41. Name two natural sources of hydrocarbons.

42. Explain what physical property of petroleum compounds is used to separate them during fractional distillation.

43. Explain the difference between saturated hydrocarbons and unsaturated hydrocarbons.

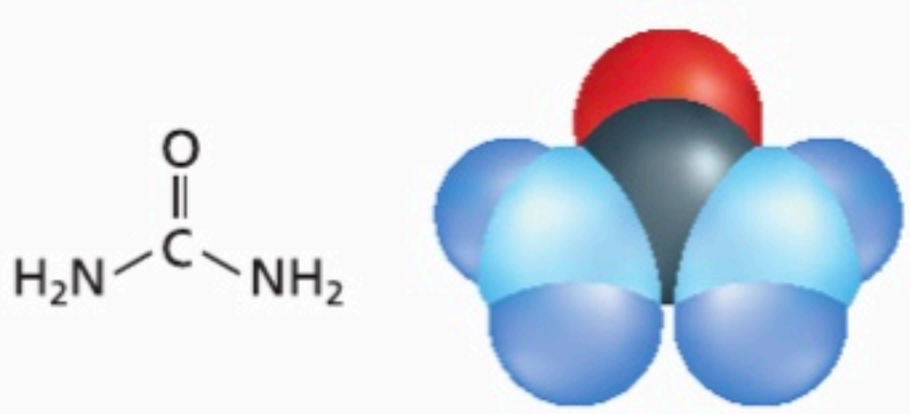
Mastering Problems

44. **Distillation** Rank the compounds listed in **Table 7** in the order in which they will be distilled out of a mixture. Rank the compounds in order of first to distill to last to distill.

Table 7 Alkane Boiling Points

Compound	Boiling Point (°C)
hexane	68.7
methane	−161.7
octane	125.7
butane	−0.5
propane	−42.1

45. How many electrons are shared between two carbon atoms in each of the following carbon-carbon bonds?
    a. single bond
    b. double bond
    c. triple bond



■ **Figure 29**

46. **Figure 29** shows two models of urea, a molecule that Friedrich Wöhler first synthesized in 1828.
    a. Identify the types of models shown.
    b. Is urea an organic or an inorganic compound? Explain your answer.

47. Molecules are modeled using molecular formulas, structural formulas, ball-and-stick models, and space-filling models. What are the advantages and disadvantages of each model?

SECTION 2

Mastering Concepts

48. Describe the characteristics of a homologous series of hydrocarbons.

49. **Fuels** Name three alkanes used as fuels and describe an additional application for each.

50. Draw the structural formula of each of the following.
    a. ethane
    b. hexane
    c. propane
    d. heptane

51. Write the condensed structural formulas for the alkanes in the previous question.

52. Write the name and draw the structure of the alkyl group that corresponds to each of the following alkanes.
    a. methane
    b. butane
    c. octane

53. How does the structure of a cycloalkane differ from that of a straight-chain or branched-chain alkane?

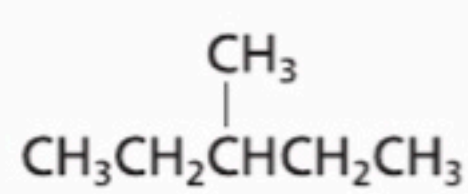
54. **Freezing and Boiling Points** Use water and methane to explain how intermolecular attractions generally affect the boiling and freezing points of a substance.

Mastering Problems

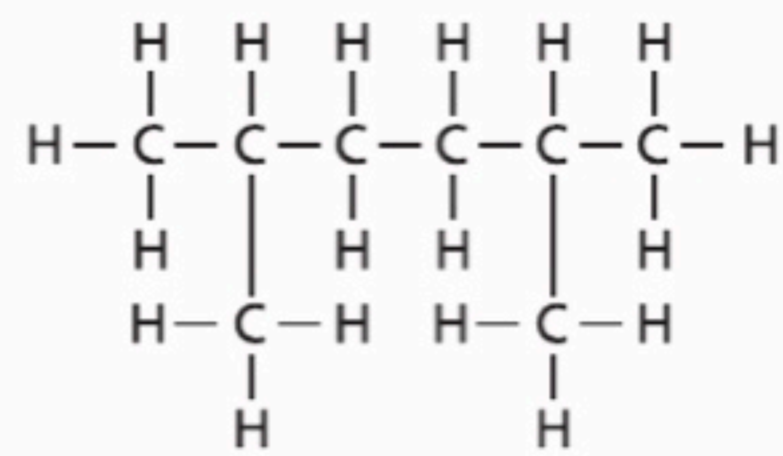
55. Name the compound represented by each of the following structural formulas.

a. $CH_3CH_2CH_2CH_2CH_3$

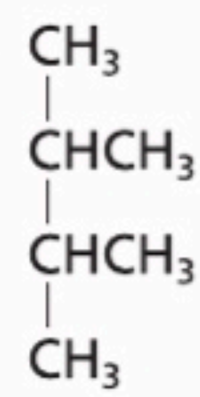
b.



c.



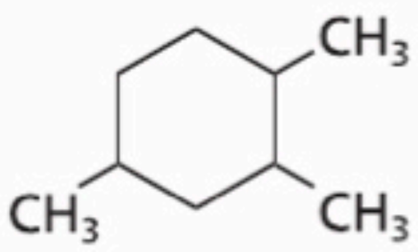
d.

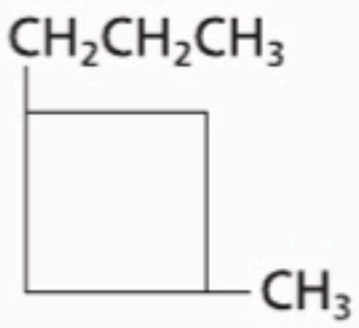


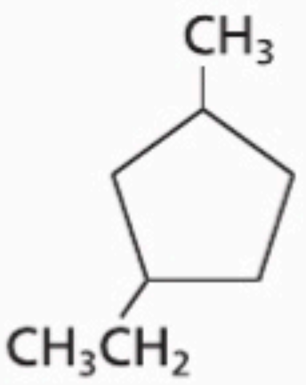
56. Draw full structural formulas for the following compounds.
    a. heptane
    b. 2-methylhexane
    c. 2,3-dimethylpentane
    d. 2,2-dimethylpropane

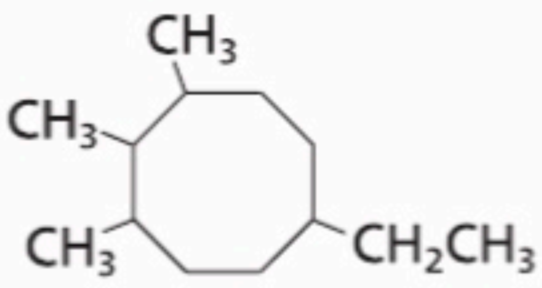
57. Draw condensed structural formulas for the following compounds. Use line structures for rings.
    a. 1,2-dimethylcyclopropane
    b. 1,1-diethyl-2-methylcyclopentane

58. Name the compound represented by each of the following structural formulas.

a. 

c. 

b. 

d. 

SECTION 3

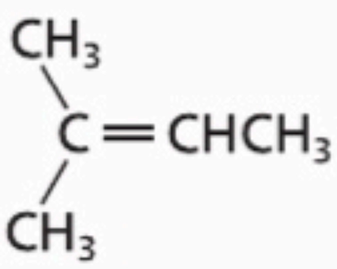
Mastering Concepts

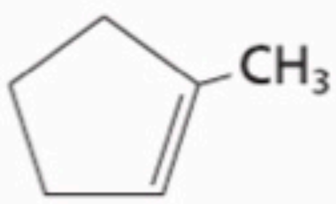
59. Explain how alkenes differ from alkanes. How do alkynes differ from both alkenes and alkanes?

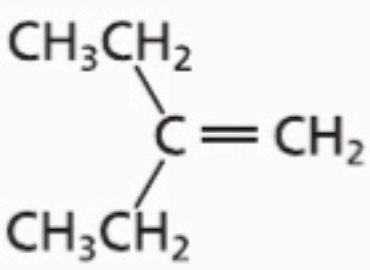
60. The name of a hydrocarbon is based on the name of the parent chain. Explain how the determination of the parent chain when naming alkenes differs from the same determination when naming alkanes.

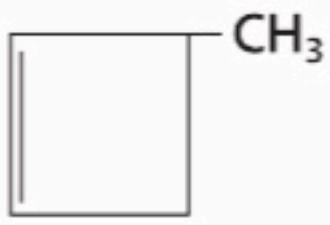
Mastering Problems

61. Name the compound represented by each of the following condensed structural formulas.

a. 

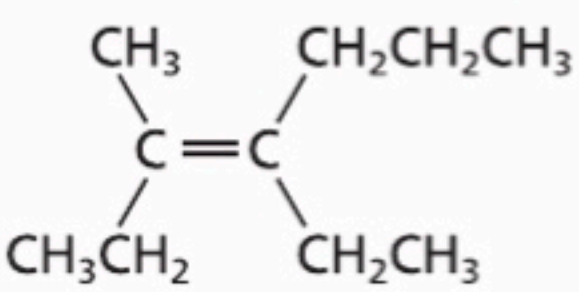
c. 

b. 

d. 

62. Draw condensed structural formulas for the following compounds. Use line structures for rings.
a. 1,4-diethylcyclohexene
b. 2,4-dimethyl-1-octene
c. 2,2-dimethyl-3-hexyne

63. Name the compound represented by the following condensed structural formula.



SECTION 4

Mastering Concepts

64. How are two isomers alike, and how are they different?

65. Describe the difference between *cis*- and *trans*-isomers in terms of geometrical arrangement.

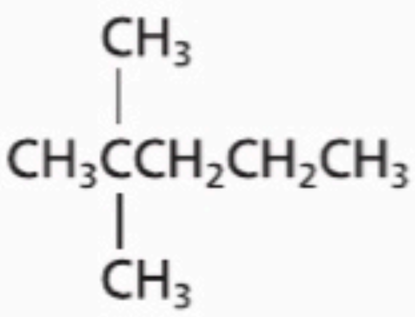
66. What are the characteristics of a chiral substance?

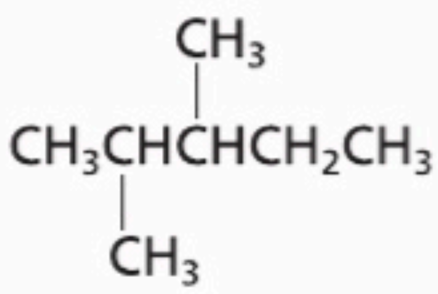
67. **Light** How does polarized light differ from ordinary light, such as light from the Sun?

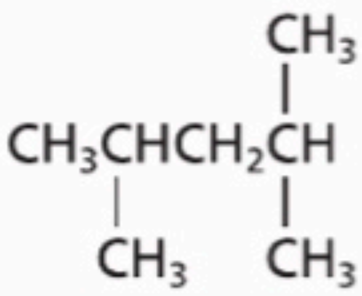
68. How do optical isomers affect polarized light?

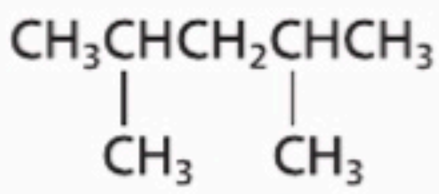
Mastering Problems

69. Identify the pair of structural isomers in the following group of condensed structural formulas.

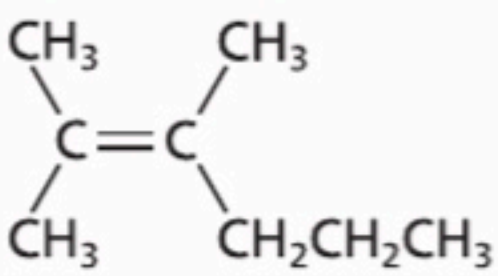
a. 

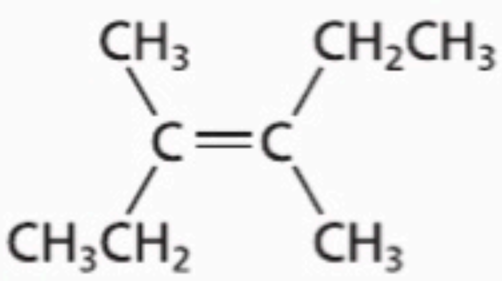
c. 

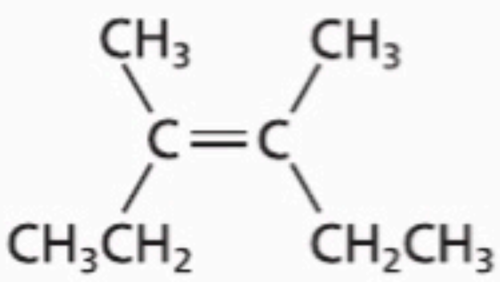
b. 

d. 

70. Identify the pair of geometric isomers among the following structures. Explain your selections. Explain how the third structure is related to the other two.

a. 

b. 

c. 

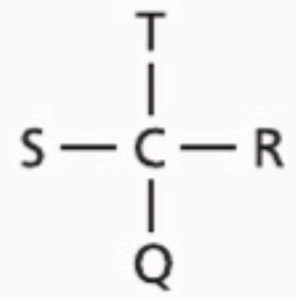
71. Draw condensed structural formulas for four different structural isomers with the molecular formula C_4H_8.

72. Draw and label the *cis*- and *trans*- isomers of the molecule represented by the following condensed formula.

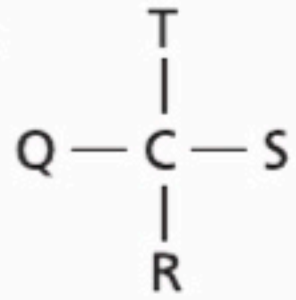
$$CH_3CH=CHCH_2CH_3$$

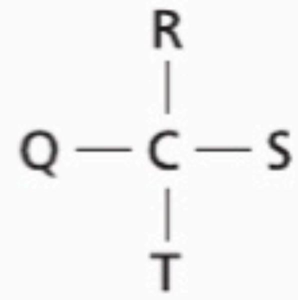
ASSESSMENT

73. Three of the following structures are exactly alike, but the fourth represents an optical isomer of the other three. Identify the optical isomer, and explain how you made your choice.

a. 

c. 

b. 

d. 

SECTION 5

Mastering Concepts

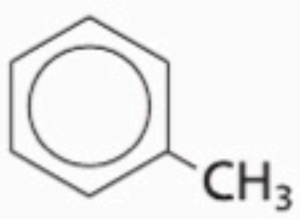
74. What structural characteristic do all aromatic hydrocarbons share?

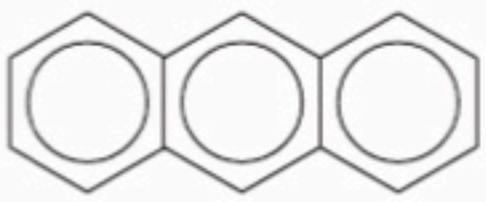
75. What are carcinogens?

Mastering Problems

76. Draw the structural formula of 1,2-dimethylbenzene.

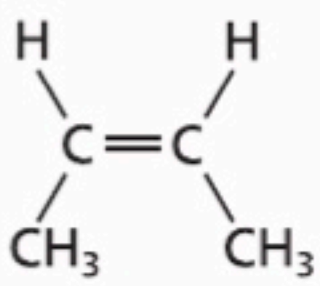
77. Name the compound represented by each of the following structural formulas.

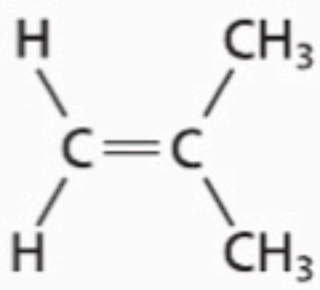
a. 

b. 

MIXED REVIEW

78. Do the following structural formulas represent the same molecule? Explain your answer.

a. 

b. 

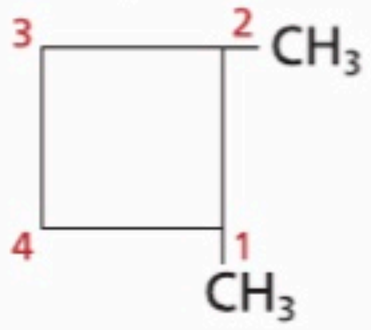
79. How many hydrogen atoms are in an alkane molecule with nine carbon atoms? How many are in an alkene with nine carbon atoms and one double bond?

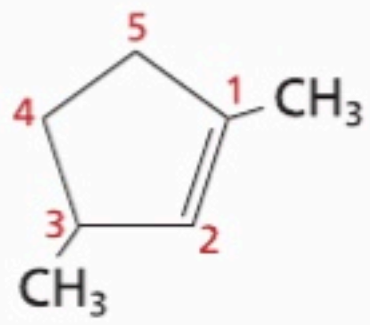
80. The general formula for alkanes is C_nH_{2n+2}. Determine the general formula for cycloalkanes.

81. Manufacturing Why are unsaturated hydrocarbons more useful than saturated hydrocarbons as starting materials in chemical manufacturing?

82. Is cyclopentane an isomer of pentane? Explain your answer.

83. Determine whether each of the following structures shows the correct numbering. If the numbering is incorrect, redraw the structure with the correct numbering.

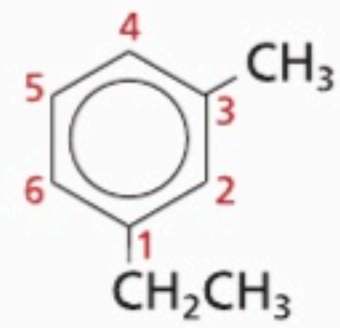
a. 

c. 

b.

1 2 3 4 5

$CH_3CH_2C \equiv CCH_3$

d. 

84. Why do chemists use structural formulas for organic compounds rather than molecular formulas, such as C_5H_{12}?

85. Which would you expect to have more similar physical properties, a pair of structural isomers or a pair of stereoisomers? Explain your reasoning.

86. Explain why numbers are needed in the IUPAC names of many unbranched alkenes and alkynes but not in the names of unbranched alkanes.

87. A compound with two double bonds is called a diene. The name of the structure shown is 1,4-pentadiene. Apply your knowledge of IUPAC nomenclature to draw the structure of 1,3-pentadiene.

$$H_2C{=}CH{-}CH_2{-}CH{=}CH_2$$

THINK CRITICALLY

88. Determine which two of the following names cannot be correct, and draw the structures of the molecules.

a. 2-ethyl-2-butene
b. 1,4-dimethylcyclohexene
c. 1,5-dimethylbenzene

89. Infer The sugar glucose is sometimes called dextrose because a solution of glucose is known to be dextrorotatory. Analyze the word *dextrorotatory*, and suggest what the word means.

90. Interpret Scientific Illustrations Draw Kekulé's structure of benzene, and explain why it does not truly represent the actual structure.

91. Recognize Cause and Effect Explain why alkanes, such as hexane and cyclohexane, are effective at dissolving grease, whereas water is not.

92. Explain Use **Table 8** to construct a statement explaining the relationship between numbers of carbon atoms and boiling points of the members of the alkane series shown.

93. Graph the information given in **Table 8.** Predict what the boiling and melting points of the 11- and 12-carbon alkanes will be. Look up the actual values and compare your predictions to the those numbers.

Table 8 Data for Selected Alkanes

Name	Melting Point (°C)	Boiling Point (°C)
CH_4	−182	−162
C_2H_6	−183	−89
C_3H_8	−188	−42
C_4H_{10}	−138	−0.5
C_5H_{12}	−130	36
C_6H_{14}	−95	69
C_7H_{16}	−91	98
C_8H_{18}	−57	126
C_9H_{20}	−54	151
$C_{10}H_{22}$	−29	174

CHALLENGE PROBLEM

94. Chiral Carbons Many organic compounds have more than one chiral carbon. For each chiral carbon in a compound, a pair of stereoisomers can exist. The total number of possible isomers for the compound is equal to 2 *n*, where *n* is the number of chiral carbons. Draw each structure, and determine how many stereoisomers are possible for each compound named below.
a. 3,5-dimethylnonane
b. 3,7-dimethyl-5-ethyldecane

CUMULATIVE REVIEW

95. What element has the following ground-state electron configuration: $[Ar]4s^23d^6$?

96. What is the charge of an ion formed from the following families?
a. alkali metals
b. alkaline earth metals
c. halogens

97. Write the chemical equations for the complete combustion of ethane, ethene, and ethyne into carbon dioxide and water.

WRITING IN ▶ Chemistry

98. Gasoline For many years, a principal antiknock ingredient in gasoline was the compound tetraethyllead. Research to learn about the structure of this compound, the history of its development and use, and why its use was discontinued in the United States. Find out if it is still used as a gasoline additive elsewhere in the world.

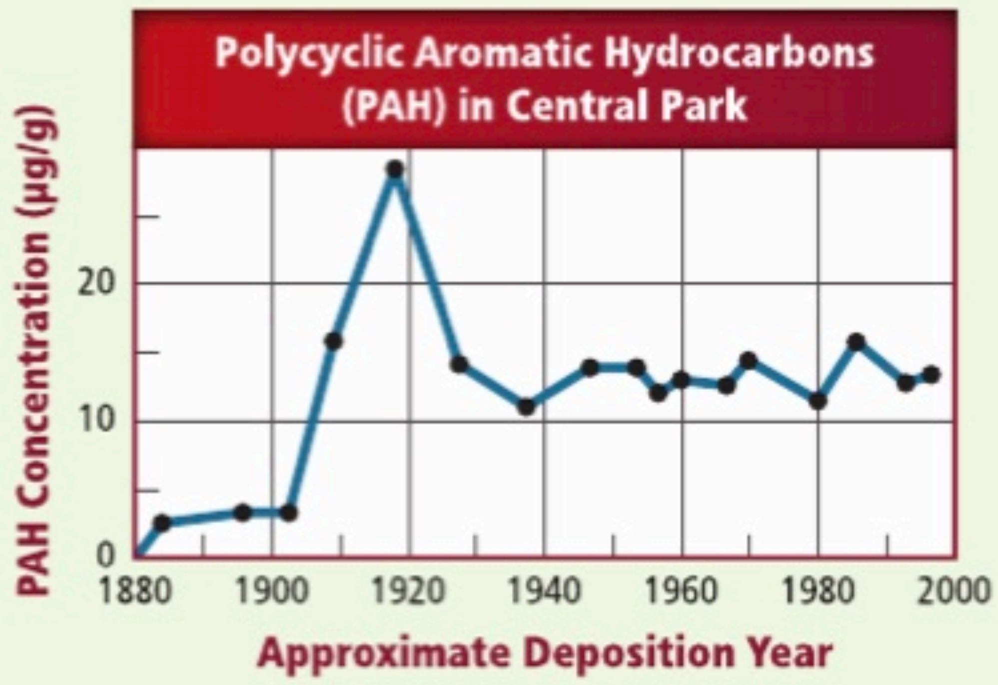
99. Perfume The musk used in perfumes and colognes contains many chemical compounds, including large cycloalkanes. Research and write a short report about the sources used for natural and synthetic musk compounds in these consumer products.

DBQ Document-Based Questions

Polycyclic Aromatic Hydrocarbons *PAH compounds are naturally occurring, but human activities can increase the concentrations in the environment. Soil samples were collected to study PAH compounds. The core sections were dated using radionuclides to determine when each section was deposited.*

Figure 30 *shows the concentration of polycyclic aromatic hydrocarbons (PAH) detected in Central Park in New York City.*

Data obtained from: Yan, B. et al, 2005. *Environmental Science Technology* 39 (18): 7012–7019.



■ **Figure 30**

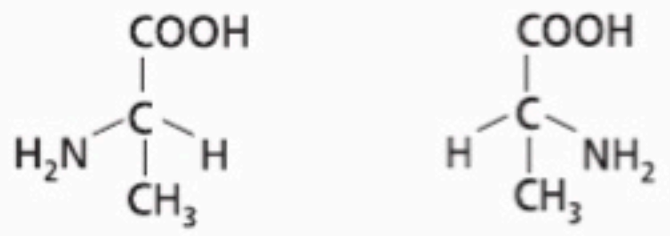
100. Compare the average PAH concentrations before 1905 and after 1925.

101. PAH compounds are produced in small amounts by some plants and animals, but most come from human activities, such as burning fossil fuels. Infer why the PAH levels were relatively low in the late 1800s and early 1900s.

CUMULATIVE STANDARDIZED TEST PRACTICE

MULTIPLE CHOICE

1. Alanine, like most amino acids, exists in two forms:



l-Alanine d-Alanine

Almost all of the amino acids found in living organisms are in the l-form. Which term best describes l-alanine and d-alanine with respect to one another?

A. structural isomers
B. geometric isomers
C. optical isomers
D. stereoisotopes

2. Which does NOT affect reaction rate?

A. catalysts
B. surface area of reactants
C. concentration of reactants
D. reactivity of products

3. What is the molality of a solution containing 0.25 g of dichlorobenzene ($C_6H_4Cl_2$) dissolved in 10.0 g of cyclohexane (C_6H_{12})?

A. 0.17 mol/kg
B. 0.014 mol/kg
C. 0.025 mol/kg
D. 0.00017 mol/kg

Use the table below to answer Questions 4 to 6.

Data for Various Hydrocarbons				
Name	Number of C Atoms	Number of H Atoms	Melting Point (°C)	Boiling Point (°C)
Heptane	7	16	−90.6	98.5
1-Heptene	7	14	−119.7	93.6
1-Heptyne	7	12	−81	99.7
Octane	8	18	−56.8	125.6
1-Octene	8	16	−101.7	121.2
1-Octyne	8	14	−79.3	126.3

4. Based on the information in the table, what type of hydrocarbon becomes a gas at the lowest temperature?

A. alkane
B. alkene
C. alkyne
D. aromatic

5. If *n* is the number of carbon atoms in the hydrocarbon, what is the general formula for an alkyne with one triple bond?

A. C_nH_{n+2}
B. C_nH_{2n+2}
C. C_nH_{2n}
D. C_nH_{2n-2}

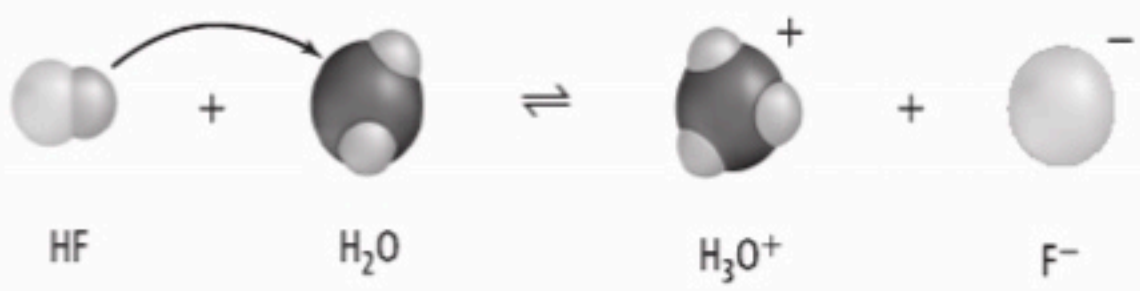
6. It can be predicted from the table that nonane will have a melting point that is

A. greater than that of octane.
B. less than that of heptane.
C. greater than that of decane.
D. less than that of hexane.

7. At a pressure of 1.00 atm and a temperature of 20°C, 1.72 g CO_2 will dissolve in 1 L of water. How much CO_2 will dissolve if the pressure is raised to 1.35 atm and the temperature stays the same?

A. 2.32 g/L
B. 1.27 g/L
C. 0.785 g/L
D. 0.431 g/L

Use the diagram below to answer Question 8.



8. In the forward reaction, which substance is the Brønsted-Lowry acid?

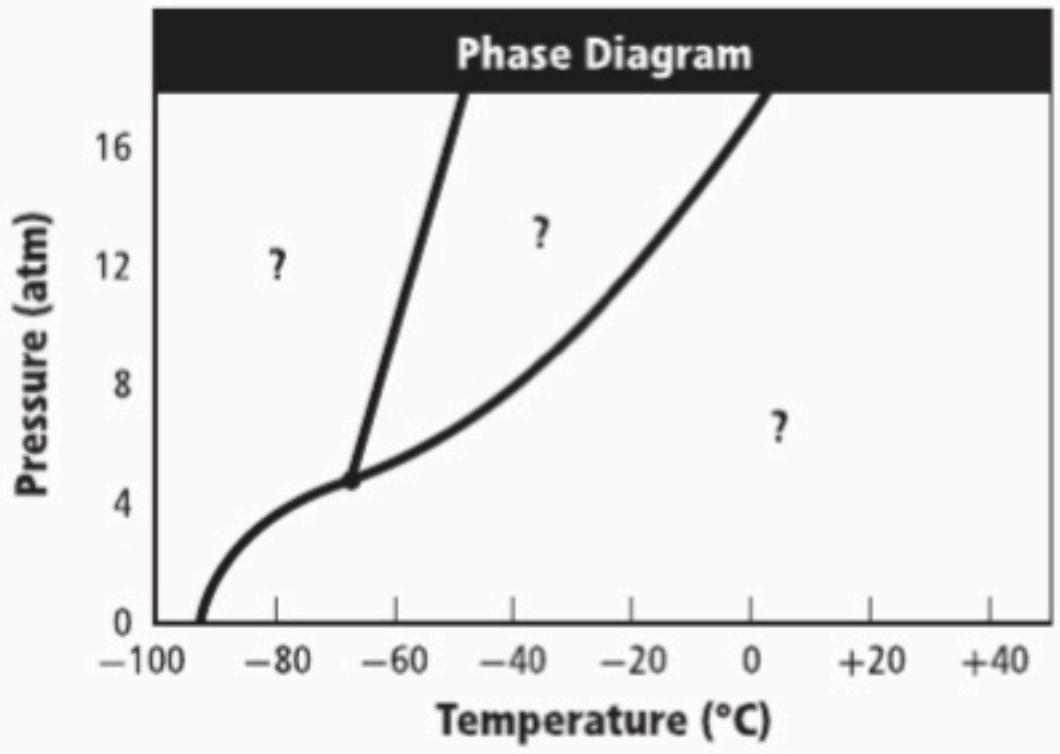
A. HF
B. H_2O
C. H_3O^+
D. F^-

9. Which does NOT describe what happens as a liquid boils?

A. The temperature of the system rises.
B. Energy is absorbed by the system.
C. The vapor pressure of the liquid is equal to atmospheric pressure.
D. The liquid is entering the gas phase.

SHORT ANSWER

Use the diagram below to answer Questions 10 to 12.



10. What state of matter is located at a temperature of −80°C and a pressure of 10 atm?

11. What are the temperature and pressure when the substance is at its triple point?

12. Describe the changes in molecular arrangement that occur when the pressure is increased from 8 atm to 16 atm, while the temperature is held constant at 0°C.

EXTENDED RESPONSE

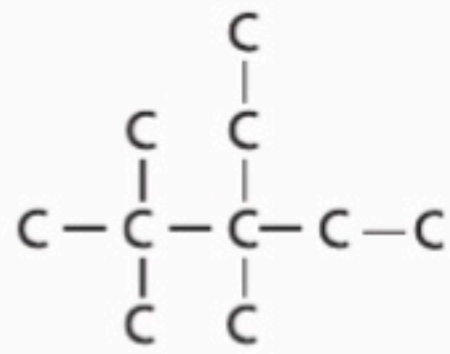
Use the data table below to answer Questions 13 and 14.

Experimental Data for the Reaction between A and B		
[A] Initial	[B] Initial	Initial rate (mol/L·s)
0.10*M*	0.10*M*	7.93
0.30*M*	0.10*M*	23.79
0.30*M*	0.20*M*	95.16

13. Find the values of *m* and *n* for the rate law expression $rate = k[A]^m[B]^n$.

14. Determine the value of *k* for this reaction.

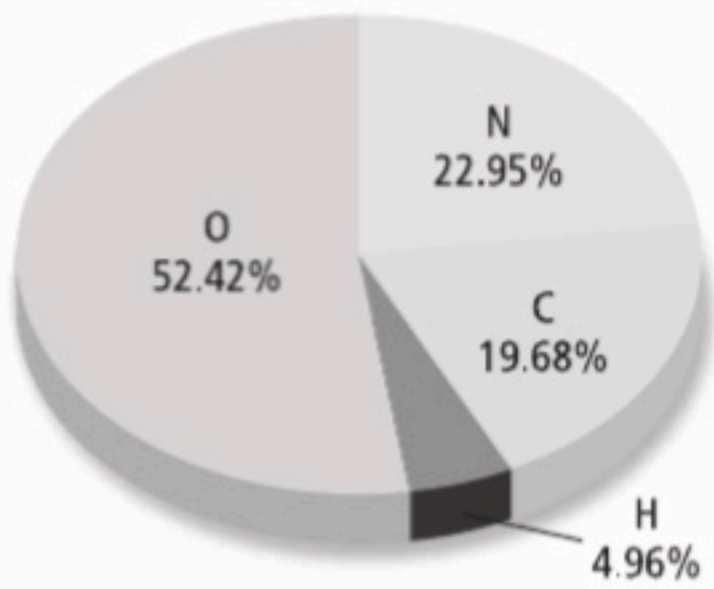
SAT SUBJECT TEST: CHEMISTRY



15. What is the name of the compound whose skeletal formula is shown above?

A. 2,2,3-trimethyl-3-ethylpentane
B. 3-ethyl-3,4,4-trimethylpentane
C. 2-butyl-2-ethylbutane
D. 3-ethyl-2,2,3-trimethylpentane
E. 2,2-dimethyl, 3-diethyl, 3-methylpropane

Use the graph below to answer Questions 16 and 17.



16. What is the formula for this compound?

A. $C_5H_{20}N_4O_2$
B. $C_8H_2N_9O_{11}$
C. $C_{1.6}H_5N_{1.6}O_{3.3}$
D. CH_3NO_2
E. $C_2H_5N_2O_5$

17. How many grams of nitrogen would be present in 475 g of this compound?

A. 33.9 g
B. 52.8 g
C. 67.9 g
D. 109 g
E. 120.0 g

CHAPTER 9

Substituted Hydrocarbons and Their Reactions

BIGIDEA **The substitution of different functional groups for hydrogen atoms in hydrocarbons results in a diverse group of organic compounds.**

SECTIONS

1 Alkyl Halides and Aryl Halides

2 Alcohols, Ethers, and Amines

3 Carbonyl Compounds

4 Other Reactions of Organic Compounds

5 Polymers

LaunchLAB

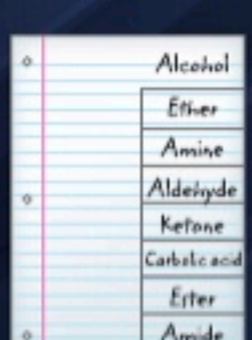
How do you make slime?

In addition to carbon and hydrogen, most organic substances contain other elements that give the substances unique properties. In this lab, you will determine how the properties of substances change when groups form bonds called crosslinks between the chains.

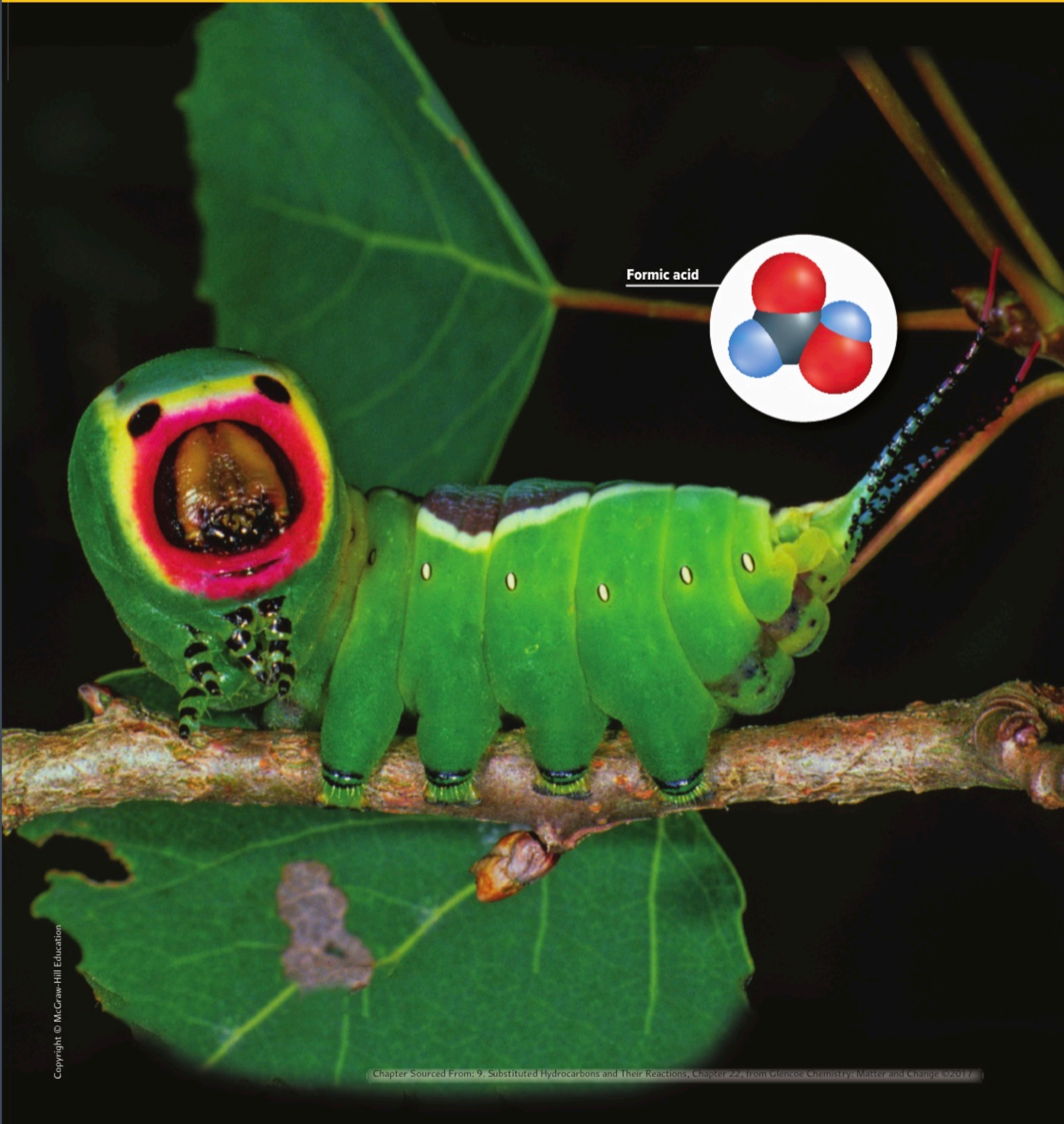
FOLDABLES® Study Organizer

Functional Groups

Make a top-tab book. Label it as shown. Use it to organize information about the functional groups of organic compounds.



The larva of the *Cerura vinula* moth squirts formic acid when threatened. Formic acid is a substituted hydrocarbon—a type of compound that forms when one or more hydrogens in a hydrocarbon are replaced by other atoms.


Formic acid

SECTION 1

Alkyl Halides and Aryl Halides

MAINIDEA A halogen atom can replace a hydrogen atom in some hydrocarbons.

Essential Questions

- What are functional groups, and what are some examples?
- How do alkyl and aryl halide structures compare and contrast?
- What factors affect the boiling points of organic halides?

Review Vocabulary

aliphatic compound: a nonaromatic hydrocarbon, such as an alkane, an alkene, or an alkyne

New Vocabulary

functional group
halocarbon
alkyl halide
aryl halide
plastic
substitution reaction
halogenation

CHEM 4 YOU If you have ever played on a sports team, were individual players substituted during the game? For example, a player who is rested might substitute for a player who is tired. After the substitution, the characteristics of the team change.

Functional Groups

You read previously that in hydrocarbons, carbon atoms are linked only to other carbon atoms or hydrogen atoms. But carbon atoms can also form strong covalent bonds with other elements, the most common of which are oxygen, nitrogen, fluorine, chlorine, bromine, iodine, sulfur, and phosphorus.

Atoms of these elements occur in organic substances as parts of functional groups. In an organic molecule, a **functional group** is an atom or group of atoms that always reacts in a certain way. The addition of a functional group to a hydrocarbon structure always produces a substance with physical and chemical properties that differ from those of the parent hydrocarbon. All the items–natural and synthetic–in **Figure 1** contain functional groups that give them their individual characteristics, such as smell. Organic compounds containing several important functional groups are shown in **Table 1.** The symbols R and R' represent carbon chains or rings bonded to the functional group. An* represents a hydrogen atom, carbon chain, or carbon ring.

Keep in mind that double and triple bonds between two carbon atoms are considered functional groups even though only carbon and hydrogen atoms are involved. By learning the properties associated with a given functional group, you can predict the properties of organic compounds for which you know the structure, even if you have never studied them.

■ **Figure 1** All of these items contain at least one of the functional groups that you will study in this chapter. For example, the fruit and flowers have sweet-smelling aromas that are due to ester molecules.

Table 1 Organic Compounds and Their Functional Groups

Compound Type	General Formula	Functional Group
Halocarbon	R—X (X = F, Cl, Br, I)	Halogen
Alcohol	R—OH	Hydroxyl
Ether	R—O—R′	Ether
Amine	$R—NH_2$	Amino
Aldehyde	$*-\overset{\displaystyle O}{\overset{\|}{C}}-H$	Carbonyl
Ketone	$R-\overset{\displaystyle O}{\overset{\|}{C}}-R'$	Carbonyl
Carboxylic acid	$*-\overset{\displaystyle O}{\overset{\|}{C}}-OH$	Carboxyl
Ester	$*-\overset{\displaystyle O}{\overset{\|}{C}}-O-R$	Ester
Amide	$*-\overset{\displaystyle O}{\overset{\|}{C}}-\overset{\displaystyle H}{\overset{\mid}{N}}-R$	Amide

Organic Compounds Containing Halogens

The most simple functional groups can be thought of as substituent groups attached to a hydrocarbon. Recall that a substituent group is a side branch attached to a parent chain. The elements in group 17 of the periodic table–fluorine, chlorine, bromine, and iodine–are the halogens. Any organic compound that contains a halogen substituent is called a **halocarbon.** If you replace any of the hydrogen atoms in an alkane with a halogen atom, you form an alkyl halide. An **alkyl halide** is an organic compound containing a halogen atom covalently bonded to an aliphatic carbon atom. The first four halogens–fluorine, chlorine, bromine, and iodine–are found in many organic compounds. For example, chloromethane is the alkyl halide formed when a chlorine atom replaces one of methane's four hydrogen atoms, as shown in **Figure 2.**

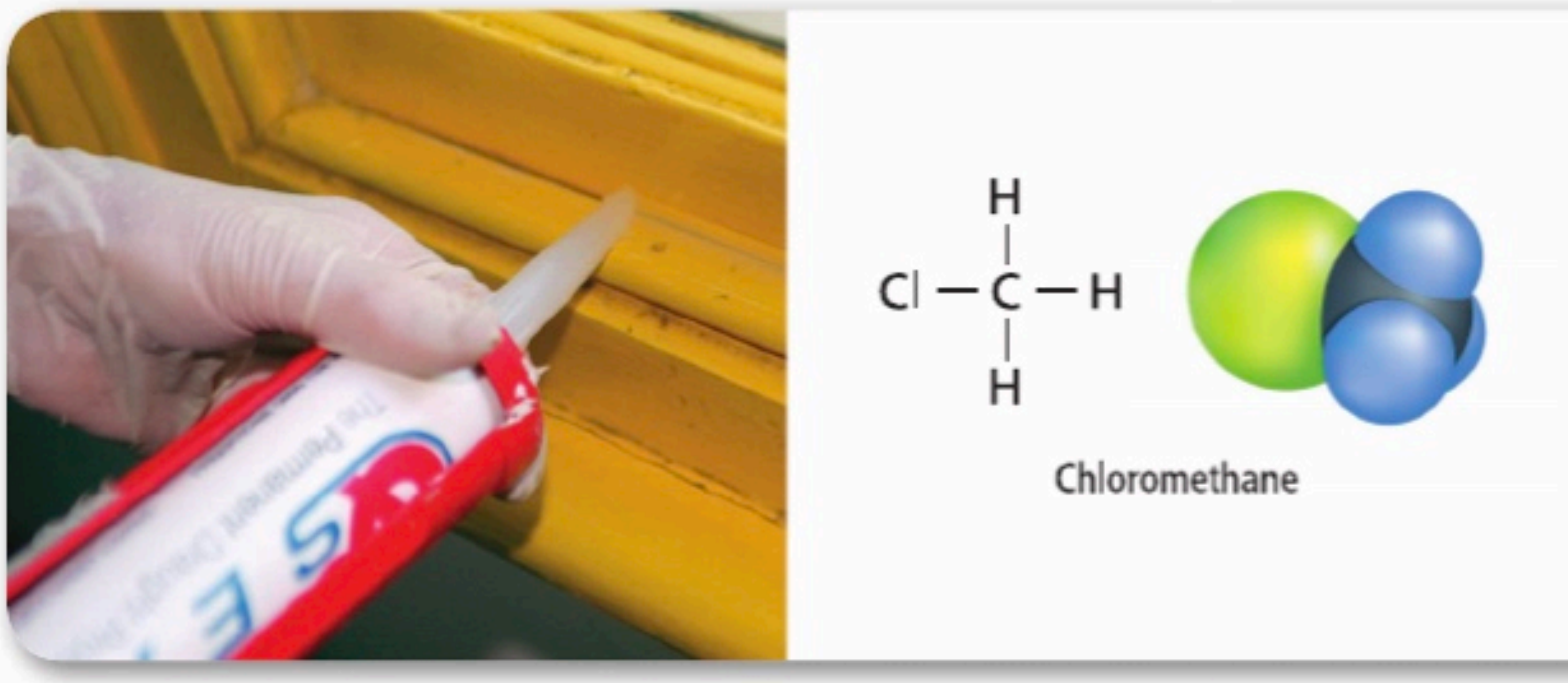


Figure 2 Chloromethane is an alkyl halide that is used in the manufacturing process for silicone products, such as window and door sealants.

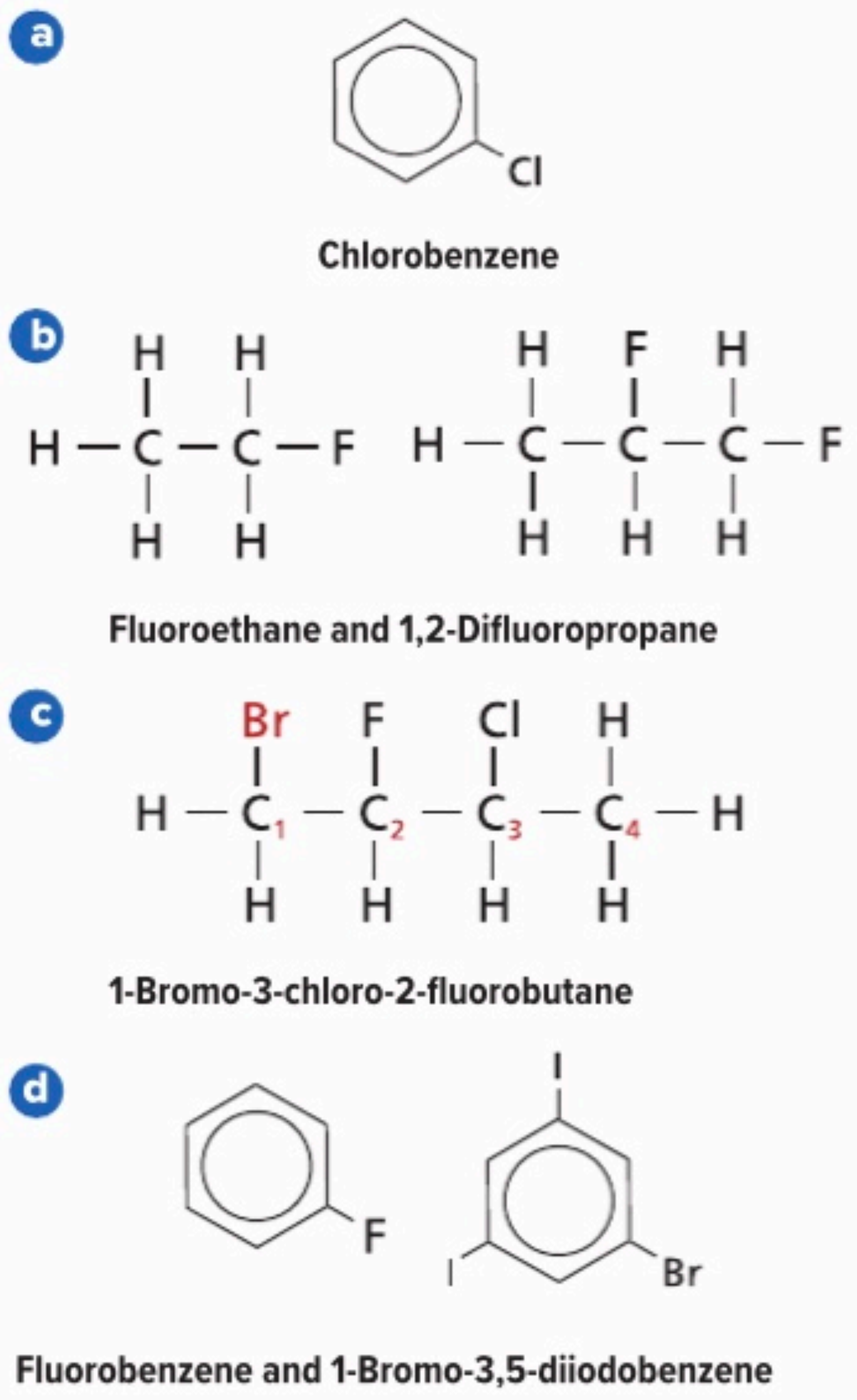


Figure 3 Organic molecules containing functional groups are named based on their main-chain alkane structure using IUPAC conventions.

An **aryl halide** is an organic compound containing a halogen atom bonded to a benzene ring or other aromatic group. The structural formula for an aryl halide is created by first drawing the aromatic structure and then replacing its hydrogen atoms with the halogen atoms specified, as shown in **Figure 3a.**

Connection to Earth Science Alkyl halides are widely used as refrigerants. Until the late 1980s, alkyl halides called chlorofluorocarbons (CFCs) were widely used in refrigerators and air-conditioning systems. Recall how CFCs affect the ozone layer. CFCs have been replaced by HFCs (hydrofluorocarbons), which contain only hydrogen and fluorine atoms bonded to carbon. One of the more common HFCs is 1,1,2-trifluoroethane, also called R134a.

Naming halocarbons Organic molecules containing functional groups are given IUPAC names based on their main-chain alkane structures. For the alkyl halides, a prefix indicates which halogen is present. The prefixes are formed by changing the *-ine* at the end of each halogen name to *-o*. Thus, the prefix for fluorine is *fluoro-*, chlorine is *chloro-*, bromine is *bromo-*, and iodine is *iodo-*, as shown in **Figure 3b.**

If more than one kind of halogen atom is present in the same molecule, the atoms are listed alphabetically in the name. The chain also must be numbered in a way that gives the lowest position number to the substituent that comes first in the alphabet. Note how the alkyl halide in **Figure 3c** is named.

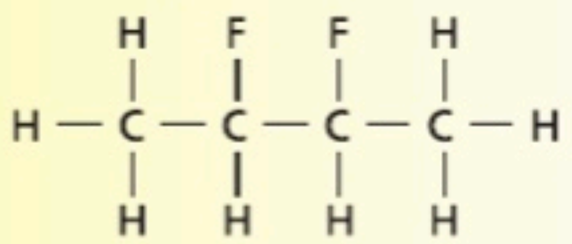
Similarly, the benzene ring in an aryl halide is numbered to give each substituent the lowest position number possible, as shown in **Figure 3d.**

☑ **READING CHECK** **Infer** why the lowest possible position number is used to name an aryl halide instead of using a randomly chosen position number.

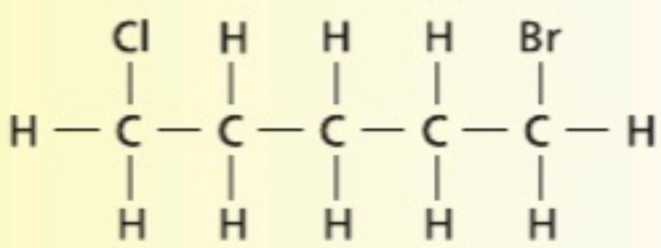
APPLICATIONS

Name the alkyl or aryl halide whose structure is shown.

1.



2.



3.

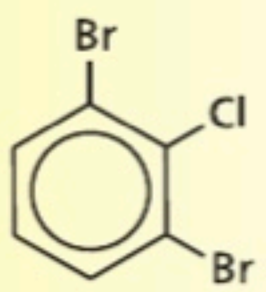


Table 2 A Comparison of Alkyl Halides and Their Parent Alkanes

Structure	Name	Boiling Point (°C)	Density (g/mL) in Liquid State
CH_4	methane	−162	0.423 at −162°C (boiling point)
CH_3Cl	chloromethane	−24	0.911 at 25°C (under pressure)
$CH_3CH_2CH_2CH_2CH_3$	pentane	36	0.626
$CH_3CH_2CH_2CH_2CH_2F$	1-fluoropentane	62.8	0.791
$CH_3CH_2CH_2CH_2CH_2Cl$	1-chloropentane	108 *Increases*	0.882 *Increases*
$CH_3CH_2CH_2CH_2CH_2Br$	1-bromopentane	130	1.218
$CH_3CH_2CH_2CH_2CH_2I$	1-iodopentane	155	1.516

Properties and uses of halocarbons It is easiest to talk about properties of organic compounds containing functional groups by comparing those compounds with alkanes, whose properties you have already studied. **Table 2** lists some of the physical properties of certain alkanes and alkyl halides.

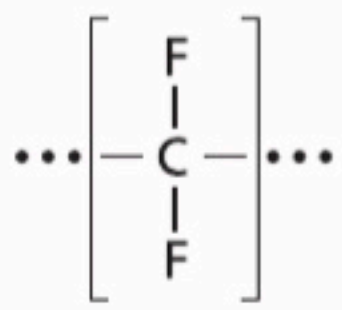
Note that each alkyl chloride has a higher boiling point and a higher density than the alkane with the same number of carbon atoms. Note also that the boiling points and densities increase as the halogen changes from fluorine to chlorine, bromine, and iodine. This trend occurs primarily because the halogens from fluorine to iodine have increasing numbers of electrons that lie farther from the halogen nucleus. These electrons shift position easily and, as a result, the halogen-substituted hydrocarbons have an increasing tendency to form temporary dipoles. Because the dipoles attract each other, the energy needed to separate the molecules also increases. Thus, the boiling points of halogen-substituted alkanes increase as the size of the halogen atom increases.

☑ **READING CHECK** **Explain** the relationship between the number of electrons in the halogen and the boiling point.

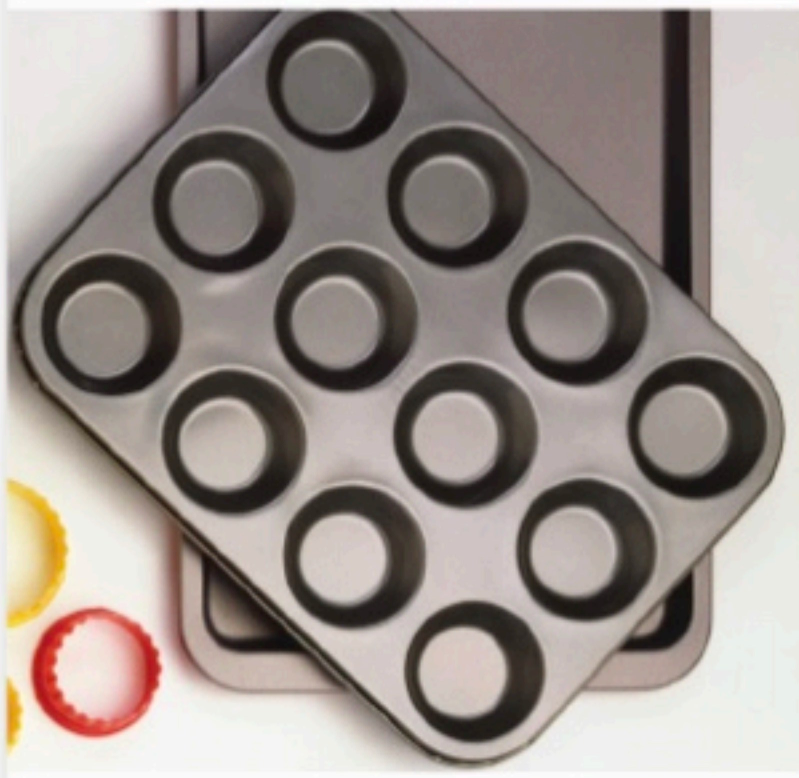
Organic halides are seldom found in nature, although human thyroid hormones are organic iodides. Halogen atoms bonded to carbon atoms are more reactive than the hydrogen atoms they replace. For this reason, alkyl halides are often used as starting materials in the chemical industry. Alkyl halides are also used as solvents and cleaning agents because they readily dissolve nonpolar molecules, such as greases. **Figure 4** shows an application of polytetrafluoroethene (PTFE), a plastic made from gaseous tetrafluoroethylene. A **plastic** is a polymer that can be heated and molded while relatively soft. Another plastic commonly called *vinyl* is polyvinyl chloride (PVC). It can be manufactured soft or hard, as thin sheets, or molded into objects.

☑ **READING CHECK** **Explain** why alkyl halides are often used in the chemical industry as starting materials instead of alkanes.

Figure 4 Polytetrafluoroethene (PTFE) is made up of hundreds of units. PTFE provides a nonstick surface for many kitchen items, including bakeware.



PTFE



PTFE Application

Table 3 Substitution Reactions

Generic Substitution Reaction $R{-}CH_3 + X_2 \rightarrow R{-}CH_2X + HX$ where X is fluorine, chlorine, or bromine	**Example of General Substitution Reaction (Halogenation)** $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$ Ethane Chloroethane
General Alkyl Halide-Alcohol Reaction $R{-}X + OH^- \rightarrow R{-}OH + X^-$ Alkyl halide Alcohol	**Example of an Alkyl Halide-Alcohol Reaction** $CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$ Chloroethane Ethanol
General Alkyl Halide-Ammonia Reaction $R{-}X + NH_3 \rightarrow R{-}NH_2 + HX$ Alkyl halide Amine	**Example of an Alkyl Halide-Ammonia Reaction** $CH_3(CH_2)_6CH_2Br + NH_3 \rightarrow CH_3(CH_2)_6CH_2NH_2 + HBr$ 1-Bromooctane 1-Octanamine

Substitution Reactions

From where does the immense variety of organic compounds come? Amazingly enough, the ultimate source of nearly all synthetic organic compounds is petroleum. The oil-field workers shown in **Figure 5** are drilling for petroleum, which is a fossil fuel that consists almost entirely of hydrocarbons, especially alkanes. How can alkanes be converted into compounds as different as alkyl halides, alcohols, and amines?

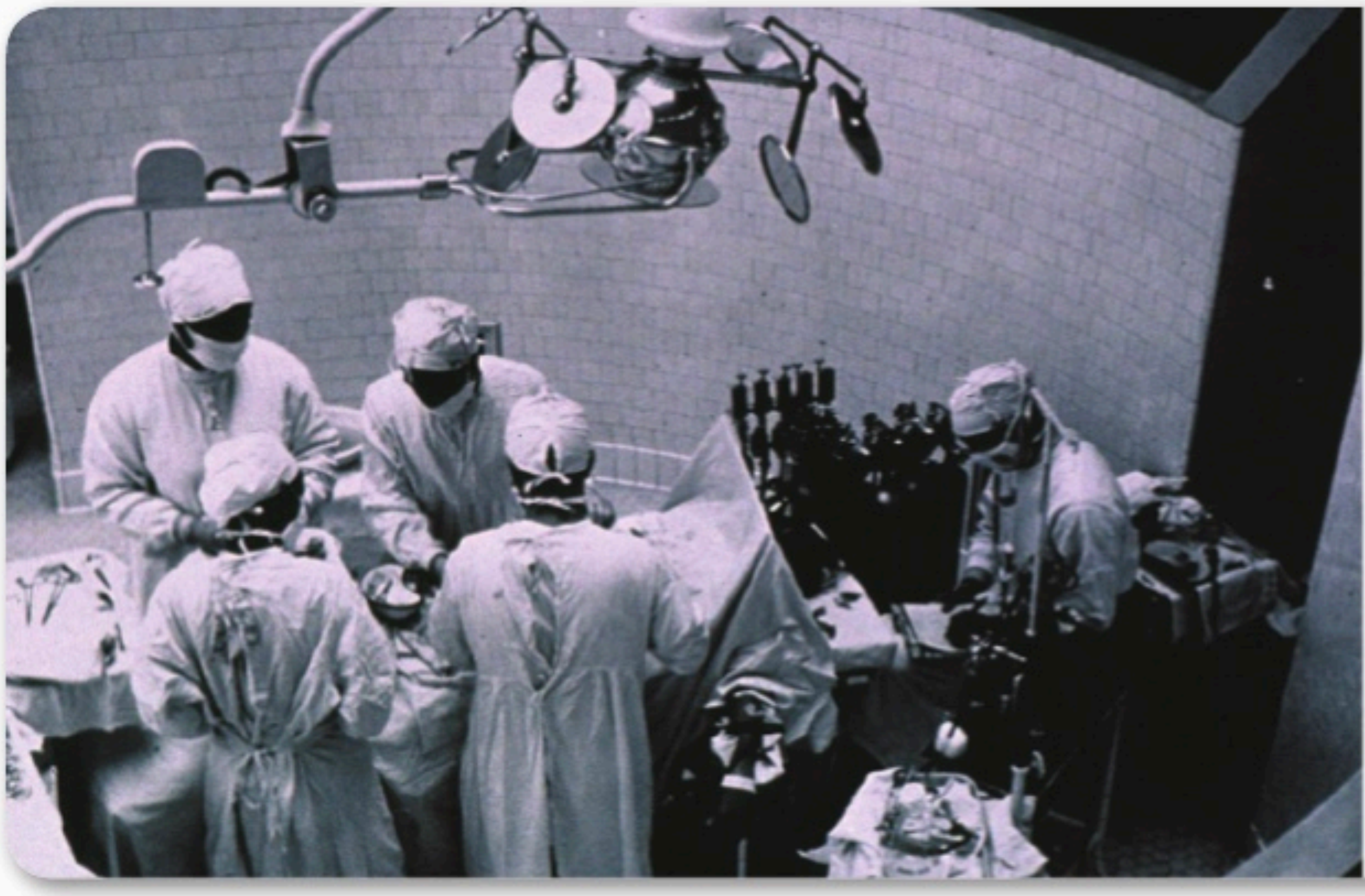
One way is to introduce a functional group through substitution, as shown in **Table 3.** A **substitution reaction** is one in which one atom or a group of atoms in a molecule is replaced by another atom or group of atoms. With alkanes, hydrogen atoms can be replaced by atoms of halogens, typically chlorine or bromine, in a process called **halogenation.** One example of a halogenation reaction, shown in **Table 3,** is the substitution of a chlorine atom for one of ethane's hydrogen atoms. **Figure 6** shows another halogenated hydrocarbon commonly called halothane (2-bromo-2-chloro-1,1,1-trifluoroethane), which was first used as a general anesthetic in the 1950s.

Equations for organic reactions are sometimes shown in generic form. **Table 3** shows the generic form of a substitution reaction. In this reaction, *X* can be fluorine, chlorine, or bromine, but not iodine. Iodine does not react well with alkanes.

☑ READING CHECK **Draw** the molecular structure of halothane.

■ **Figure 5** These oil-field workers are drilling for petroleum. A single oil well can extract more than 100 barrels per day.

Explain ***the relationship between petroleum and synthetic organic compounds.***



■ **Figure 6** Halothane was introduced into medicine in the 1950s as a general anesthetic for patients undergoing surgery.

Further substitution Once an alkane has been halogenated, the resulting alkyl halide can undergo other types of substitution reactions in which the halogen atom is replaced by another atom or group of atoms. For example, reacting an alkyl halide with a basic solution results in the replacement of the halogen atom by an –OH group, forming an alcohol. An example of an alkyl halide-alcohol reaction is shown in **Table 3.** The generic form of the alkyl halide-alcohol reaction is also shown in **Table 3.**

Reacting an alkyl halide with ammonia (NH_3) replaces the halogen atom with an amino group ($-NH_2$), forming an alkyl amine, also shown in **Table 3.** The alkyl amine is one of the products produced in this reaction. Some of the newly formed amines continue to react, resulting in a mixture of amines.

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SECTION 1 REVIEW

Section Summary

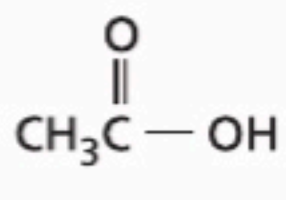
- The substitution of functional groups for hydrogen in hydrocarbons creates a wide variety of organic compounds.
- An alkyl halide is an organic compound that has one or more halogen atoms bonded to a carbon atom in an aliphatic compound.

4. MAINIDEA Compare and contrast alkyl halides and aryl halides.

5. Draw structures for the following molecules.

a. 2-chlorobutane
b. 1,3-difluorohexane
c. 1,1,1-trichloroethane
d. 1-bromo-4-chlorobenzene

6. Define *functional group* and name the group present in each of the following structures. Name the type of organic compound each substance represents.

a. $CH_3CH_2CH_2OH$
b. CH_3CH_2F
c. $CH_3CH_2NH_2$
d. 

7. Evaluate How would you expect the boiling points of propane and 1-chloropropane to compare? Explain your answer.

8. Interpret Scientific Illustrations Examine the pair of substituted hydrocarbons illustrated at right, and decide whether it represents a pair of optical isomers. Explain your answer.

SECTION 2

Alcohols, Ethers, and Amines

MAINIDEA **Oxygen and nitrogen are two of the most-common atoms found in organic functional groups.**

Essential Questions

- Which functional groups define alcohols, ethers, and amines?
- How are the structures of alcohols, ethers, and amines drawn?
- What are some properties and uses of alcohols, ethers, and amines?

Review Vocabulary

miscible: describes two liquids that are soluble in each other

New Vocabulary

hydroxyl group
alcohol
denatured alcohol
ether
amine

CHEM 4 YOU **The last time you had a vaccination, the nurse probably disinfected your skin with an alcohol wipe before giving you the injection. Did you know that the nurse was using a substituted hydrocarbon?**

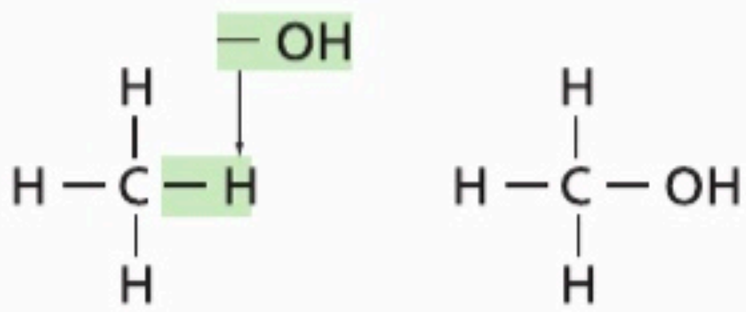
Alcohols

Many organic compounds contain oxygen atoms bonded to carbon atoms. Because an oxygen atom has six valence electrons, it commonly forms two covalent bonds to gain a stable octet. An oxygen atom can form a double bond with a carbon atom, replacing two hydrogen atoms, or it can form one single bond with a carbon atom and another single bond with another atom, such as hydrogen. An oxygen-hydrogen group covalently bonded to a carbon atom is called a **hydroxyl group** (–OH). An organic compound in which a hydroxyl group replaces a hydrogen atom of a hydrocarbon is called an **alcohol.** As shown in **Table 4,** the general formula for an alcohol is ROH. **Table 4** also illustrates the relationship of the simplest alkane, methane, to the simplest alcohol, methanol.

Ethanol and carbon dioxide are produced by yeasts when they ferment sugars, such as those in grapes and bread dough. Ethanol is found in alcoholic beverages and medicinal products. Because it is an effective antiseptic, ethanol can be used to swab skin before an injection is given. It is also a gasoline additive and an important starting material for the synthesis of more complex organic compounds.

Figure 7 shows a model of an ethanol molecule and a model of a water molecule. As you compare the models, notice that the covalent bonds from the oxygen in ethanol are at roughly the same angle as the bonds around the oxygen in the water molecule. Therefore, the hydroxyl groups of alcohol molecules are moderately polar, as with water, and are able to form hydrogen bonds with the hydroxyl groups of other alcohol molecules. Due to this hydrogen bonding, alcohols have much higher boiling points than hydrocarbons of similar shape and size.

Table 4 **Alcohols**

General Formula	Simple Alcohol and Simple Hydrocarbon
ROH R represents carbon chains or rings bonded to the functional group	 Methane (CH_4) Alkane — Methanol (CH_3OH) Alcohol

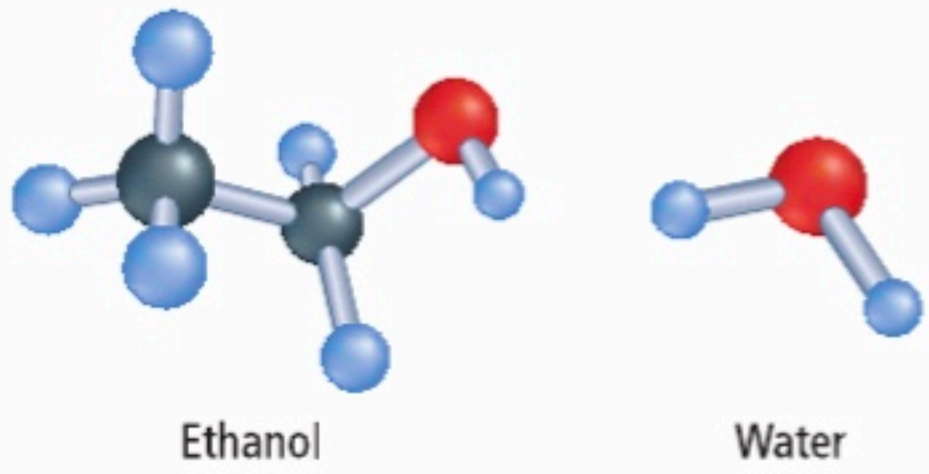


Figure 7 The covalent bonds from oxygen have approximately the same bonding angle in ethanol and water.

Also, because of polarity and hydrogen bonding, ethanol is completely miscible with water. In fact, once they are mixed, it is difficult to separate water and ethanol completely. Distillation is used to remove ethanol from water, but even after that process is complete, about 5% water remains in the ethanol-water mixture.

On the shelves of drugstores, you can find bottles of ethanol labeled *denatured alcohol*. **Denatured alcohol** is ethanol to which small amounts of noxious materials, such as aviation gasoline or other organic solvents, have been added. Ethanol is denatured in order to make it unfit to drink. Because of their polar hydroxyl groups, alcohols make good solvents for other polar organic substances. For example, methanol, the smallest alcohol, is a common industrial solvent found in some paint strippers, and 2-butanol is found in some stains and varnishes.

Note that the names of alcohols are based on alkane names, like the names of alkyl halides. For example, CH_4 is methane and CH_3OH is methanol; CH_3CH_3 is ethane and CH_3CH_2OH is ethanol. When naming a simple alcohol based on an alkane carbon chain, the IUPAC rules call for naming the parent carbon chain or ring first and then changing the *-e* at the end of the name to *-ol* to indicate the presence of a hydroxyl group. In alcohols of three or more carbon atoms, the hydroxyl group can be at two or more positions. To indicate the position, a number is added, as shown in **Figure 8a** and **8b.**

READING CHECK **Explain** why *4-butanol* and *3-butanol* are not the correct names for the compounds in **Figure 8a** and **8b.**

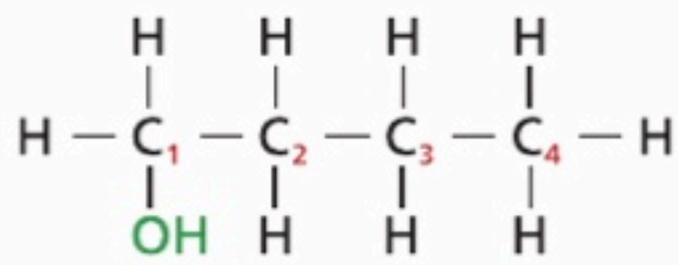
Now look at **Figure 8c.** The compound's ring structure contains six carbons with only single bonds, so you know that the parent hydrocarbon is cyclohexane. Because an –OH group is bonded to a carbon, it is an alcohol and the name will end in *-ol.* No number is necessary because all carbons in the ring are equivalent. This compound is called cyclohexanol. It is a poisonous compound used as a solvent for certain plastics and in the manufacture of insecticides.

A carbon chain can also have more than one hydroxyl group. To name these compounds, prefixes such as *di-*, *tri-*, and *tetra-* are used before the *-ol* to indicate the number of hydroxyl groups present. The full alkane name, including *-ane*, is used before the prefix.

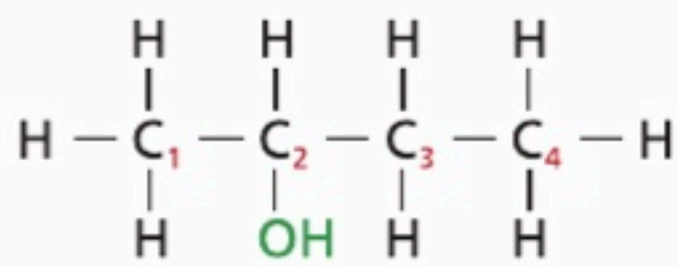
Figure 8d shows the molecule 1,2,3-propanetriol, commonly called glycerol. It is an alcohol containing more than one hydroxyl group. Glycerol is often used as an antifreeze and as an airplane deicing fluid.

READING CHECK **Explain** why numbers are not used to name the compound shown in **Figure 8c.**

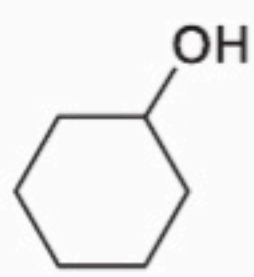
Figure 8 The names of alcohols are based on alkane names.



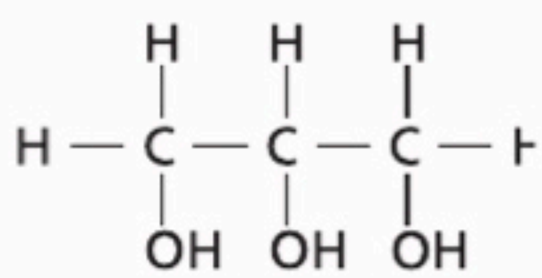
a. 1-Butanol



b. 2-Butanol

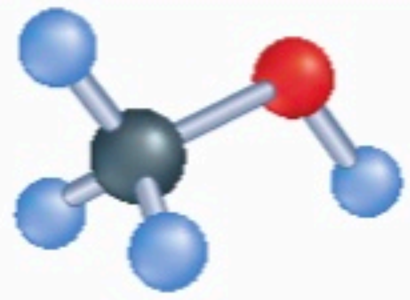
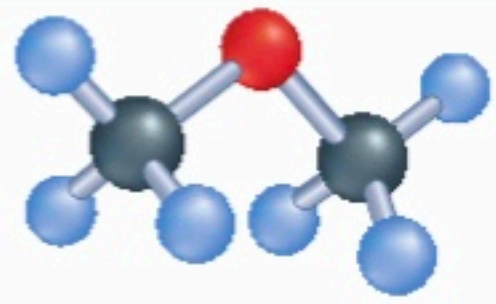


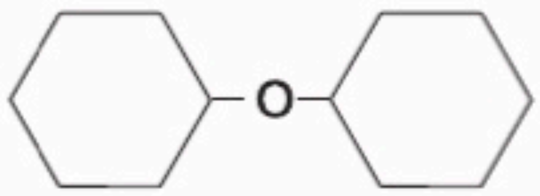
c. Cyclohexanol



d. 1,2,3-Propanetriol (glycerol)

Table 5 Ethers

General Formula	Methanol and Methyl ether
ROR′ where R and R′ represent carbon chains or rings bonded to functional groups	 Methanol bp = 65°C  Methyl ether bp = −25°C

Examples of Ethers	
 Cyclohexyl ether	$CH_3CH_2CH_2-O-CH_2CH_2CH_3$ Propyl ether
$CH_3CH_2-O-CH_2CH_2CH_2CH_3$ Butyl ethyl ether	$CH_3CH_2-O-CH_3$ Ethyl methyl ether

VOCABULARY

ACADEMIC VOCABULARY

Bond
to connect, bind, or join
An oxygen atom bonds to two carbon atoms in an ether.

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Ethers

Ethers are another group of organic compounds in which oxygen is bonded to carbon. An **ether** is an organic compound containing an oxygen atom bonded to two carbon atoms. Ethers have the general formula ROR′, as shown in **Table 5.** The simplest ether is one in which oxygen is bonded to two methyl groups. Note the similarity between methanol and methyl ether shown in **Table 5.**

The term *ether* was first used in chemistry as a name for ethyl ether, the volatile, highly flammable substance that was commonly used as an anesthetic in surgery from 1842 until the twentieth century. As time passed, the term *ether* was applied to other organic substances having two hydrocarbon chains attached to the same oxygen atom.

Because ethers have no hydrogen atoms bonded to the oxygen atom, their molecules cannot form hydrogen bonds with each other. Therefore, ethers are generally more volatile and have much lower boiling points than alcohols of similar size and mass. Ethers are much less soluble in water than alcohols because they have no hydrogen to donate to a hydrogen bond. However, the oxygen atom can act as a hydrogen bond receptor for the hydrogen atoms of water molecules.

READING CHECK **Infer** why ethyl ether is undesirable as an anesthetic.

When naming ethers that have two identical alkyl chains bonded to oxygen, first name the alkyl group and then add the word *ether*. **Table 5** shows the structures and names of two of these symmetrical ethers, propyl ether and cyclohexyl ether. If the two alkyl groups are different, the groups are listed in alphabetical order and then followed by the word *ether*. **Table 5** contains two examples of these asymmetrical ethers, butyl ethyl ether and ethyl methyl ether.

Amines

Amines contain nitrogen atoms bonded to carbon atoms in aliphatic chains or aromatic rings and have the general formula RNH_2, as shown in **Table 6.**

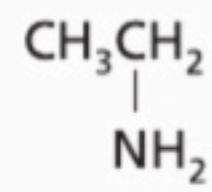
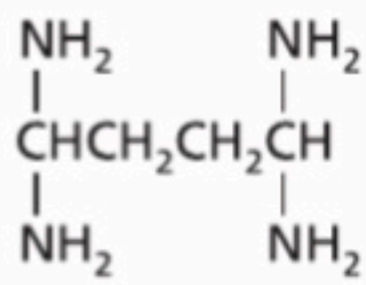
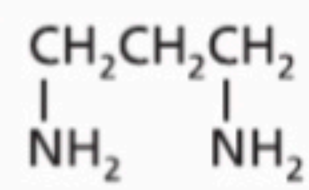
Chemists consider amines to be derivatives of ammonia (NH_3). Amines are considered primary, secondary, or tertiary amines depending on whether one, two, or three of the hydrogens in ammonia have been replaced by organic groups.

When naming amines, the $-NH_2$ (amino) group is indicated by the suffix *-amine.* When necessary, the position of the amino group is designated by a number, as shown in the examples in **Table 6.** When only one amino group is present, the final -e of the root hydrocarbon is dropped, as in 1-butanamine. If more than one amino group is present, the prefixes *di-*, *tri-*, *tetra-*, and so on are used to indicate the number of groups.

The amine aniline is used in the production of dyes with deep shades of color. The common name *aniline* is derived from the plant from which it was historically obtained. Cyclohexylamine and ethylamine are important in the manufacture of pesticides, plastics, pharmaceuticals, and rubber that is used to make tires.

All volatile amines have odors that humans find offensive, and amines are responsible for many of the odors characteristic of dead, decaying organisms. Two amines found in decaying human remains are putrescine and cadaverine. Specially trained animals are used to locate human remains using these distinctive odors. Sniffer dogs are often used after catastrophic events and in forensic investigations.

Table 6 Amines

General Formula
RNH_2 where R represents a carbon chain or ring bonded to the functional group
Examples of Amines
 Cyclohexylamine ·  Ethylamine ·  Aniline
 1,1,4,4-Butanetetraamine ·  1,3-Propanediamine

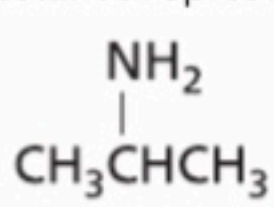
SECTION 2 REVIEW

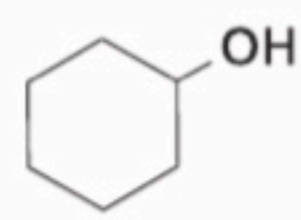
Section Summary

- Alcohols, ethers, and amines are formed when specific functional groups substitute for hydrogen in hydrocarbons.
- Because they readily form hydrogen bonds, alcohols have higher boiling points and higher water solubilities than other organic compounds.

9. MAINIDEA Identify two elements that are commonly found in functional groups.

10. Identify the functional group present in each of the following structures. Name the substance represented by each structure.

a. 

b. 

c. $CH_3-O-CH_2CH_2CH_3$

11. Draw the structure for each molecule.

a. 1-propanol

b. 1,3-cyclopentanediol

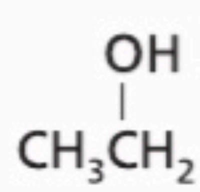
c. propyl ether

d. 1,2-propanediamine

12. Discuss the properties of alcohols, ethers, and amines, and give one use of each.

13. Analyze Based on the molecular structures below, which compound would you expect to be more soluble in water? Explain your reasoning.

CH_3-O-CH_3



SECTION 3

Carbonyl Compounds

MAINIDEA **Carbonyl compounds contain a double-bonded oxygen in the functional group.**

Essential Questions

- Which structures identify various carbonyl compounds?
- What are the properties of compounds containing the carbonyl group?

Review Vocabulary

electronegative: indicates the relative ability of an element's atoms to attract electrons in a chemical bond

New Vocabulary

carbonyl group
aldehyde
ketone
carboxylic acid
carboxyl group
ester
amide
condensation reaction

CHEM 4 YOU **Have you ever eaten a piece of fruit-flavored candy that tasted like real fruit? Many natural fruits, such as strawberries, contain dozens of organic molecules that combine to give the distinctive aroma and flavor of fruits. The carbonyl group is found in many common types of artificial flavorings.**

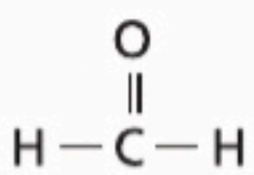
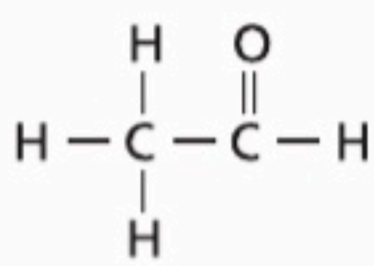
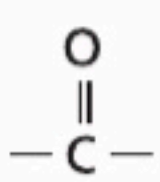
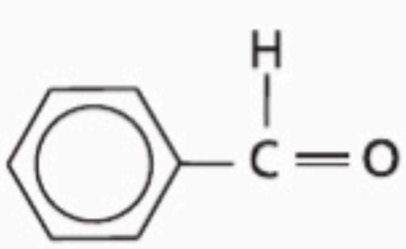
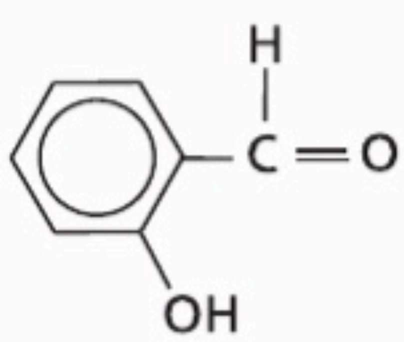
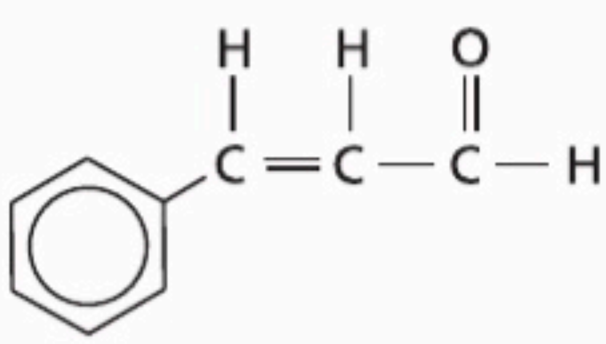
Organic Compounds Containing the Carbonyl Group

The arrangement in which an oxygen atom is double-bonded to a carbon atom is called a **carbonyl group**. This group is the functional group in organic compounds known as aldehydes and ketones.

Aldehydes An **aldehyde** is an organic compound in which a carbonyl group located at the end of a carbon chain is bonded to a carbon atom on one side and a hydrogen atom on the other. Aldehydes have the general formula *CHO, where * represents an alkyl group or a hydrogen atom, as shown in **Table 7.**

Aldehydes are formally named by changing the final *-e* of the name of the alkane with the same number of carbon atoms to the suffix *-al.* Thus, the formal name of the compound methanal, shown in **Table 7,** is based on the one-carbon alkane methane. Because the carbonyl group in an aldehyde always occurs at the end of a carbon chain, no numbers are used in the name unless branches or additional functional groups are present. Methanal is also commonly called formaldehyde. Ethanal has the common name *acetaldehyde*. Scientists often use the common names of organic compounds because they are familiar to chemists.

Table 7 **Aldehydes**

General Formula	Examples of Aldehydes		
*CHO *represents an alkyl group or a hydrogen atom	 Methanal (formaldehyde)		 Ethanal (acetaldehyde)
 Carbonyl group	 Benzaldehyde	 Salicylaldehyde	 Cinnamaldehyde

An aldehyde molecule contains a polar, reactive structure. However, like ethers, aldehyde molecules cannot form hydrogen bonds among themselves because the molecules have no hydrogen atoms bonded to an oxygen atom. Therefore, aldehydes have lower boiling points than alcohols with the same number of carbon atoms. Water molecules can form hydrogen bonds with the oxygen atom of aldehydes, so aldehydes are more soluble in water than alkanes but not as soluble as alcohols or amines.

Formaldehyde has been used for preservation for many years, as shown in **Figure 9.** Industrially, large quantities of formaldehyde are reacted with urea to manufacture a type of grease-resistant, hard plastic used to make buttons, appliance and automotive parts, and electrical outlets, as well as the glue that holds the layers of plywood together. Benzaldehyde and salicylaldehyde, shown in **Table 7,** are two components that give almonds their natural flavor. The aroma and flavor of cinnamon, a spice that comes from the bark of a tropical tree, are produced largely by cinnamaldehyde, also shown in **Table 7.**

Figure 9 A water solution of formaldehyde was used in the past to preserve biological specimens. However, formaldehyde's use has been restricted in recent years because studies indicate it might cause cancer.

☑ **READING CHECK** **Identify** two uses for aldehydes.

Ketones A carbonyl group can also be located within a carbon chain rather than at the end. A **ketone** is an organic compound in which the carbon of the carbonyl group is bonded to two other carbon atoms. Ketones have the general formula shown in **Table 8.** The carbon atoms on either side of the carbonyl group are bonded to other atoms. The simplest ketone, commonly known as acetone, has only hydrogen atoms bonded to the side carbons, as shown in **Table 8.**

Ketones are formally named by changing the *-e* at the end of the alkane name to *-one,* and including a number before the name to indicate the position of the ketone group. In the previous example, the alkane name propane is changed to propan*one.* The carbonyl group can be located only in the center, but the prefix *2-* is usually added to the name for clarity, as shown in **Table 8.**

Ketones and aldehydes share many chemical and physical properties because their structures are similar. Ketones are polar molecules and are less reactive than aldehydes. For this reason, ketones are popular solvents for other moderately polar substances, including waxes, plastics, paints, lacquers, varnishes, and glues. Like aldehydes, ketone molecules cannot form hydrogen bonds with each other but can form hydrogen bonds with water molecules. Therefore, ketones are somewhat soluble in water. Acetone is completely miscible with water.

Table 8 Ketones

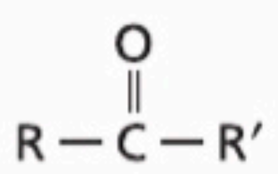
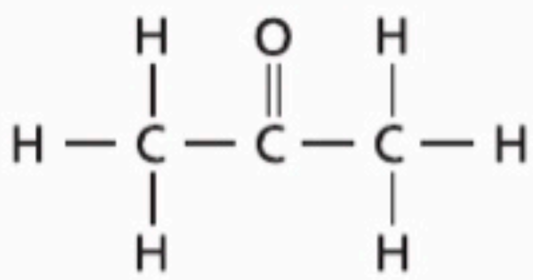
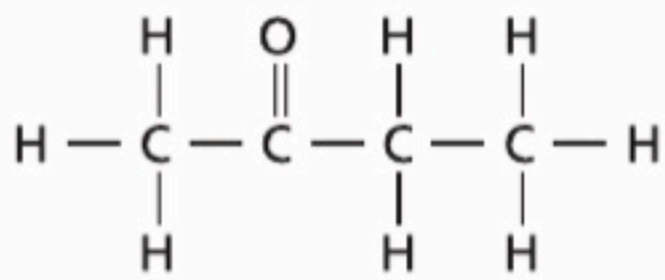
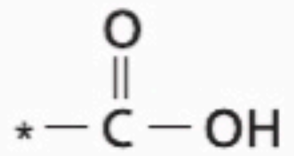
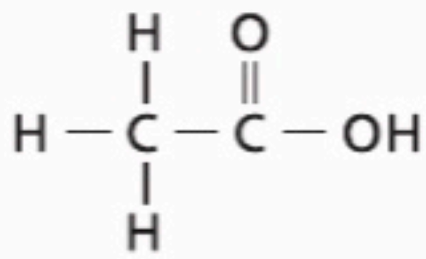
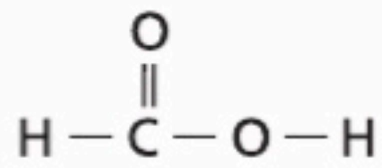
General Formula	Examples of Ketones	
 where R and R' represent carbon chains or rings bonded to functional groups	 2-Propanone (acetone)	 2-Butanone (methyl ethyl ketone)

Table 9 Carboxylic Acids

General Formula	Examples of Carboxylic Acids	
 where * represents a hydrogen atom, carbon chain or ring bonded to the functional group	 Ethanoic acid (acetic acid)	 Methanoic acid (formic acid)

Carboxylic Acids

A **carboxylic acid** is an organic compound that has a carboxyl group. A **carboxyl group** consists of a carbonyl group bonded to a hydroxyl group. Thus, carboxylic acids have the general formula shown in **Table 9.** One diagram shown in **Table 9** is the structure of a familiar carboxylic acid–acetic acid, the acid found in vinegar. Although many carboxylic acids have common names, the formal name is formed by changing the *-ane* of the parent alkane to *-anoic acid*. Thus, the formal name of acetic acid is ethanoic acid.

A carboxyl group is usually represented in condensed form by writing –COOH. For example, ethanoic acid can be written as CH_3COOH. The simplest carboxylic acid consists of a carboxyl group bonded to a single hydrogen atom, HCOOH, shown in **Table 9.** Its formal name is methanoic acid, but it is more commonly known as formic acid. Some insects produce formic acid as a defense mechanism, as shown in **Figure 10.**

READING CHECK **Explain** how the name *ethanoic acid* is derived.

Carboxylic acids are polar and reactive. Those that dissolve in water ionize weakly to produce hydronium ions, the anion of the acid in equilibrium with water, and the unionized acid. The ionization of ethanoic acid is an example.

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

Ethanoic acid (acetic acid) Ethanoate ion (acetate ion)

Carboxylic acids can ionize in water solution because the two oxygen atoms are highly electronegative and attract electrons away from the hydrogen atom in the –OH group. As a result, the hydrogen proton can transfer to another atom that has a pair of electrons not involved in bonding, such as the oxygen atom of a water molecule. Because they ionize in water, soluble carboxylic acids turn blue litmus paper red and have a sour taste.

Some important carboxylic acids, such as oxalic acid and adipic acid, have two or more carboxyl groups. An acid with two carboxyl groups is called a dicarboxylic acid. Others have additional functional groups such as hydroxyl groups, as in the lactic acid found in yogurt. Typically, these acids are more soluble in water and often more acidic than acids with only a carboxyl group.

READING CHECK **Evaluate** Using the information above, explain why carboxylic acids are classified as acids.

Figure 10 Stinging ants defend themselves with a venom that contains formic acid.

Identify *another name for formic acid.*

Table 10 Esters

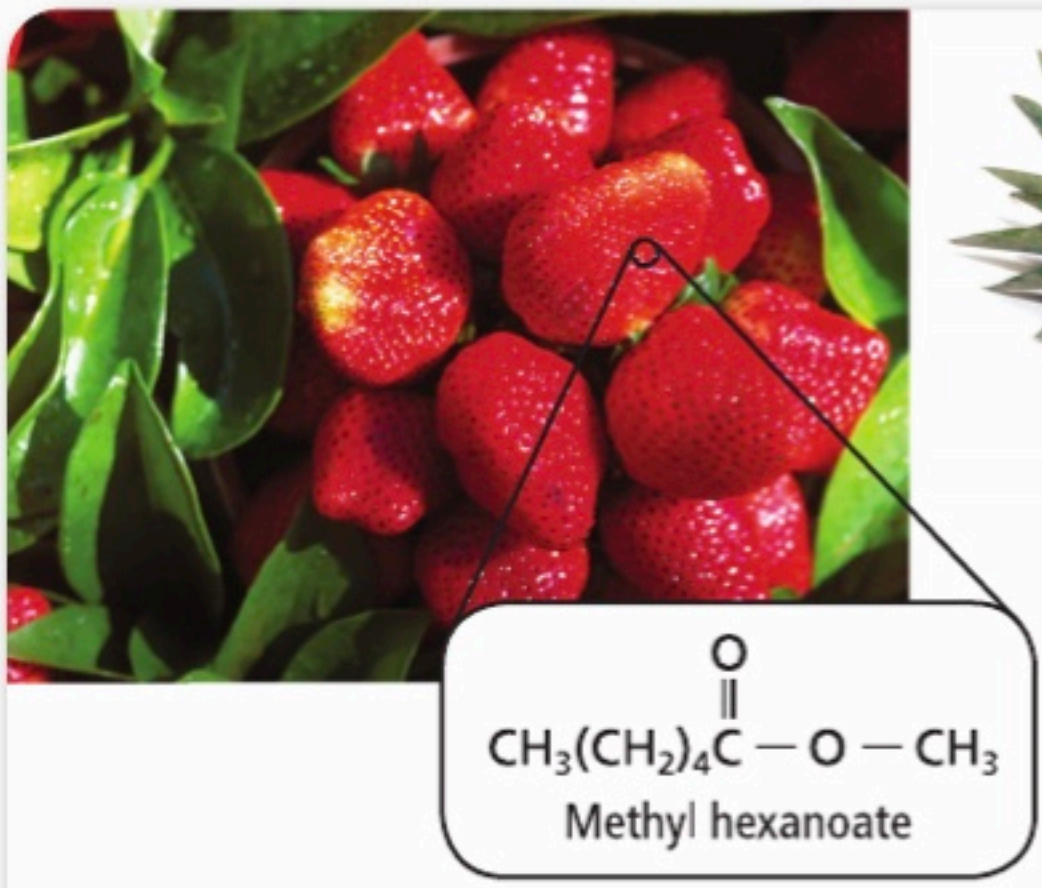
General Formula	Example of an Ester
$*-\overset{O}{\overset{\|}{C}}-O-R$ Ester group	Ethanoate group: $CH_3-\overset{O}{\overset{\|}{C}}$; Propyl group: $CH_2CH_2CH_3$; Ester group: $-\overset{O}{\overset{\|}{C}}-O-$ $CH_3-\overset{O}{\overset{\|}{C}}-O-CH_2CH_2CH_3$ Propyl ethanoate (propyl acetate)

Organic Compounds Derived from Carboxylic Acids

Several classes of organic compounds have structures in which the hydrogen or the hydroxyl group of a carboxylic acid is replaced by a different atom or group of atoms. The two most common classes are esters and amides.

Esters An **ester** is any organic compound with a carboxyl group in which the hydrogen of the hydroxyl group has been replaced by an alkyl group, producing the arrangement shown in **Table 10.** The name of an ester is formed by writing the name of the alkyl group followed by the name of the acid with the *-ic acid* ending replaced by *-ate,* as illustrated by the example shown in **Table 10.** Note how the name *propyl* results from the structural formula. The name shown in parentheses is based on the name *acetic acid,* the common name for ethanoic acid.

Esters are polar molecules and many are volatile and sweet-smelling. Many kinds of esters are found in the natural fragrances and flavors of flowers and fruits, as shown in **Figure 11.** Natural flavors, such as apple or banana, result from mixtures of many different organic molecules, including esters, but some of these flavors can be imitated by a single ester structure. Consequently, esters are manufactured for use as flavors in many foods and beverages and as fragrances in candles, perfumes, and other scented items.



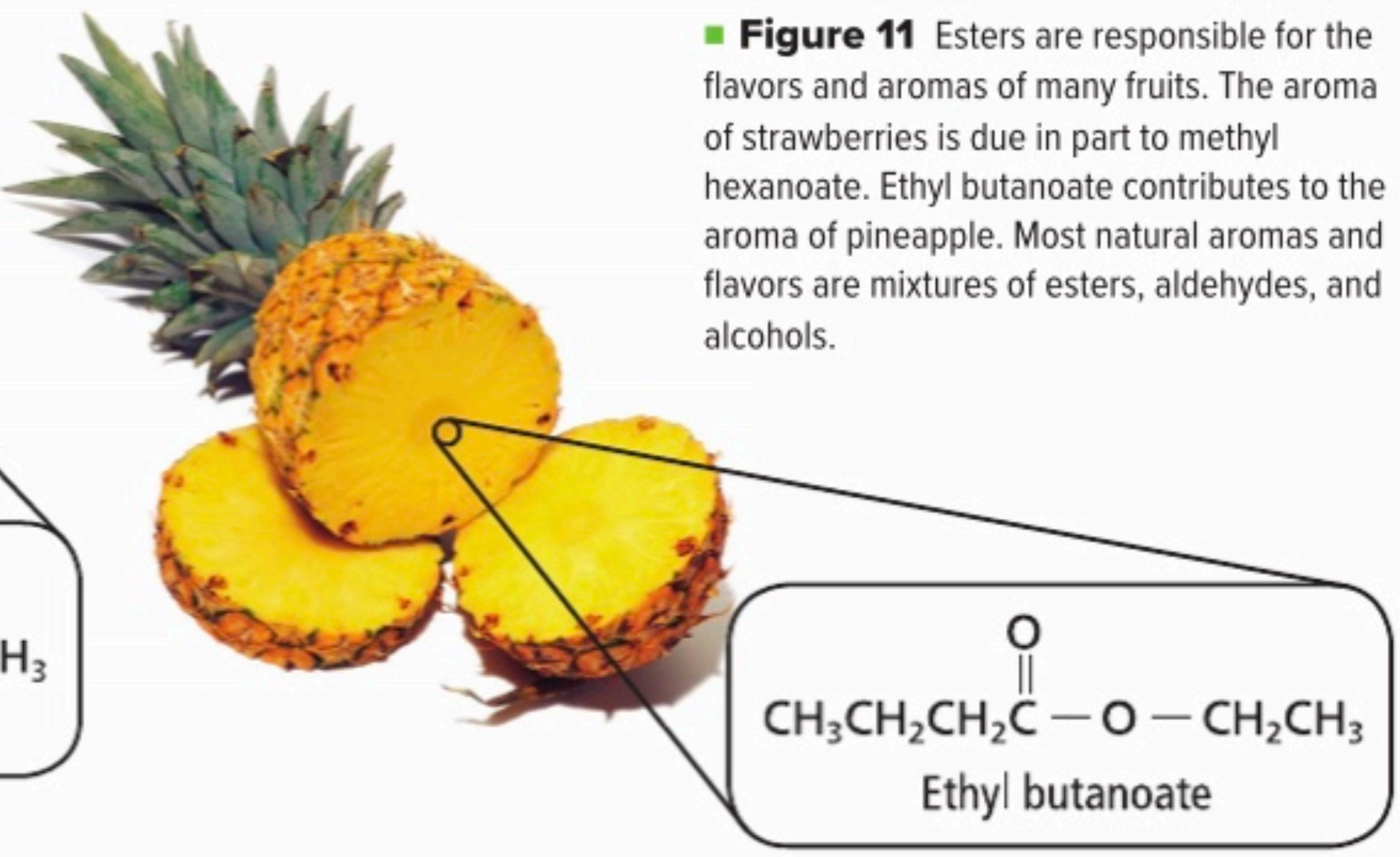


Figure 11 Esters are responsible for the flavors and aromas of many fruits. The aroma of strawberries is due in part to methyl hexanoate. Ethyl butanoate contributes to the aroma of pineapple. Most natural aromas and flavors are mixtures of esters, aldehydes, and alcohols.

MiniLAB

Make an Ester

How can you recognize an ester?

Procedure 

1. Identify the safety concerns of this lab before work begins.
2. Prepare a hot-water bath by pouring 150 mL of **tap water** into a **250-mL beaker.** Place the beaker on a **hot plate** set to medium.
3. Use a **balance** and **weighing paper** to measure 1.5 g of **salicylic acid.** Place the salicylic acid in a **small test tube** and add 3 mL of **distilled water.** Use a **10-mL graduated cylinder** to measure the water. Then add 3 mL of **methanol.** Use a **Beral pipette** to add 3 drops of **concentrated sulfuric acid** to the test tube.
   WARNING: ***Concentrated sulfuric acid can cause burns. Methanol fumes are explosive—keep away from open flame. Handle chemicals with care.***
4. When the water is hot but not boiling, place the test tube in the bath for 5 min. Use a **test-tube clamp** to remove the test tube from the bath and place in a **test-tube holder** until needed.
5. Place a **cotton ball** in a **petri dish half.** Pour the contents of the test tube onto the cotton ball. Record your observation of the odor of the product.

Analysis

1. **Name** The common name of the ester that you produced is *oil of wintergreen*. Name some products that you think could contain the ester.
2. **Evaluate** the advantages and disadvantages of using synthetic esters in consumer products as compared to using natural esters.

Amides An amide is an organic compound in which the –OH group of a carboxylic acid is replaced by a nitrogen atom bonded to other atoms. The general structure of an amide is shown in **Table 11.** Amides are named by writing the name of the alkane with the same number of carbon atoms, and then replacing the final *-e* with *-amide*. Thus, the amide shown in **Table 11** is called ethanamide, but it can also be named acetamide from its common name, acetic acid.

READING CHECK How does an amide differ from a carboxylic acid?

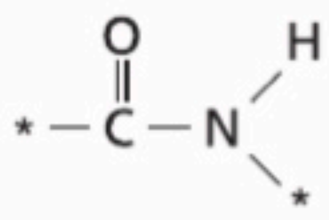
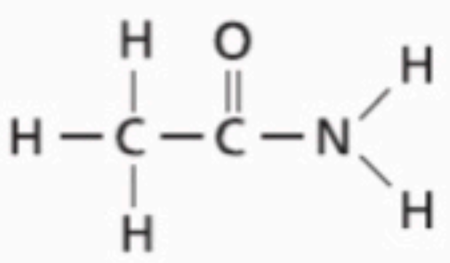
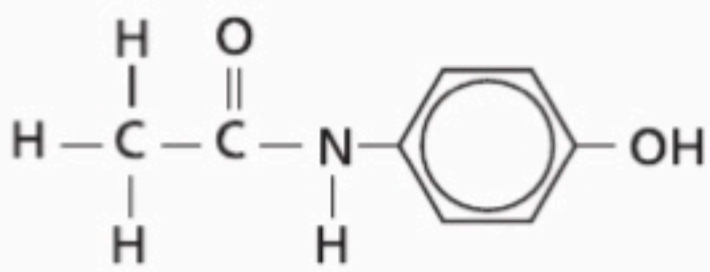
The amide functional group is found repeated many times in natural proteins and some synthetic materials. For example, you might have used a nonaspirin pain reliever containing acetaminophen. In the acetaminophen structure shown in **Table 11,** notice that the amide (–NH–) group connects a carbonyl group and an aromatic group.

One important amide is caramide (NH_2CONH_2), or urea, as it is commonly known. Urea is an end product in the metabolic breakdown of proteins in mammals. It is found in the blood, bile, milk, and perspiration of mammals. When proteins are broken down, amino groups (NH_2) are removed from the amino acids. The amino groups are then converted to ammonia (NH_3) molecules that are toxic to the body. The toxic ammonia is converted to nontoxic urea in the liver. The urea is filtered out of the blood in the kidneys and passed from the body in urine.

Because of the high nitrogen content of urea and because it is easily converted to ammonia in the soil, urea is a common commercial fertilizer. Urea is also used as a protein supplement for ruminant animals, such as cattle and sheep. These animals use urea to produce proteins in their bodies.

READING CHECK **Identify** an amide that is found in the human body.

Table 11 Amides

General Formula	Examples of Amides	
 Amide group	 Ethanamide (acetamide)	 Acetaminophen

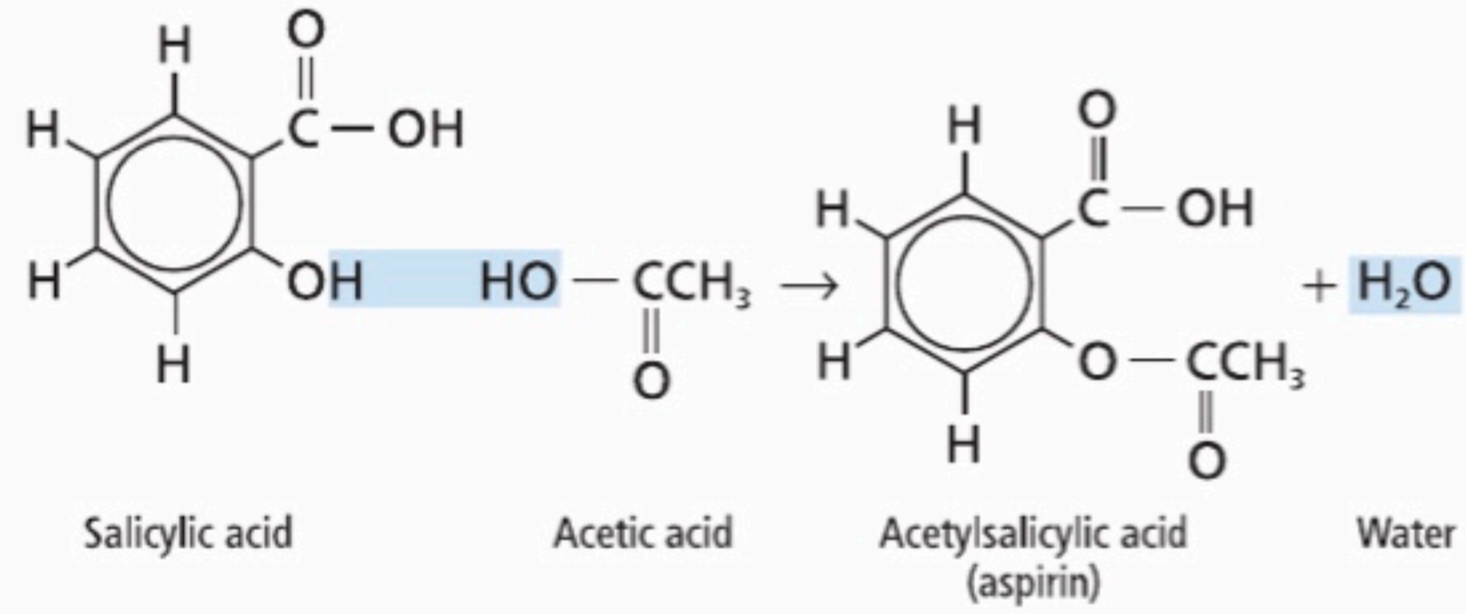


Figure 12 To synthesize aspirin, two organic molecules are combined in a condensation reaction to form a larger molecule.

Condensation Reactions

Many laboratory syntheses and industrial processes involve the reaction of two organic reactants to form a larger organic product, such as the aspirin shown in **Figure 12.** This type of reaction is known as a condensation reaction.

In a **condensation reaction,** two smaller organic molecules combine to form a more complex molecule, accompanied by the loss of a small molecule such as water. Typically, the molecule lost is formed from one particle from each of the reactant molecules. In essence, a condensation reaction is an elimination reaction in which a bond is formed between two atoms not previously bonded to each other.

The most common condensation reactions involve the combining of carboxylic acids with other organic molecules. A common way to synthesize an ester is by a condensation reaction between a carboxylic acid and an alcohol. Such a reaction can be represented by the following general equation.

$$RCOOH + R'OH \rightarrow RCOOR' + H_2O$$

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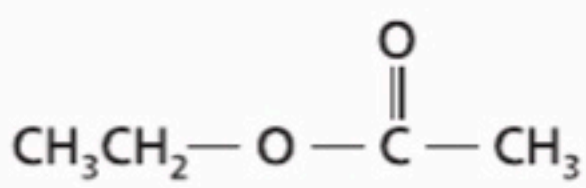
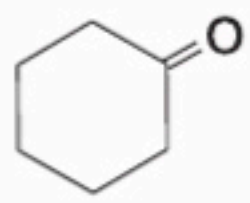
SECTION 3 REVIEW

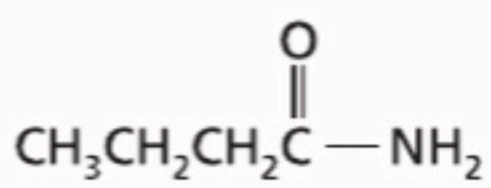
Section Summary

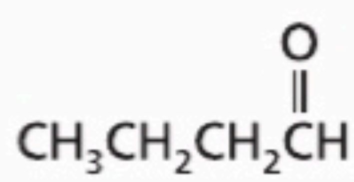
- Carbonyl compounds are organic compounds that contain the C=O group.
- Five important classes of organic compounds containing carbonyl compounds are aldehydes, ketones, carboxylic acids, esters, and amides.

14. MAINIDEA Classify each of the carbonyl compounds as one of the types of organic substances you have studied in this section.

a. 

c. 

b. 

d. 

15. Describe the products of a condensation reaction between a carboxylic acid and an alcohol.

16. Determine The general formula for alkanes is C_nH_{2n+2}. Derive a general formula to represent an aldehyde, a ketone, and a carboxylic acid.

17. Infer why water-soluble organic compounds with carboxyl groups exhibit acidic properties in solutions, whereas similar compounds with aldehyde structures do not exhibit these properties.

SECTION 4

Other Reactions of Organic Compounds

MAINIDEA **Classifying the chemical reactions of organic compounds makes predicting products of reactions much easier.**

Essential Questions

- How are organic reactions classified?
- Why is it useful to draw structural formulas when writing equations for reactions of organic compounds?
- How can classifying a reaction help you predict the reaction's products?

Review Vocabulary

catalyst: a substance that increases the rate of a chemical reaction by lowering activation energies but is not consumed in the reaction

New Vocabulary

elimination reaction
dehydrogenation reaction
dehydration reaction
addition reaction
hydration reaction
hydrogenation reaction

CHEM 4 YOU As you eat lunch, the oxidation of organic compounds is probably not on your mind. However, that is exactly what is about to occur as your cells break down the food that you eat to obtain energy for your body.

Classifying Reactions of Organic Substances

Organic chemists have discovered thousands of reactions by which organic compounds can be changed into different organic compounds. By using combinations of these reactions, chemical industries convert simple molecules from petroleum and natural gas into the large, complex organic molecules found in many useful products–including lifesaving drugs and many other consumer products as shown in **Figure 13.**

You have already read about substitution and condensation reactions. Two other important types of reactions by which organic compounds can be changed into different compounds are elimination reactions and addition reactions.

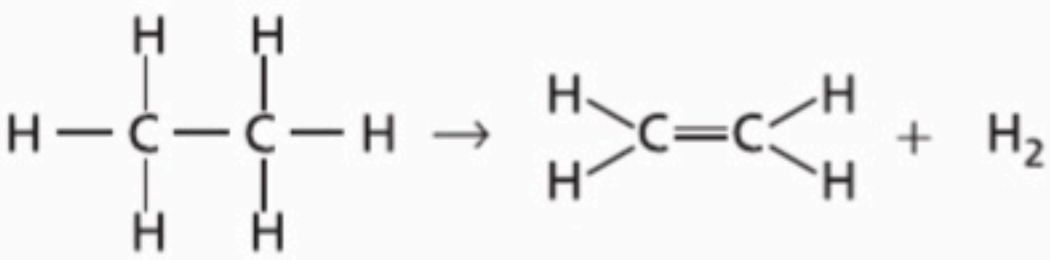
Elimination reactions One way to change an alkane into a chemically reactive substance is to form a second covalent bond between two carbon atoms, producing an alkene. Forming double bonds from single bonds between carbon atoms is an **elimination reaction,** a reaction in which a combination of atoms is removed from two adjacent carbon atoms, forming an additional bond between them. The atoms that are eliminated usually form stable molecules, such as H_2O, HCl, or H_2.

READING CHECK **Define** *elimination reaction* in your own words.

■ **Figure 13** Many consumer products, such as plastic containers, fibers in ropes and clothing, and oils and waxes in cosmetics, are made from petroleum and natural gas.

■ **Figure 14** Low density polyethylene (LDPE) is made from gaseous ethene under high pressure in the presence of a catalyst. LDPE is used for playground equipment because it is easy to mold into various shapes, it is easy to dye into many colors, and it is durable. The name *polyethylene* comes from *ethylene,* which is the common name for ethene.

Ethene, the starting material for the playground equipment shown in **Figure 14,** is produced by the elimination of two hydrogen atoms from ethane. A reaction that eliminates two hydrogen atoms is called a **dehydrogenation reaction.** Note that the two hydrogen atoms form a molecule of hydrogen gas.

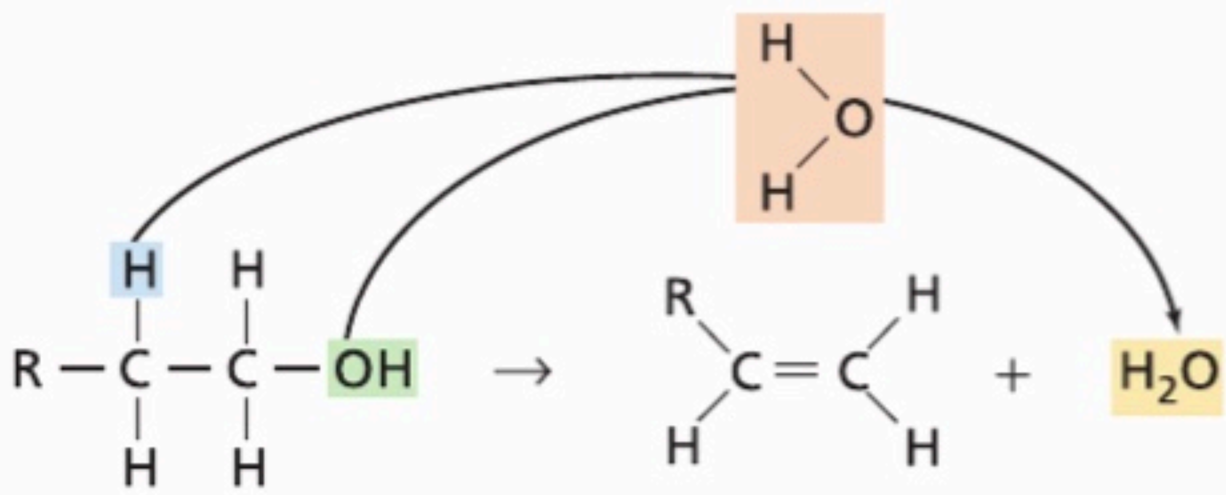


Ethane Ethene

Alkyl halides can undergo elimination reactions to produce an alkene and a hydrogen halide, as shown here.

$$\underset{\text{Alkyl halide}}{R\text{–}CH_2\text{–}CH_2\text{–}X} \rightarrow \underset{\text{Alkene}}{R\text{–}CH{=}CH_2} + \underset{\text{Hydrogen halide}}{HX}$$

Likewise, alcohols can also undergo elimination reactions by losing a hydrogen atom and a hydroxyl group to form water, as shown below. An elimination reaction in which the atoms removed form water is called a **dehydration reaction.** In the dehydration reaction, the alcohol is broken down into an alkene and water.

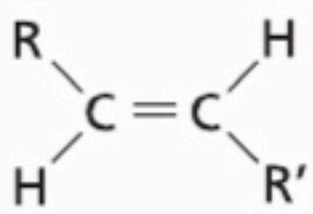
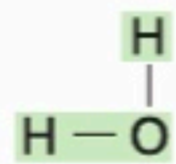
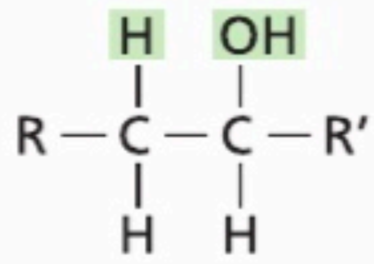
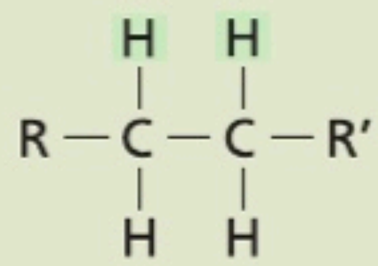
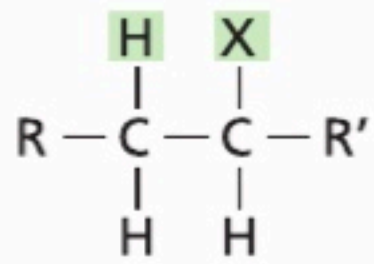
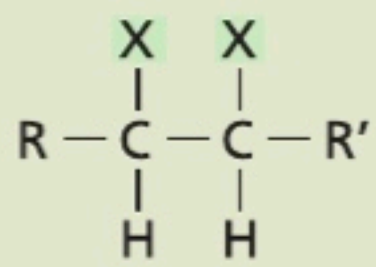


Alcohol Alkene Water

The generic form of this dehydration reaction can be written as follows.

$$R\text{–}CH_2\text{–}CH_2\text{–}OH \rightarrow R\text{–}CH{=}CH_2 + H_2O$$

Table 12 Summary of Addition Reactions

Reactant Alkene	Addition Reactant	Product
	Water (hydration) 	Alcohol 
	Hydrogen (hydrogenation) $H-H$	Alkane 
	Hydrogen halide $H-X$	Alkyl halide 
	Halogen $X-X$	Alkyl dihalide 

Addition reactions Another type of organic reaction appears to be an elimination reaction in reverse. An **addition reaction** results when other atoms bond to each of two atoms bonded by double or triple covalent bonds. Addition reactions typically involve double-bonded carbon atoms in alkenes or triple-bonded carbon atoms in alkynes. Addition reactions occur because double and triple bonds have a rich concentration of electrons. Therefore, molecules and ions that attract electrons tend to form bonds that use some of the electrons from the multiple bonds. The most common addition reactions are those in which H_2O, H_2, HX, or X_2 add to an alkene, as shown in **Table 12.**

A **hydration reaction,** also shown in **Table 12,** is an addition reaction in which a hydrogen atom and a hydroxyl group from a water molecule add to a double or triple bond. The generic equation shown in **Table 12** shows that a hydration reaction is the opposite of a dehydration reaction.

A reaction that involves the addition of hydrogen to atoms in a double or triple bond is called a **hydrogenation reaction.** One molecule of H_2 reacts to fully hydrogenate each double bond in a molecule. When H_2 adds to the double bond of an alkene, the alkene is converted to an alkane.

☑ READING CHECK **Identify** the reaction that is the reverse of a hydrogenation reaction.

Catalysts are usually needed in the hydrogenation of alkenes because the reaction's activation energy is too large without them. Catalysts such as powdered platinum or palladium provide a surface that adsorbs the reactants and makes their electrons more available to bond to other atoms.

Hydrogenation reactions are commonly used to convert the liquid unsaturated fats found in oils from plants such as soybean, corn, and peanuts into saturated fats that are solid at room temperature. These hydrogenated fats are then used to make margarine and solid shortening.

Alkynes can also be hydrogenated to produce alkenes or alkanes. One molecule of H_2 must be added to each triple bond in order to convert an alkyne to an alkene, as shown here.

$$R{-}C{\equiv}C{-}H + H_2 \rightarrow R{-}CH{=}CH_2$$

After the first molecule of H_2 is added, the alkyne is converted to an alkene. A second molecule of H_2 follows the hydrogenation reaction.

$$R{-}CH{=}CH_2 + H_2 \rightarrow R{-}CH_2{-}CH_3$$

In a similar mechanism, the addition of hydrogen halides to alkenes is an addition reaction useful to industry for the production of alkyl halides. The generic equation for this reaction is shown below.

$$R{-}CH{=}CH{-}R' + HX \rightarrow R{-}CHX{-}CH_2{-}R'$$

Data Analysis LAB

Based on Real Data*

Interpret Data

What are the optimal conditions to hydrogenate canola oil? Edible vegetable oil is hydrogenated to preserve its flavor and to alter its melting properties. Because evidence suggests that *trans*-fatty acids are associated with increased risk of heart disease and cancer, the minimum amount of *trans*-fatty acids and the maximum amount of *cis*-oleic acid are desired.

Computer models were used to simulate processing conditions and to alter eight variables to optimize the output of the desirable oil. Multiple optimal operating conditions were determined. A small-scale industrial plant was used to confirm the results of the computer simulation.

Data and Observations

The table at right shows some of the data from this investigation.

Data for Canadian Canola Oil

Trial Run	Computer Simulation: *trans*-Fatty Acids (wt. %)	Computer Simulation: *cis*-Oleic Acid (wt. %)	Experimental: *trans*-Fatty Acids (wt. %)	Experimental: *cis*-Oleic Acid (wt. %)
1	4.90	69.10	5.80	70.00
2	4.79	63.75	4.61	64.00
3	4.04	68.96	4.61	67.00
4	5.99	62.80	7.10	65.00
5	4.60	68.10	5.38	66.50

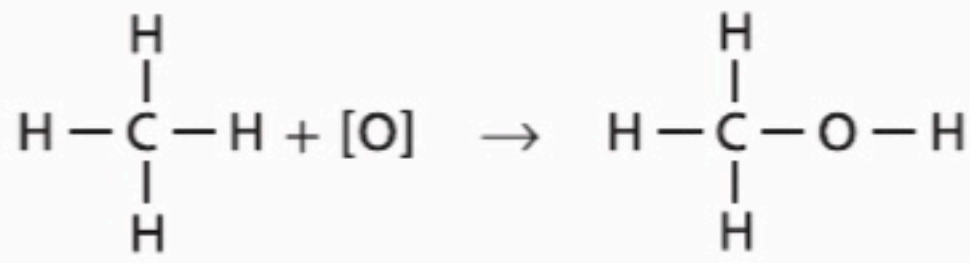
Data obtained from Izadifar, M. 2005. Application of genetic algorithm for optimization of vegetable oil hydrogenation process. *Journal of Food Engineering.* 78 (2007) 1–8.

Think Critically

1. **Calculate** the percent yield for each of the trials shown in the table.
2. **Evaluate** Which trial(s) produced the highest yield of *cis*-oleic acid and the lowest yield of *trans*-fatty acids?
3. **Explain** why the techniques used in this investigation are useful in manufacturing processes.

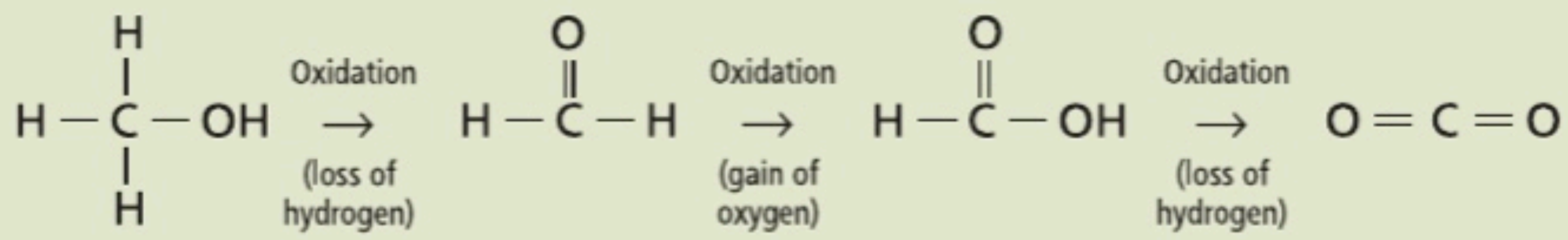
Table 13 Oxidation-Reduction Reactions

Oxidation of an alkane to an alcohol



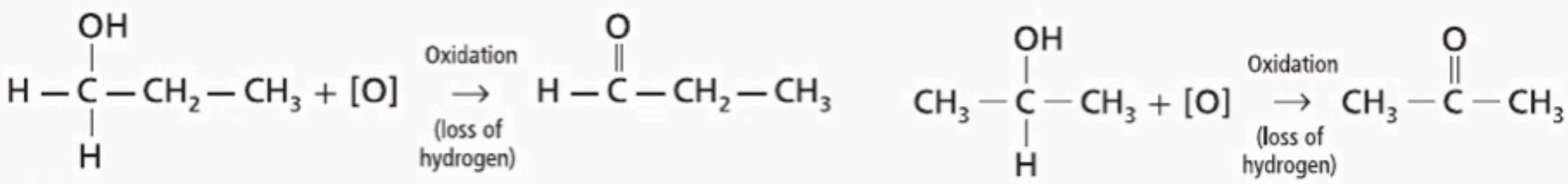
Methane → Methanol

A sequence of oxidation reactions



Methanol (methyl alcohol) — Methanal (formaldehyde) — Methanoic acid (formic acid) — Carbon dioxide

Oxidation of two isomers



1-Propanol — Propanal — 2-Propanol — 2-Propanone

Oxidation-reduction reactions Many organic compounds can be converted to other compounds by oxidation and reduction reactions. For example, suppose you want to convert methane, the main constituent of natural gas, to methanol, a common industrial solvent and raw material for making formaldehyde and methyl esters. The conversion of methane to methanol can be represented by the equation shown in **Table 13,** in which [O] represents oxygen from an agent such as copper(II) oxide, potassium dichromate, or sulfuric acid.

What happens to methane in this reaction? Before answering, it might be helpful to review the definitions of oxidation and reduction. Oxidation is the loss of electrons, and a substance is oxidized when it gains oxygen or loses hydrogen. Reduction is the gain of electrons, and a substance is reduced when it loses oxygen or gains hydrogen. Thus, methane is oxidized as it gains oxygen and is converted to methanol. Of course, every redox reaction involves both an oxidation and a reduction; however, organic redox reactions are described based on the change in the organic compound.

Oxidizing the methanol shown in **Table 13** is the first step in the sequence of reactions that can be used to produce an aldehyde, which are also shown in **Table 13.** For clarity, oxidizing agents are omitted. Preparing an aldehyde by this method is not always a simple task because the oxidation might continue, forming the carboxylic acid.

☑ **READING CHECK** **Identify** Use **Table 13** to identify two possible products that are produced when the aldehyde is further oxidized.

However, not all alcohols can be oxidized to aldehydes and, subsequently, carboxylic acids. To understand why, compare the oxidations of 1-propanol and 2-propanol, shown in **Table 13.** Note that oxidizing 2-propanol yields a ketone, not an aldehyde. Unlike aldehydes, ketones resist further oxidation to carboxylic acids. Thus, while the propanal formed by oxidizing 1-propanol easily oxidizes to form propanoic acid, the 2-propanone formed by oxidizing 2-propanol does not react to form a carboxylic acid.

☑ **READING CHECK** **Write** the equation using molecular structures like those in **Table 13** for the formation of propanoic acid.

How important are organic oxidations and reductions? You have seen that oxidation and reduction reactions can change one functional group into another. That ability enables chemists to use organic redox reactions, in conjunction with the substitution and addition reactions you read about earlier in the chapter, to synthesize a tremendous variety of useful products. On a personal note, all living systems–including you–depend on the energy released by oxidation reactions. Of course, some of the most dramatic oxidation-reduction reactions are combustion reactions. All organic compounds that contain carbon and hydrogen burn in excess oxygen to produce carbon dioxide and water. For example, the highly exothermic combustion of ethane is described by the following thermochemical equation.

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l) \qquad \Delta H = -3120 \text{ kJ}$$

As you read previously, much of the world relies on the combustion of hydrocarbons as a primary source of energy. Our reliance on the energy from organic oxidation reactions is illustrated in **Figures 15.**

RealWorld CHEMISTRY

Polycyclic Aromatic Hydrocarbons (PAHs)

BIOLOGICAL MOLECULES
Hydrocarbons composed of multiple aromatic rings are called PAHs. They have been found in meteorites and identified in the material surrounding dying stars. Scientists simulated conditions in space and found that about 10% of the PAHs were converted to alcohols, ketones, and esters. These molecules can be used to form compounds that are important in biological systems.

Predicting Products of Organic Reactions

The generic equations representing the different types of organic reactions you have learned–substitution, elimination, addition, oxidation-reduction, and condensation–can be used to predict the products of other organic reactions of the same types. For example, suppose you were asked to predict the product of an elimination reaction in which 1-butanol is a reactant. You know that a common elimination reaction involving an alcohol is a dehydration reaction.

■ **Figure 15** People around the world depend on the oxidation of hydrocarbons to get to work and to transport products.

The generic equation for the dehydration of an alcohol is as follows.

$$R\text{–}CH_2\text{–}CH_2\text{–}OH \rightarrow R\text{–}CH{=}CH_2 + H_2O$$

FOLDABLES® Incorporate information from this section into your Foldable.

To determine the actual product, first draw the structure of 1-butanol. Then use the generic equation as a model to see how 1-butanol would react. The generic reaction shows that the –OH and a H– are removed from the carbon chain. Finally, draw the structure of the likely products, as shown in the following equation.

$$\underset{\text{1-Butanol}}{CH_3\text{–}CH_2\text{–}CH_2\text{–}CH_2\text{–}OH} \rightarrow \underset{\text{1-Butene}}{CH_3\text{–}CH_2\text{–}CH{=}CH_2} + H_2O$$

As another example, suppose that you wish to predict the product of the reaction between cyclopentene and hydrogen bromide. Recall that the generic equation for an addition reaction between an alkene and an alkyl halide is as follows.

$$R\text{–}CH{=}CH\text{–}R' + HX \rightarrow R\text{–}CHX\text{–}CH_2\text{–}R'$$

First, draw the structure for cyclopentene, the organic reactant, and add the formula for hydrogen bromide, the other reactant. From the generic equation, you can see that a hydrogen atom and a halide atom add across the double bond to form an alkyl halide. Finally, draw the formula for the likely product. If you are correct, you have written the following equation.

Cyclopentene   Hydrogen bromide   Bromocyclopentane

SECTION 4 REVIEW

Section Summary

- Most reactions of organic compounds can be classified into one of five categories: substitution, elimination, addition, oxidation-reduction, and condensation.
- Knowing the types of organic compounds reacting can enable you to predict the reaction products.

18. MAINIDEA Classify each reaction as substitution, elimination, addition, or condensation.

a. $CH_3CH = CHCH_2CH_3 + H_2 \rightarrow CH_3CH_2\text{—}CH_2CH_2CH_3$

b. $CH_3CH_2CH_2\underset{\displaystyle OH}{\underset{|}{C}}HCH_3 \rightarrow CH_3CH_2CH = CHCH_3 + H_2O$

19. Identify the type of organic reaction that would best accomplish each conversion.

a. alkyl halide → alkene

b. alkene → alcohol

c. alcohol + carboxylic acid → ester

d. alkene → alkyl dihalide

20. Complete each equation by writing the condensed structural formula for the product that is most likely to form.

a. $CH_3CH = CHCH_2CH_3 + H_2 \rightarrow$

b. $CH_3CH_2\underset{\displaystyle Cl}{\underset{|}{C}}HCH_2CH_3 + OH^- \rightarrow$

21. Predicting Products Explain why the hydration reaction involving 1-butene might yield two distinct products, whereas the hydration of 2-butene yields only one product.

SECTION 5

Polymers

Essential Questions

- How does drawing a diagram help you understand the relationship between a polymer and the monomers from which it forms?
- What distinguishes addition and condensation polymerization reactions?
- How can you use molecular structures and the presence of functional groups to predict the properties of polymers?

Review Vocabulary

molecular mass: the mass of one molecule of a substance

New Vocabulary

polymer
monomer
polymerization reaction
addition polymerization
condensation polymerization
thermoplastic
thermosetting

MAINIDEA **Synthetic polymers are large organic molecules made up of repeating units that are linked together by addition or condensation reactions.**

CHEM 4 YOU **Think how different your life would be without plastic sandwich bags, plastic foam cups, nylon and polyester fabrics, vinyl siding on buildings, foam cushions, and a variety of other synthetic materials. These products all have at least one thing in common—they are made of polymers.**

The Age of Polymers

The compact discs shown in **Figure 16** contain polycarbonate, which is made of extremely long molecules with groups of atoms that repeat in a regular pattern. This molecule is an example of a synthetic polymer. **Polymers** are large molecules consisting of many repeating structural units. In **Figure 16,** the letter *n* beside the structural unit of polycarbonate represents the number of structural units in the polymer chain. Because polymer *n* values vary widely, molecular masses of polymers range from less than 10,000 amu to more than 1,000,000 amu. A typical chain in nonstick coating on skillets has about 400 units, giving it a molecular mass of around 40,000 amu.

Before the development of synthetic polymers, people were limited to using natural substances such as stone, wood, metals, wool, and cotton. By the turn of the twentieth century, a few chemically treated natural polymers such as rubber and the first plastic, celluloid, had become available. Celluloid is made by treating cellulose from cotton or wood fiber with nitric acid.

The first synthetic polymer, synthesized in 1909, was a hard, brittle plastic called Bakelite. Because of its resistance to heat, it is still used today in stove-top appliances. Since 1909, hundreds of other synthetic polymers have been developed. Because of the widespread use of polymers, people might refer to this time as the Age of Polymers.

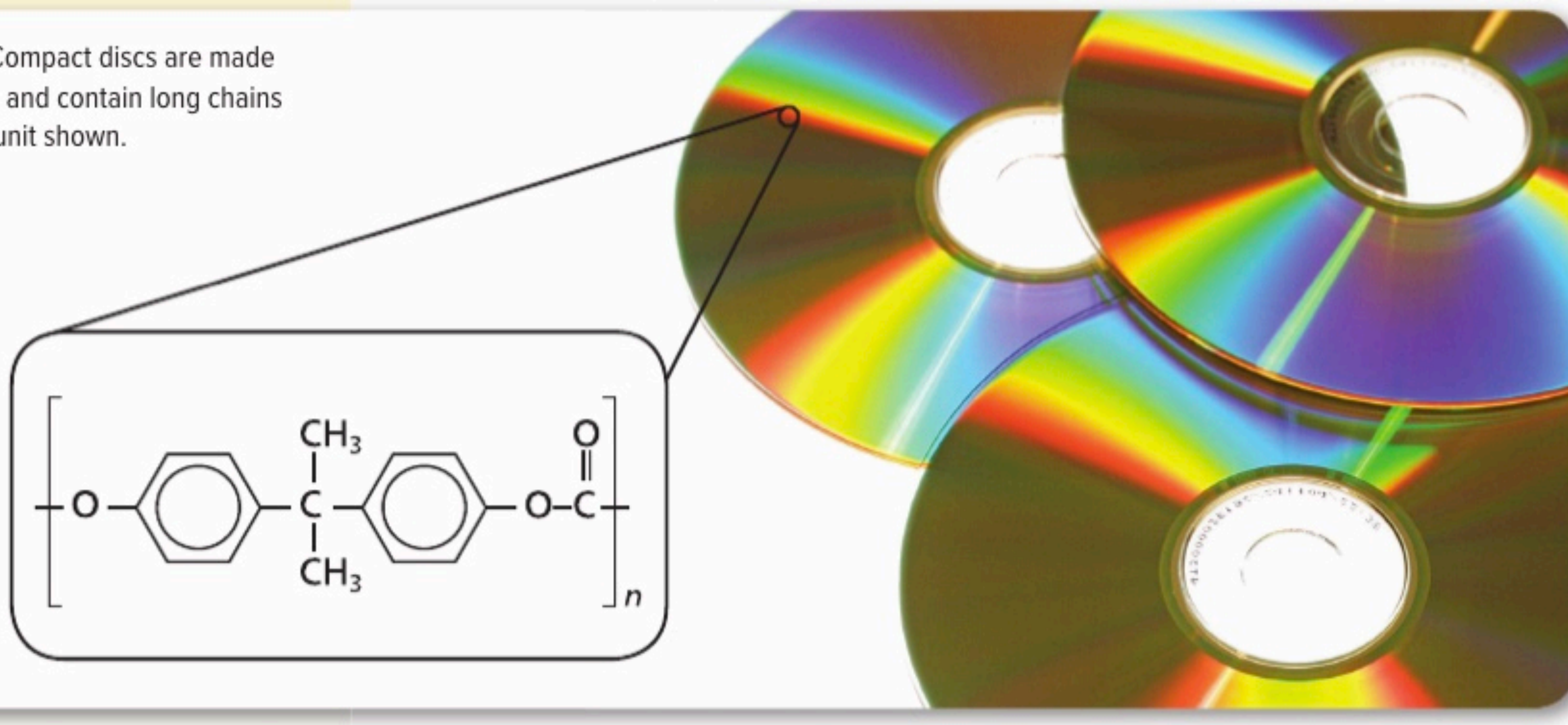


Figure 16 Compact discs are made of polycarbonate and contain long chains of the structural unit shown.

■ **Figure 17** Polyethylene is a nontoxic, unbreakable polymer that is used to make toys for children.

Reactions Used to Make Polymers

Polymers are relatively easy to manufacture. Polymers can usually be synthesized in one step in which the major reactant is a substance consisting of small, simple organic molecules called monomers. A **monomer** is a molecule from which a polymer is made.

When a polymer is made, monomers bond together one after another in a rapid series of steps. A catalyst is usually required for the reaction to take place at a reasonable pace. With some polymers, such as polyester fabric and nylon, two or more kinds of monomers bond to each other in an alternating sequence. A reaction in which monomer units are bonded together to form a polymer is called a **polymerization reaction.** The repeating group of atoms formed by the bonding of the monomers is called the structural unit of the polymer. The structural unit of a polymer made from two different monomers has the components of both monomers.

Figure 17 shows unbreakable children's toys that are made of low-density polyethylene (LDPE), which is synthesized by polymerizing ethene under pressure. Ethene can also be made into ethylene glycol, which is the starting point for polyethylene terephthalate (PETE). PETE can be made into bottles or spun into fibers. As a fiber, it is called polyester.

Figure 18 shows highlights of polymer development that led to the Age of Polymers. Although the first synthetic polymer was developed in 1909, the industry did not flourish until after World War II.

READING CHECK **Compare and contrast** a monomer and a structural unit of a polymer.

■ **Figure 18**

The Age of Polymers

Scientists working to understand the structure and properties of organic compounds have developed products that affect people everywhere. Their contributions helped usher in the Age of Polymers.

1830 — 1860 — 1890

1840s Physicians begin using ether as an anesthetic during surgery.

1865 The structure of benzene is determined. It becomes the basis for the production of aromatic compounds.

1879 Saccharin is accidentally discovered by a chemist working with coal-tar derivatives.

1899 Aspirin is widely distributed by physicians as a pain treatment. It quickly becomes the number-one selling drug worldwide.

1909 The first plastic made from synthetic polymers, Bakelite, is developed.

$$n\text{HOOC}-(\text{CH}_2)_4-\text{COOH} + n\text{H}_2\text{N}-(\text{CH}_2)_6-\text{NH}_2 \rightarrow \left[\overset{\text{O}}{\overset{\|}{\text{C}}}-(\text{CH}_2)_4-\overset{\text{O}}{\overset{\|}{\text{C}}}-\text{NH}-(\text{CH}_2)_6-\text{NH}\right]_n + n\text{H}_2\text{O}$$

Adipic acid — 1,6–Diamino hexane — Nylon 6,6

Figure 19 Nylon is a polymer consisting of thin strands that resemble silk.

Addition polymerization In **addition polymerization,** all of the atoms present in the monomers are retained in the polymer product. When the monomer is ethene, an addition polymerization results in the polymer polyethylene. Unsaturated bonds are broken in addition polymerization, just as they are in addition reactions. The difference is that the molecule added is a second molecule of the same substance, ethene. Note that the addition polymers in **Table 14** on the next page are similar in structure to polyethylene. That is, the molecular structure of each is equivalent to polyethylene in which other atoms or groups of atoms are attached to the chain in place of hydrogen atoms. All of these polymers are made by addition polymerization.

Condensation polymerization **Condensation polymerization** takes place when monomers containing at least two functional groups combine with the loss of a small by-product, usually water. Nylon and a type of bulletproof fabric are made this way. Nylon was first synthesized in 1931 and soon became popular because it is strong and can be drawn into thin strands resembling silk. Nylon 6,6 is the name of one type of nylon that is synthesized. One monomer is a chain, with the end carbon atoms being part of carboxyl groups, as shown in **Figure 19.** The other monomer is a chain having amino groups at both ends. These monomers undergo a condensation polymerization that forms amide groups linking the subunits of the polymer, as shown by the tinted box in **Figure 19.** Note that one water molecule is released for every new amide bond formed.

1939–1945 During World War II, nylon is allocated solely for military items such as parachutes, as shown in the photo, tents, and ponchos.

1946 Products with nonstick coating (PTFE), including bearings, bushings, gears, and cookware, become commercially available.

1950

1959 Spandex, an elastic fiber, is commercially produced.

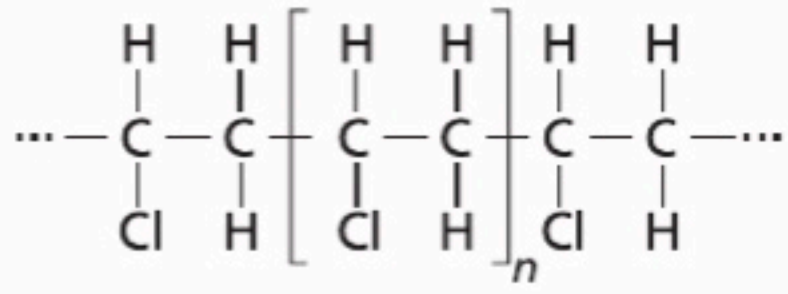
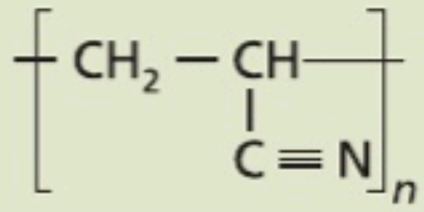
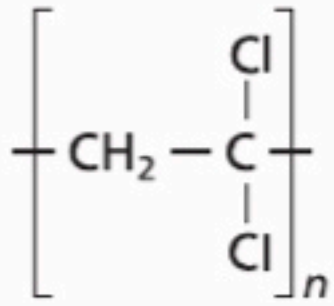
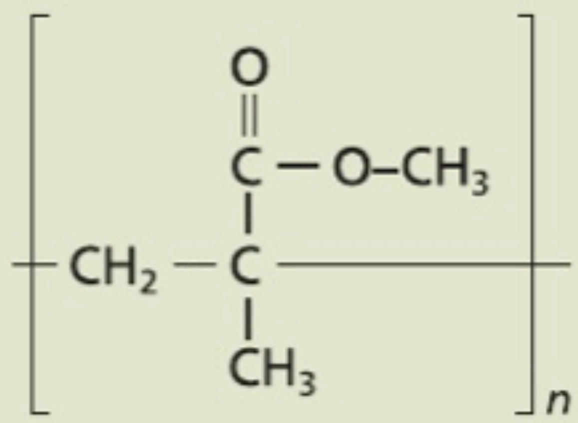
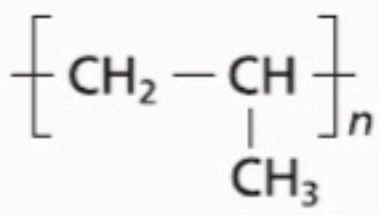
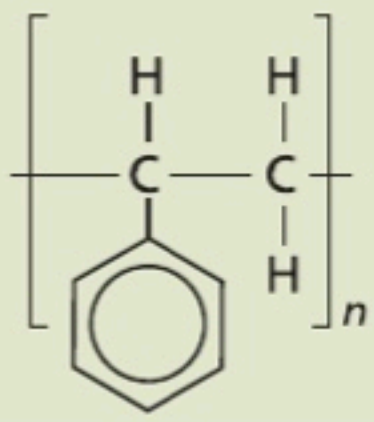
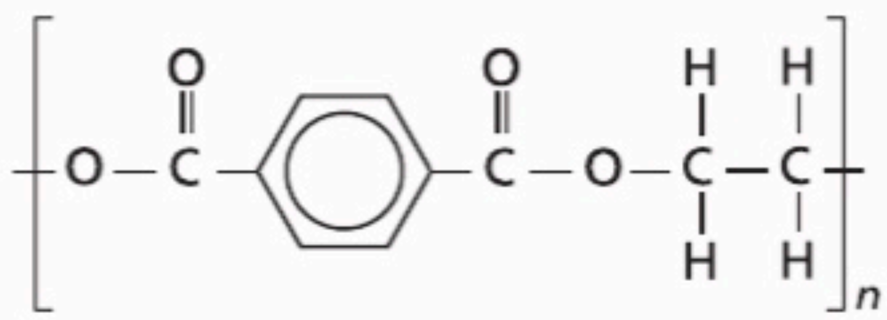
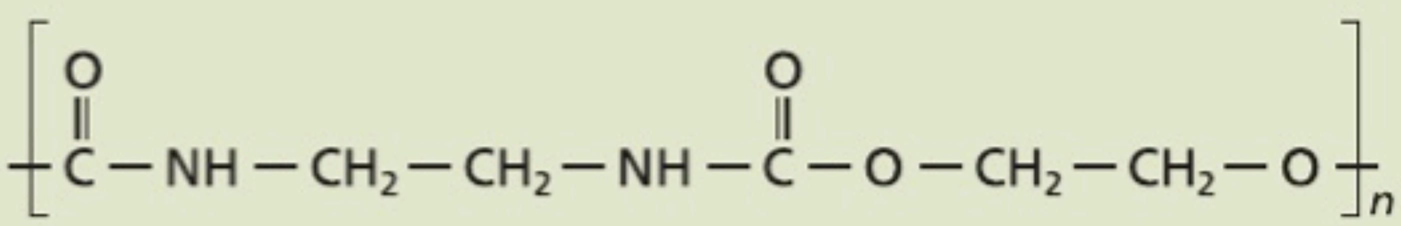
1980

1988 The world's first polymer banknote is issued by the Reserve Bank of Australia. By 1996, all Australians use plastic money.

2006 Researchers develop a paper-thin, radiation-resistant, liquid-crystal polymer in which electronic circuits can be imbedded, making it useful in space applications.

2010 Scientists create a semiconducting, transparent polymer doped with fullerenes. Once the film absorbs light, it produces an electric charge. This ability could lead to applied technology, such as transparent solar cells that can be coated on windows.

Table 14 Common Polymers

Polymer	Applications	Structural Unit
Polyvinyl chloride (PVC)	Plastic pipes, meat wrap, upholstery, rainwear, house siding, garden hose 	 Polyvinyl chloride
Polyacrylonitrile	Fabrics for clothing and upholstery, carpet	
Polyvinylidene chloride	Food wrap, fabrics 	
Polymethyl methacrylate	"Nonbreakable" (acrylic glass) windows, inexpensive lenses, art objects 	
Polypropylene (PP)	Beverage containers, rope, netting, kitchen appliances	
Polystyrene (PS) and styrene plastic	Foam packing and insulation, plant pots, disposable food containers, model kits 	
Polyethylene terephthalate (PETE)	Soft-drink bottles, tire cord, clothing, recording tape, replacements for blood vessels	
Polyurethane	Foam furniture cushions, waterproof coatings, parts of shoes	

■ **Figure 20** Plastic lumber is made from recycled plastic, such as used soft-drink bottles, milk jugs, and other polyethylene waste.

Properties and Recycling of Polymers

Why do we use so many different polymers today? One reason is that they are easy to synthesize. Another reason is that the starting materials used to make them are inexpensive. Still another, more important, reason is that polymers have a wide range of properties. Some polymers can be drawn into fine fibers that are softer than silk, while others are as strong as steel. Polymers do not rust like steel does, and many polymers are more durable than natural materials such as wood. Fencing and decking materials made of plastic, like those shown in **Figure 20,** do not decay and do not need to be repainted.

Properties of polymers Another reason why polymers are in such great demand is that it is easy to mold them into different shapes or to draw them into thin fibers. It is not easy to do this with metals and other natural materials because they must be heated either to high temperatures, do not melt at all, or are too weak to be used to form small, thin items.

As with all substances, polymers have properties that result directly from their molecular structure. For example, polyethylene is a long-chain alkane. Thus, it has a waxy feel, does not dissolve in water, is nonreactive, and is a poor electrical conductor. These properties make it ideal for use in food and beverage containers and as an insulator in electrical wire and TV cable.

Polymers fall into two different categories, based on their melting characteristics. A **thermoplastic** polymer is one that can be melted and molded repeatedly into shapes that are retained when cooled. Polyethylene and nylon are examples of thermoplastic polymers. A **thermosetting** polymer is one that can be molded when it is first prepared, but after it cools, it cannot be remelted. This property is explained by the fact that thermosetting polymers begin to form networks of bonds in many directions when they are synthesized. By the time they have cooled, thermosetting polymers have become, in essence, a single large molecule. Bakelite is an example of a thermosetting polymer. Instead of melting, Bakelite decomposes when overheated.

☑ READING CHECK **Compare and contrast** thermoplastic and thermosetting polymers.

CAREERS IN CHEMISTRY

Polymer Chemist Does the thought of developing new and better polymers sound inspiring and challenging to you? Polymer chemists develop new polymers and create uses or manufacturing processes for older ones.

VOCABULARY

WORD ORIGIN

Thermoplastic

thermo- comes from the Greek word *thermē* which means heat; *plastic* comes from the Greek word *plastikos* which means to mold or form

Figure 21 Codes on plastic products aid in recycling because they identify the composition of the plastic.

Present your ideas for creating water. Where will it go? How will it work? What will it be made of? What will the water it collects be used for?

Recycling polymers The starting materials for the synthesis of most polymers are derived from fossil fuels. As the supply of fossil fuels becomes depleted, recycling plastics becomes more important. Recycling and buying goods made from recycled plastics decreases the amount of fossil fuels used, which conserves fossil fuels.

Currently, about 5% of the plastics used in the United States are recycled. Plastics recycling is somewhat difficult due to the large variety of different polymers found in products. Usually, the plastics must be sorted according to polymer composition before they can be reused. Thermosetting polymers are more difficult to recycle than thermoplastic polymers because only thermoplastic materials can be melted and remolded repeatedly. The task of separating plastics can be time-consuming and expensive. That is why the plastics industry and the government have tried to improve the process by providing standardized codes that indicate the composition of each plastic product. The standardized codes for plastics are shown in **Figure 21.** These codes provide a quick way for recyclers to sort plastics.

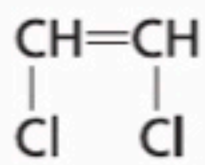
SECTION 5 REVIEW

Section Summary

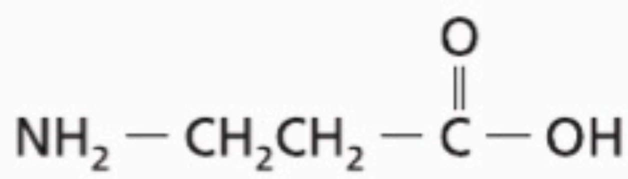
- Polymers are large molecules formed by combining smaller molecules called monomers.
- Polymers are synthesized through addition or condensation reactions.
- The functional groups present in polymers can be used to predict polymer properties.

22. MAINIDEA Draw the structure for the polymer that could be produced from each of the following monomers by the method stated.

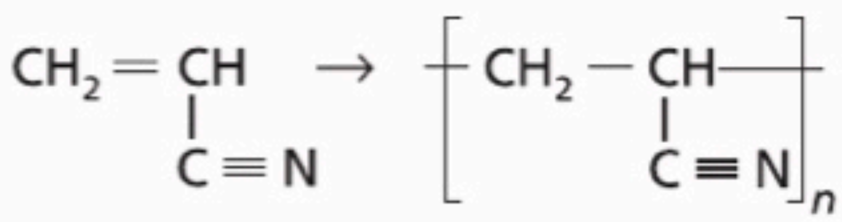
a. Addition



b. Condensation

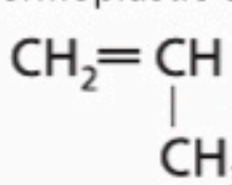


23. Label the following polymerization reaction as *addition* or *condensation.* Explain your answer.



24. Identify Synthetic polymers often replace stone, wood, metals, wool, and cotton in many applications. Identify some advantages and disadvantages of using synthetic materials instead of natural materials.

25. Predict the physical properties of the polymer that is made from the following monomer. Mention solubility in water, electrical conductivity, texture, and chemical reactivity. Do you think it will be thermoplastic or thermosetting? Give reasons for your predictions.



everydayCHEMISTRY

Garlic: Pleasure and Pain

Did you know that the flavors of fresh and roasted garlic are very different? Fresh garlic, shown in **Figure 1,** contains substances that cause a burning sensation in your mouth. However, roasted garlic does not produce this sensation. These sensations, pleasure or pain, are results of chemical reactions.

When raw garlic is bruised, cut, or crushed, it produces a chemical called allicin, as shown in **Figure 2.** The production of allicin is a chemical defense mechanism for the garlic plant against other organisms. Allicin is an unstable compound and is converted to other compounds over time or when garlic is heated or roasted, which explains why roasted garlic does not cause the burning sensation in your mouth.

Sensing temperature and pain Temperature and pain are sensed by neurons embedded in the skin, including the skin inside your mouth. These neurons have temperature-detecting molecules on their surfaces that are called transient receptor potential (TRP) ion channels. Different TRP channels are activated by different temperature ranges. For example, when a person touches something hot, some of the TRP ion channels open and allow charged calcium ions to enter the nerve cell. This increases the charge within the nerve cell. When the charge increases enough, an electrical signal is sent to the brain, where it is interpreted as a hot sensation.

Figure 1 Fresh garlic contains a pain-producing chemical as a defense against predators.

Allicin also activates neurons. Allicin apparently acts on a pair of ion channel proteins called TRPA1 and TRPV1. When the chemical allicin is present, these channels allow ions to enter the nerve cell. The additional electric charge in the nerve cell signals the brain, where the signal is interpreted by the brain as a burning sensation.

Probing pain receptors While it is interesting to know why tasting raw garlic is painful, the understanding of how allicin causes that pain sensation is even more interesting and useful. Researchers hope that a further understanding of how these receptors work will lead to new methods for controlling chronic pain in patients.

$$\underset{\text{Alliin}}{2H_2C{=}CH{-}CH_2{-}\overset{O}{\overset{\|}{S}}{-}CH_2{-}\underset{NH_2}{\underset{|}{CH}}{-}COO^-} \xrightarrow[+\,H_2O]{\text{Alliinase}} \underset{\text{Allicin}}{H_2C{=}CH{-}CH_2{-}\overset{O}{\overset{\|}{S}}{-}S{-}CH_2{-}CH{=}CH_2} + 2\,\underset{\text{Pyruvate}}{CH_3{-}\overset{O}{\overset{\|}{C}}{-}COO^-} + 2NH_4^+$$

Figure 2 When garlic is bruised or damaged, alliin and the enzyme alliinase produce allicin. When you taste fresh garlic, neurons embedded in your mouth cause an electrical signal to be sent to your brain. The brain interprets the electrical signal as a burning sensation.

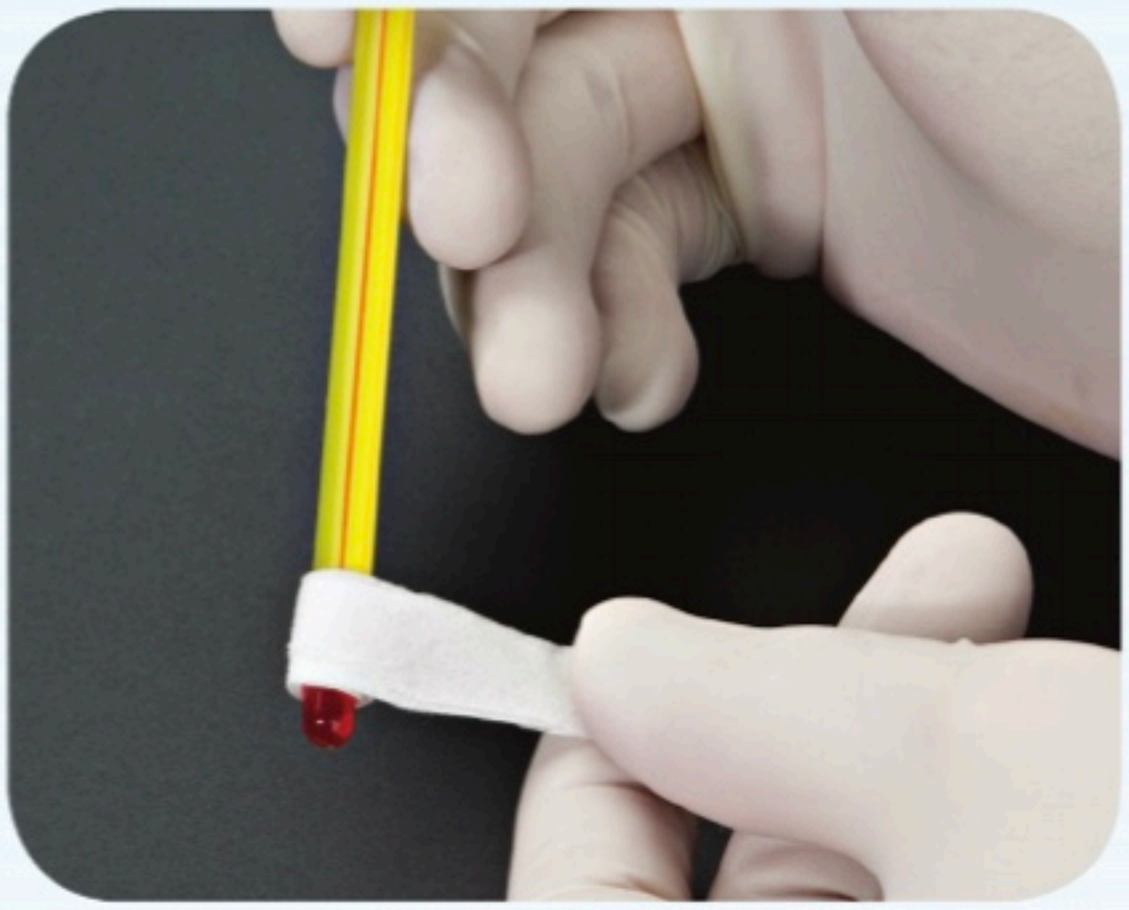
WRITING IN ▶ Chemistry
Research and prepare a poster that shows other chemical reactions in plants.

SMALL SCALE **ChemLAB**

Observe Properties of Alcohols

Background: **Alcohols are organic compounds that contain the –OH functional group. How fast various alcohols evaporate indicates the strength of intermolecular forces in alcohols. The evaporation of a liquid is an endothermic process, absorbing energy from the surroundings. This means that the temperature will decrease as evaporation occurs.**

Question: *How do intermolecular forces differ in three alcohols?*



Materials

nonmercury thermometer
stopwatch
facial tissue
cloth towel
Beral pipettes (5)
methanol
ethanol (95%)
2-propanol (99%)
wire twist tie or small rubber band
piece of cardboard for use as a fan

Safety Precautions

WARNING: ***Alcohols are flammable. Keep liquids and vapors away from open flames and sparks.***

Procedure

1. Discuss the safety concerns of this lab before work begins.
2. Prepare data tables for recording data.
3. Cut five 2-cm by 6-cm strips of tissue.
4. Place a thermometer on a folded towel lying on a flat table so that the bulb of the thermometer extends over the edge of the table. Make sure the thermometer cannot roll off the table.
5. Wrap a strip of tissue around the bulb of the thermometer. Secure the tissue with a wire twist tie placed above the bulb of the thermometer.
6. Choose one person to control the stopwatch and read the temperature on the thermometer. A second person will put a small amount of the liquid to be tested into a Beral pipette.
7. When both people are ready, squeeze enough liquid onto the tissue to completely saturate it. At the same time, the other person starts the stopwatch, reads the temperature, and records it in the data table.
8. Fan the tissue-covered thermometer bulb with a piece of cardboard or other stiff paper. After 1 min, read and record the final temperature in the data table. Remove the tissue and wipe the bulb dry.
9. Repeat Steps 5 through 8 for each of the three alcohols: methanol, ethanol, and 2-propanol.
10. Obtain the classroom temperature and humidity data from your teacher.
11. **Cleanup and Disposal** Place the used tissues in the trash. Pipettes can be reused.

Analyze and Conclude

1. **Observe and Infer** What can you conclude about the relationship between heat transfer and the differences in the temperature changes you observed?
2. **Evaluate** Molar enthalpies of vaporization (kJ/mol) for the three alcohols at 25°C are: methanol, 37.4; ethanol, 42.3; and 2-propanol, 45.4. What can you conclude about the relative strength of intermolecular forces existing in the three alcohols?
3. **Compare** Make a general statement comparing the molecular size of an alcohol in terms of the number of carbons in the carbon chain to the rate of evaporation of that alcohol.
4. **Observe and Infer** Compare your data with those of your classmates. Infer why there are differences.
5. **Error Analysis** Determine where errors might have been introduced in your procedure.

INQUIRY EXTENSION

Design an Experiment Suggest a way to make this experiment more quantitative and controlled. Design an experiment using your new method.

CHAPTER 9 STUDY GUIDE

BIGIDEA **The substitution of different functional groups for hydrogen atoms in hydrocarbons results in a diverse group of organic compounds.**

SECTION 1 Alkyl Halides and Aryl Halides

MAINIDEA A halogen atom can replace a hydrogen atom in some hydrocarbons.

- The substitution of functional groups for hydrogen in hydrocarbons creates a wide variety of organic compounds.
- An alkyl halide is an organic compound that has one or more halogen atoms bonded to a carbon atom in an aliphatic compound.

VOCABULARY
- functional group
- halocarbon
- alkyl halide
- aryl halide
- plastic
- substitution reaction
- halogenation

SECTION 2 Alcohols, Ethers, and Amines

MAINIDEA Oxygen and nitrogen are two of the most-common atoms found in organic functional groups.

- Alcohols, ethers, and amines are formed when specific functional groups substitute for hydrogen in hydrocarbons.
- Because they readily form hydrogen bonds, alcohols have higher boiling points and higher water solubilities than other organic compounds.

VOCABULARY
- hydroxyl group
- alcohol
- ether
- amine

SECTION 3 Carbonyl Compounds

MAINIDEA Carbonyl compounds contain a double-bonded oxygen in the functional group.

- Carbonyl compounds are organic compounds that contain the C=O group.
- Five important classes of organic compounds containing carbonyl compounds are aldehydes, ketones, carboxylic acids, esters, and amides.

VOCABULARY
- carbonyl group
- aldehyde
- ketone
- carboxylic acid
- carboxyl group
- ester
- amide
- condensation reaction

SECTION 4 Other Reactions of Organic Compounds

MAINIDEA Classifying the chemical reactions of organic compounds makes predicting products of reactions much easier.

- Most reactions of organic compounds can be classified into one of five categories: substitution, elimination, addition, oxidation-reduction, and condensation.
- Knowing the types of organic compounds reacting can enable you to predict the reaction products.

VOCABULARY
- elimination reaction
- dehydrogenation reaction
- dehydration reaction
- addition reaction
- hydration reaction
- hydrogenation reaction

SECTION 5 Polymers

MAINIDEA Synthetic polymers are large organic molecules made up of repeating units linked together by addition or condensation reactions.

- Polymers are large molecules formed by combining smaller molecules called monomers.
- Polymers are synthesized through addition or condensation reactions.
- The functional groups present in polymers can be used to predict polymer properties.

VOCABULARY
- polymer
- monomer
- polymerization reaction
- addition polymerization
- condensation polymerization
- thermoplastic
- thermosetting

CHAPTER 9 ASSESSMENT

SECTION 1

Mastering Concepts

26. What is a functional group?

27. Describe and compare the structures of alkyl halides and aryl halides.

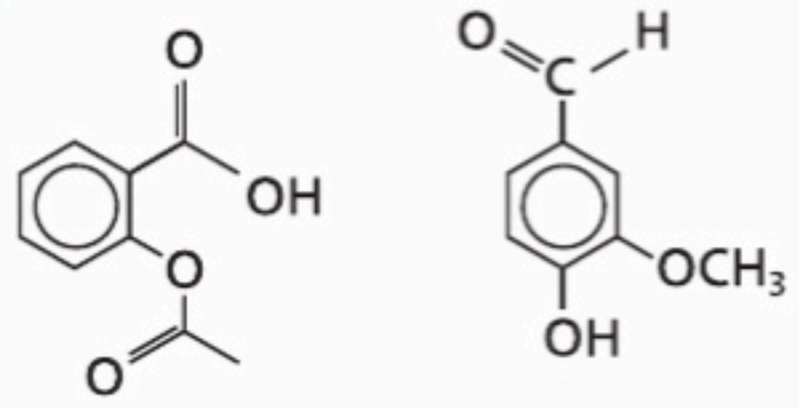
28. What reactant would you use to convert methane to bromomethane?

29. Name the amines represented by each of the condensed formulas.

a. $CH_3(CH_2)_3CH_2NH_2$
b. $CH_3(CH_2)_5CH_2NH_2$
c. $CH_3(CH_2)_2CH(NH_2)CH_3$
d. $CH_3(CH_2)_8CH_2NH_2$

30. Explain why the boiling points of alkyl halides increase in order going down the column of halides in the periodic table, from fluorine through iodine.

Mastering Problems



a Acetylsalicylic acid **b** Vanillin

■ **Figure 22**

31. Name and write the general formula of each of the functional groups attached to the benzene rings shown in **Figure 22.**

32. Draw structures for these alkyl and aryl halides.

a. chlorobenzene
b. 1-bromo-4-chlorohexane
c. 1,2-difluoro-3-iodocyclohexane
d. 1,3-dibromobenzene
e. 1,1,2,2-tetrafluoroethane

33. For 1-bromo-2-chloropropane:

a. Draw the structure.
b. Does the compound have optical isomers?
c. If the compound has optical isomers, identify the chiral carbon atom.

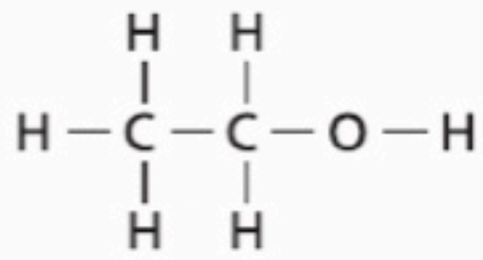
34. Draw and name all of the structural isomers possible for an alkyl halide with no branches and the molecular formula $C_5H_{10}Br_2$.

35. Name one structural isomer created by changing the position of one or more halogen atoms in each alkyl halide.

a. 2-chloropentane
b. 1,1-difluropropane
c. 1,3-dibromocyclopentane
d. 1-bromo-2-chloroethane

SECTION 2

Mastering Concepts



■ **Figure 23**

36. How is the compound shown in **Figure 23** denatured? What is the name of the compound?

37. Practical Applications Name one alcohol, amine, or ether that is used for each of the following purposes.

a. antiseptic
b. solvent in paint strippers
c. antifreeze
d. anesthetic
e. dye production

38. Explain why an alcohol molecule will always have a higher solubility in water than an ether molecule having an identical molecular mass.

39. Explain why ethanol has a much higher boiling point than aminoethane, even though their molecular masses are nearly equal.

Mastering Problems

40. Name one ether that is a structural isomer of each alcohol.

a. 1-butanol
b. 2-hexanol

41. Draw structures for the following alcohol, amine, and ether molecules.

a. 1,2-butanediol
b. 2-aminohexane
c. isopropyl ether
d. 2-methyl-1-butanol
e. butyl pentyl ether
f. cyclobutyl methyl ether
g. 1,3-diaminobutane
h. cyclopentanol

SECTION 3

Mastering Concepts

42. Draw the general structure for each of the following classes of organic compounds.

a. aldehyde
b. ketone
c. carboxylic acid
d. ester
e. amide

43. Common Uses Name an aldehyde, ketone, carboxylic acid, ester, or amide used for each of the following purposes.

a. preserving biological specimens
b. solvent in fingernail polish
c. acid in vinegar
d. flavoring in foods and beverages

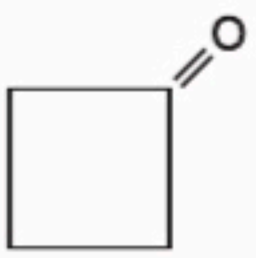
44. What type of reaction is used to produce aspirin from salicylic acid and acetic acid?

Mastering Problems

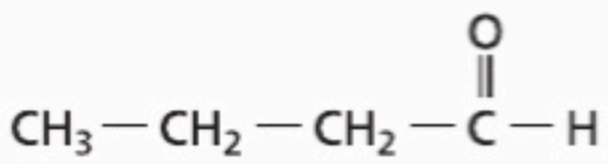
45. Draw structures for each of the following carbonyl compounds.
- **a.** 2,2-dichloro-3-pentanone
- **b.** 4-methylpentanal
- **c.** isopropyl hexanoate
- **d.** octanamide
- **e.** 3-fluoro-2-methylbutanoic acid
- **f.** cyclopentanal
- **g.** hexyl methanoate

46. Name each of the following carbonyl compounds.

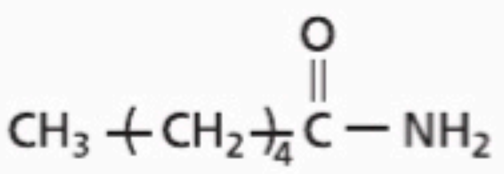
a.



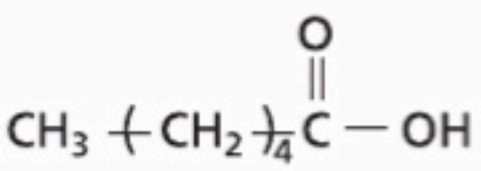
b.



c.



d.



SECTION 4

Mastering Concepts

47. Synthetic Organic Compounds What is the starting material for making most synthetic organic compounds?

48. Explain the importance of classifying reactions.

49. List the type of organic reaction needed to perform each of the following transformations.
- **a.** alkene → alkane
- **b.** alkyl halide → alcohol
- **c.** alkyl halide → alkene
- **d.** amine + carboxylic acid → amide
- **e.** alcohol → alkyl halide
- **f.** alkene → alcohol

Mastering Problems

50. Classify each of the following organic reactions as substitution, addition, oxidation-reduction elimination, or condensation.
- **a.** 2-butene + hydrogen → butane
- **b.** propane + fluorine → 2-fluoropropane + hydrogen fluoride
- **c.** 2-propanol → propene + water
- **d.** cyclobutene + water → cyclobutanol

51. Use structural formulas to write equations for the following reactions.
- **a.** the substitution reaction between 2-chloropropane and water yielding 2-propanol and hydrogen chloride
- **b.** the addition reaction between 3-hexene and chlorine yielding 3,4-dichlorohexane

52. What type of reaction converts an alcohol into each of the following types of compounds?
- **a.** ester
- **b.** alkyl halide
- **c.** alkene
- **d.** aldehyde

53. Use structural formulas to write the equation for the condensation reaction between ethanol and propanoic acid.

SECTION 5

Mastering Concepts

54. Explain the difference between addition polymerization and condensation polymerization.

55. Which type of polymer is easier to recycle, thermosetting or thermoplastic? Explain your answer.

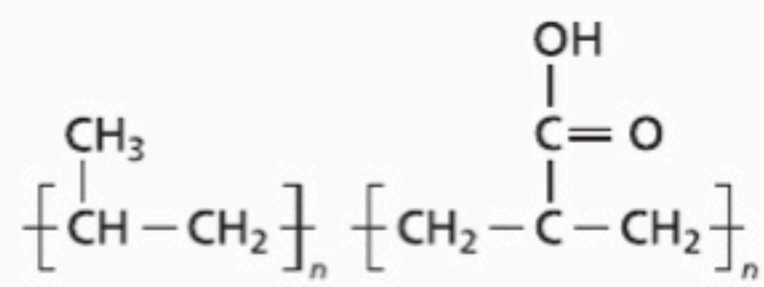
Mastering Problems

56. Manufacturing Polymers Draw the monomers that react to form each polymer.
- **a.** polyethylene
- **b.** polyvinyl chloride (PVC)
- **c.** polytetrafluoroethylene (PTFE)

57. Name the polymers made from the following monomers.
- **a.** $H_2C = CHCl$
- **b.** $CH_2 = CCl_2$

58. Choose the polymer of each pair that you expect to have the higher water solubility.

a.



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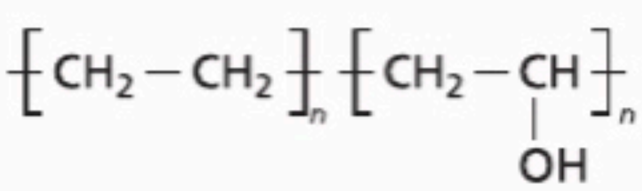
b.



59. Examine the structures of the following polymers. Decide whether each is made by addition or condensation polymerization.
- **a.** nylon
- **b.** polyacrylonitrile
- **c.** polyurethane
- **d.** polypropylene

60. Human Hormones Which halogen is found in hormones made by a normal human thyroid gland?

MIXED REVIEW

61. Describe the properties of carboxylic acids.

62. Draw structures of the following compounds.
a. butanone
b. propanal
c. hexanoic acid
d. heptanamide

63. Name the type of organic compound formed by each of the following reactions.
a. elimination from an alcohol
b. addition of hydrogen chloride to an alkene
c. addition of water to an alkene
d. substitution of a hydroxyl group for a halogen atom

64. List two uses for each of the following polymers.
a. polypropylene
b. polyurethane
c. polytetrafluoroethylene
d. polyvinyl chloride

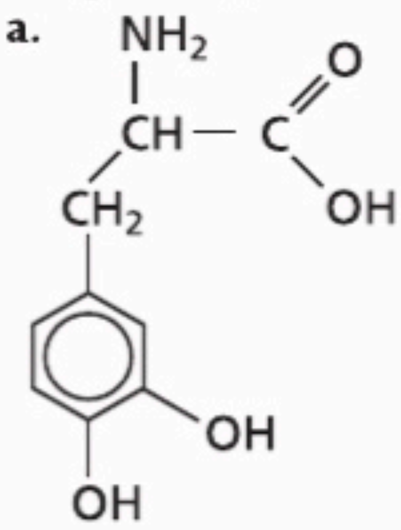
65. Draw structures of and supply names for the organic compounds produced by reacting ethene with each of the following substances.
a. water
b. hydrogen
c. hydrogen chloride
d. fluorine

66. Environmentally-Safe Propellants Hydrofluoroalkanes (HFAs) are replacing chlorofluorocarbons in hand-held asthma inhalers, because of CFC damage to the ozone layer. Draw the structures of the HFAs listed below.
a. 1,1,1,2,3,3,3-heptafluoropropane
b. 1,1,1,2-tetrafluoroethane

THINK CRITICALLY

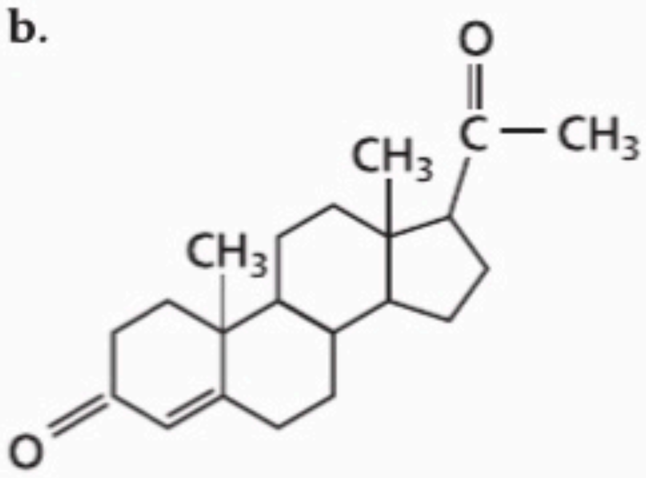
67. Interpret Scientific Illustrations List all the functional groups present in each of the following complex organic molecules.

a.



Levadopa

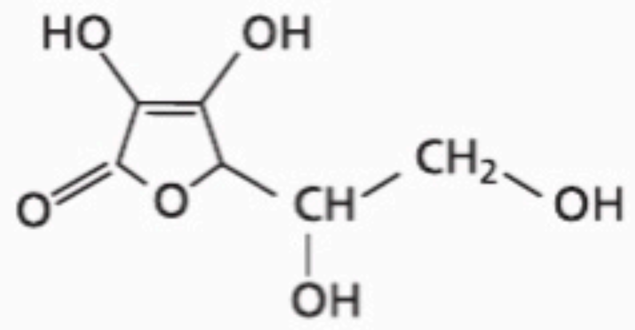
b.



Progesterone

68. Evaluate Ethanoic acid (acetic acid) is very soluble in water. However, naturally occurring long-chain carboxylic acids, such as palmitic acid ($CH_3(CH_2)_{14}COOH$), are insoluble in water. Explain.

69. Communicate Write structural formulas for all structural isomers of molecules having the following formulas. Name each isomer.
a. C_3H_8O
b. $C_2H_4Cl_2$



Vitamin C

■ **Figure 24**

70. Interpret Scientific Illustrations Human cells require vitamin C to properly synthesize materials that make up connective tissue such as that found in ligaments. List the functional groups present in the vitamin C molecule shown in **Figure 24.**

71. Identify Draw the structure of an example of an organic molecule that has four carbons and falls into each of the compound types listed.
a. ester
b. aldehyde
c. ether
d. alcohol

72. Predict A monohalogenation reaction describes a substitution reaction in which a single hydrogen atom is replaced by a halogen. A dihalogenation reaction is a reaction in which two hydrogen atoms are replaced by two halogen atoms.
a. Draw the structures of all the possible monohalogenation products that can form when pentane reacts with Cl_2.
b. Draw the structures of all the possible dihalogenation products that can form when pentane reacts with Cl_2.

Table 15 Alcohol Solubility in Water (mol/100 g H_2O)

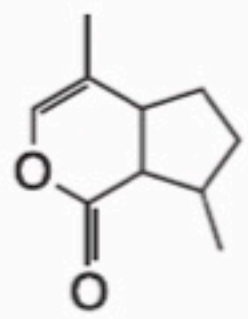
Name	Alcohol	Solubility
Methanol	CH_3OH	infinite
Ethanol	C_2H_5OH	infinite
Propanol	C_3H_7OH	infinite
Butanol	C_4H_9OH	0.11
Pentanol	$C_5H_{11}OH$	0.030
Hexanol	$C_6H_{13}OH$	0.0058
Heptanol	$C_7H_{15}OH$	0.0008

73. Evaluate Examine **Table 15** comparing some alcohols and their solubility in water. Use the table to answer the following questions.
a. What type of bond forms between the -OH group of alcohols and water?
b. State a relationship between water solubility and alcohol size from the data in the table.
c. Provide an explanation for the relationship you stated in Part b.

74. Recognize Most useful organic molecules are made from raw materials using several steps. This is called a multistep synthesis pathway. Label the types of reaction or process taking place in each step of the multistep synthesis pathway below.

petroleum → ethane → chloroethane → ethene → ethanol → ethanoic (acetic) acid

CHALLENGE PROBLEM



■ **Figure 25**

75. Animal Pheromones Catnip contains an organic chemical known as *nepetalactone*, shown in **Figure 25,** that is thought to mimic feline sex pheromones. Cats will rub in it, roll over it, paw at it, chew it, lick it, leap about, then purr loudly, growl, and meow for several minutes before losing interest. It takes up to two hours for the cat to "reset" and then have the same response to the catnip.

a. What type of organic compound is nepetalactone?

b. Draw the structural formula for nepetalactone on a sheet of paper and then draw in all the missing hydrogen atoms. Remember that carbon atoms must have four bonds to be stable.

c. Write the molecular formula for nepetalactone.

CUMULATIVE REVIEW

76. Explain why the concentration of ozone over Antarctica decreases at about the same time every year.

77. Why do the following characteristics apply to transition metals?

a. Ions vary in charge.

b. Many of their solids are colored.

c. Many are hard solids.

78. Determine the number of atoms in each of the following.

a. 56.1 g Al **b.** 2 moles C

79. What is a rate-determining step?

80. According to Le Châtelier's principle, how would increasing the volume of the reaction vessel affect the equilibrium $2SO_2(g) + O_2(g) \leftrightarrows 2SO_3(g)$?

81. Compare and contrast saturated and unsaturated hydrocarbons.

WRITING IN ▶ Chemistry

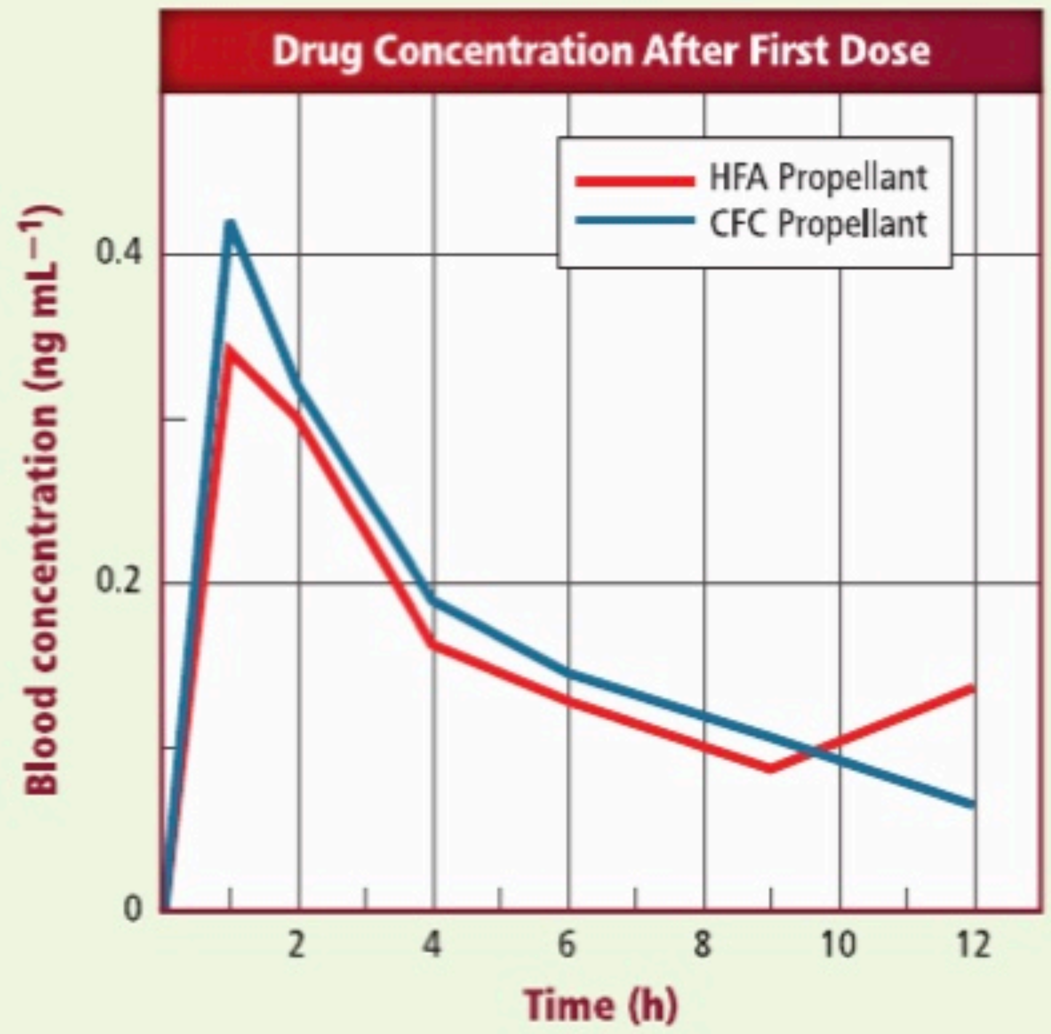
82. Historical Perspective Write a short story describing how your life would differ if you lived in the 1800s, before the development of synthetic polymers.

DBQ Document-Based Questions

Pharmaceutical Propellants *Many inhaled medications used to treat asthma contained chlorofluorocarbons (CFCs). However, the Montreal Protocol called for a ban of CFCs as a propellant in pharmaceutical products by 2008. Two hydrofluoroalkanes (HFAs) appear to be effective in delivering asthma medications to the lungs. However, the medication dosage had to be cut in half with the new HFA propellents.*

Figure 26 *shows the concentration after one dose of the drug beclomethasone in the blood of volunteers using a CFC or an HFA propellant in the inhaler.*

Data obtained from: Anderson, P.J. 2006. *Chest: The Cardiopulmonary and Critical Care Journal.* 120:89–93



■ **Figure 26**

83. After one dose of the drug beclomethasone was given, which propellant resulted in the highest concentration of medication in the blood, HFA or CFC?

84. When does the drug reach its peak concentration?

85. Only one-half the amount of medication is needed with the HFA propellant when compared to the CFC propellant to achieve a similar blood-concentration level. Infer the advantages of using a lower dose of medication to get similar results.

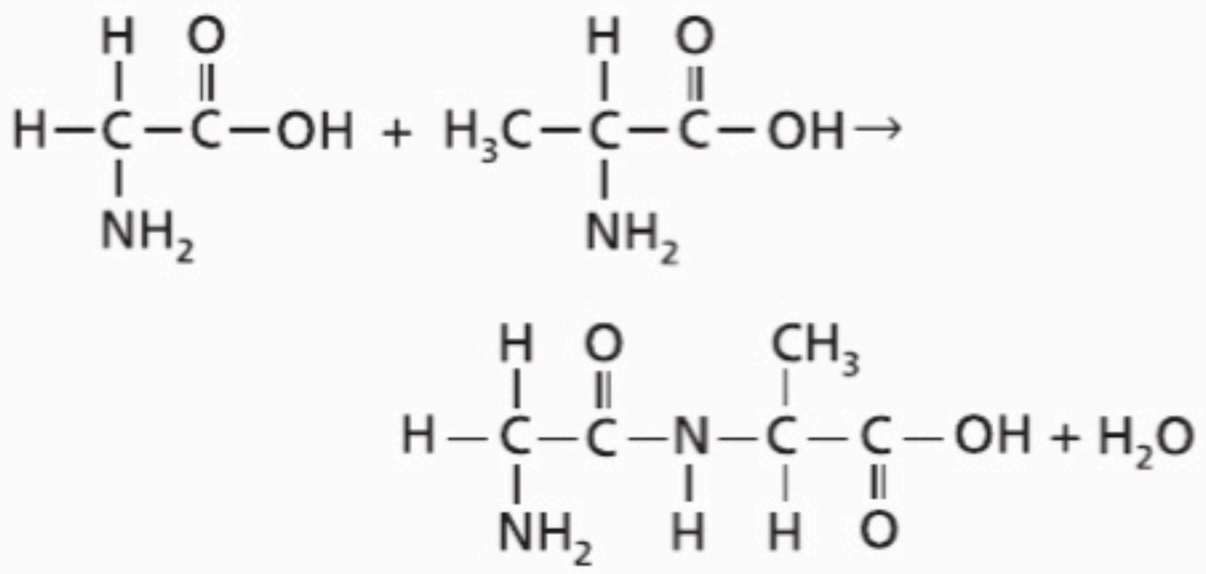
MULTIPLE CHOICE

1. What are the products of this reaction?

$CH_3CH_2CH_2Br + NH_3 \rightarrow ?$

A. $CH_3CH_2CH_2NH_2Br$ and H_2
B. $CH_3CH_2CH_2NH_3$ and Br_2
C. $CH_3CH_2CH_2NH_2$ and HBr
D. $CH_3CH_2CH_3$ and NH_2Br

2. What kind of reaction is this?



A. substitution
B. condensation
C. addition
D. elimination

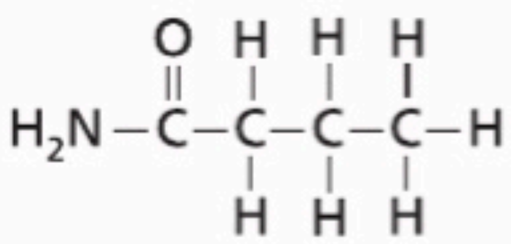
3. What are the oxidation numbers of the elements in $CuSO_4$?

A. Cu = +2, S = +6, O = −2
B. Cu = +3, S = +5, O = −2
C. Cu = +2, S = +2, O = −1
D. Cu = +2, S = 0, O = −2

4. The corrosion, or rusting, of iron is an example of a naturally occurring voltaic cell. To prevent corrosion, sacrificial anodes are sometimes attached to rust-susceptible iron. Sacrificial anodes must

A. be more likely to be reduced than iron.
B. have a higher reduction potential than iron.
C. be more porous and abraded than iron.
D. lose electrons more easily than iron.

5. What type of compound does this molecule represent?

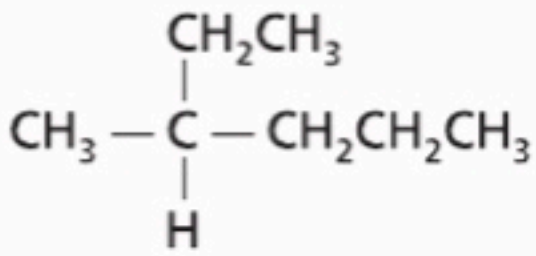


A. amine
B. amide
C. ester
D. ether

6. Diprotic succinic acid ($H_2C_4H_4O_4$) is an important part of the process that converts glucose to energy in the human body. What is the K_a expression for the second ionization of succinic acid?

A. $K_a = [H_3O^+][HC_4H_4O_4^-] / [H_2C_4H_4O_4]$
B. $K_a = [H_3O^+][C_4H_4O_4^{2-}] / [HC_4H_4O_4^-]$
C. $K_a = [H_2C_4H_4O_4] / [H_3O^+][HC_4H_4O_4^-]$
D. $K_a = [H_2C_4H_4O_4] / [H_3O^+][C_4H_4O_4^{2-}]$

Use the figure below to answer Question 7.



7. Which is the correct name for this compound?

A. 3-methylhexane
B. 2-ethylpentane
C. 2-propylbutane
D. 1-ethyl-1-methylbutane

8. A strip of metal X is immersed in a 1*M* solution of X^+ ions. When this half-cell is connected to a standard hydrogen electrode, a voltmeter reads a positive reduction potential. Which is true of the X electrode?

A. It accepts electrons more readily than H^+ ions.
B. It is undergoing oxidation.
C. It is adding positive X^+ ions to its solution.
D. It acts as the anode in the cell.

9. What is the mass of one formula unit of barium hexafluorosilicate ($BaSiF_6$)?

A. 4.64×10^{-22} g
B. 1.68×10^{26} g
C. 2.16×10^{21} g
D. 6.02×10^{-23} g

10. Which type of compound accepts H^+ ions?

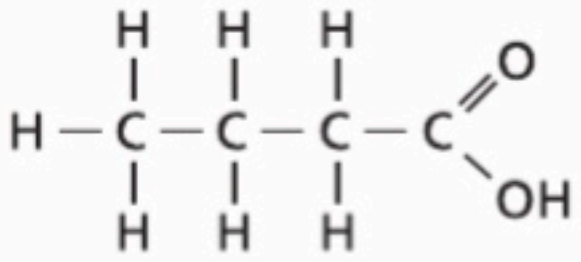
A. an Arrhenius acid
B. an Arrhenius base
C. a Brønsted-Lowry acid
D. a Brønsted-Lowry base

11. Which substituted hydrocarbon has the general formula R–OH?

A. alcohol
B. amine
C. ketone
D. carboxylic acid

SHORT ANSWER

Use the figure below to answer Questions 12 and 13.

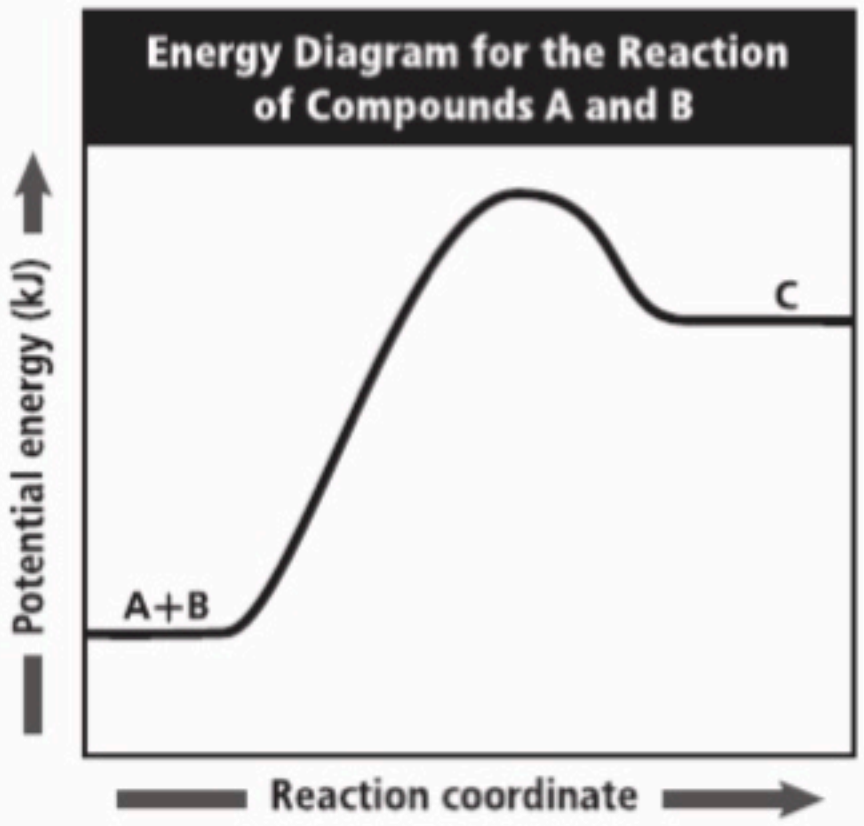


12. What is the functional group present in this compound?

13. Give the name for this compound.

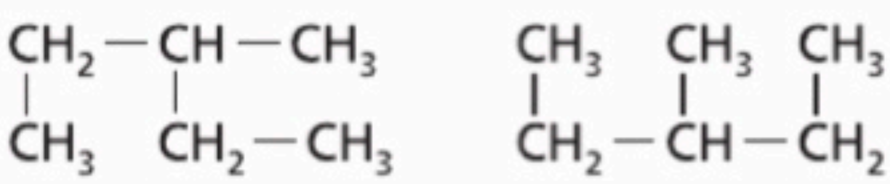
EXTENDED RESPONSE

Use the graph below to answer Question 14.



14. Discuss the reaction that results in the shape of the energy graph shown.

Use the figure below to answer Question 15.

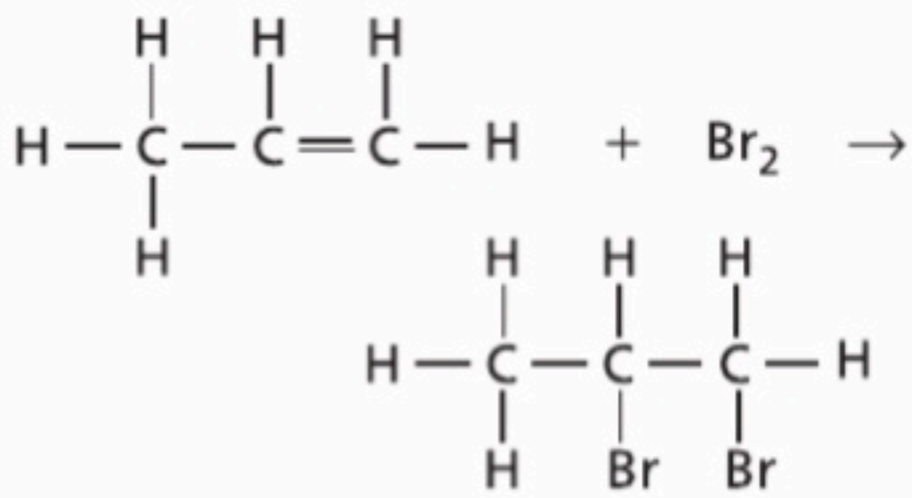


15. The two structures above both have the molecular formula C_6H_{14}. Are they isomers of one another? Explain how you can tell.

SAT SUBJECT TEST: CHEMISTRY

16. To electroplate an iron fork with silver,
- **A.** the silver electrode must have more mass than the fork.
- **B.** the iron fork must act as the anode in the cell.
- **C.** electric current must be applied to the iron fork.
- **D.** iron ions must be present in the cell solution.
- **E.** the electric current must be pulsed.

17. Which type of reaction is shown below?



- **A.** condensation
- **B.** dehydration
- **C.** polymerization
- **D.** halogenation
- **E.** hydration

Use the table below to answer Question 18.

Experimental Data for A + B → C			
Time	[A]*M*	[B]*M*	[C]*M*
0.00 sec	0.35	0.50	0.00
5.00 sec	0.15	0.30	0.40

18. Which is the rate of this reaction in terms of product produced in mol/(L•s)?
- **A.** 0.40 mol/(L•s)
- **B.** 0.85 mol/(L•s)
- **C.** 0.08 mol/(L•s)
- **D.** 0.17 mol/(L•s)
- **E.** 0.93 mol/(L•s)

STUDENT RESOURCES

Elements Handbook EH-1

Hydrogen EH-4
Group 1: Alkali Metals EH-6
Group 2: Alkaline Earth Metals EH-10
Groups 3–12: Transition Elements EH-16
Group 13: Boron Group EH-22
Group 14: Carbon Group EH-26
Group 15: Nitrogen Group EH-32
Group 16: Oxygen Group EH-36
Group 17: Halogen Group EH-40
Group 18: Noble Gases EH-44

Math Handbook MH-1

Scientific Notation MH-1
Operations with Scientific Notation MH-3
Square and Cube Roots MH-4
Significant Figures MH-4
Solving Algebraic Equations MH-9
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Unit Conversion MH-12
Drawing Line Graphs MH-14
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Ratios, Fractions, and Percents MH-19
Operations Involving Fractions MH-20
Logarithms and Antilogarithms MH-21

Reference Tables RT-1

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R-2 Symbols and Abbreviations RT-1
R-3 Solubility Product Constants RT-2
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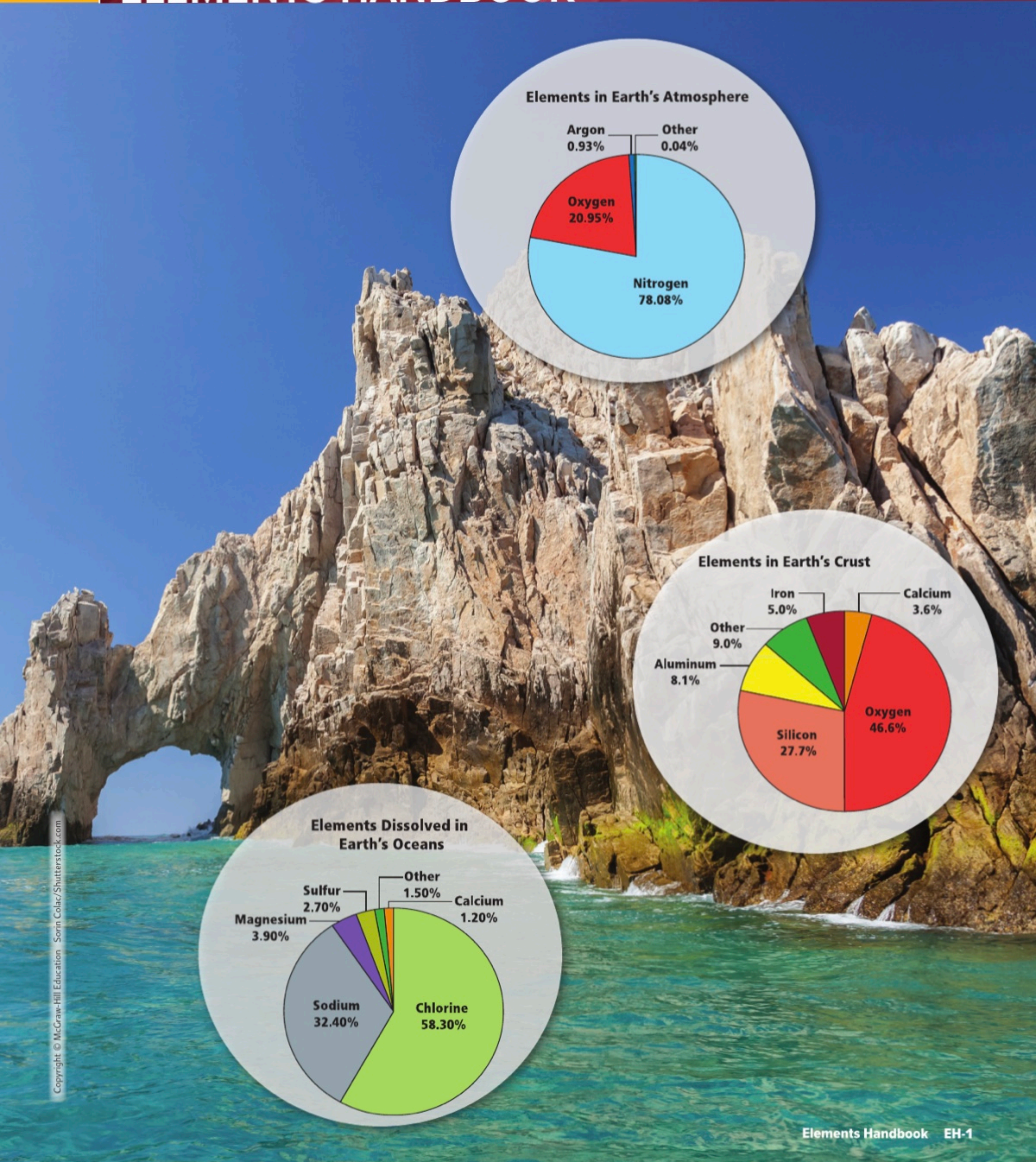
Supplemental Practice Problems SPP-8

Selected Solutions SS-7

Science Resources SR-1

ELEMENTS HANDBOOK



REFERENCE TABLES

Reference Tables

Table R-1 Color Key

	**Carbon**		**Bromine**		**Sodium/ Other metals**
	**Hydrogen**		**Iodine**		**Gold**
	**Oxygen**		**Sulfur**		**Copper**
	**Nitrogen**		**Phosphorus**		**Electron**
	**Chlorine**		**Silicon**		**Proton**
	**Fluorine**		**Helium**		**Neutron**

Table R-2 Symbols and Abbreviations

- α = rays from radioactive materials, helium nuclei
- β = rays from radioactive materials, electrons
- γ = rays from radioactive materials, high-energy quanta
- Δ = change in
- λ = wavelength
- ν = frequency
- A = ampere *(electric current)*
- amu = atomic mass unit
- Bq = becquerel *(nuclear disintegration)*
- °C = Celsius degree *(temperature)*
- C = coulomb *(quantity of electricity)*
- c = speed of light
- cd = candela *(luminous intensity)*
- c = specific heat
- *D* = density
- *E* = energy, electromotive force
- *F* = force
- *G* = free energy
- g = gram *(mass)*
- Gy = gray *(radiation)*
- *H* = enthalpy
- Hz = hertz *(frequency)*
- *h* = Planck's constant
- h = hour *(time)*
- J = joule *(energy)*
- K = kelvin *(temperature)*
- K_a = ionization constant *(acid)*
- K_b = ionization constant *(base)*
- K_{eq} = equilibrium constant
- K_{sp} = solubility product constant
- kg = kilogram *(mass)*
- *M* = molarity
- *m* = mass, molality
- m = meter *(length)*
- mol = mole *(amount)*
- min = minute *(time)*
- N = newton *(force)*
- N_A = Avogadro's number
- *n* = number of moles
- *P* = pressure, power
- Pa = pascal *(pressure)*
- *q* = heat
- Q_{sp} = ion product
- *R* = ideal gas constant
- *S* = entropy
- s = second *(time)*
- Sv = sievert *(absorbed radiation)*
- *T* = temperature
- *V* = volume
- V = volt *(electric potential)*
- *v* = velocity
- W = watt *(power)*
- *w* = work
- *X* = mole fraction

Table R-3 Solubility Product Constants at 298 K

Compound	K_{sp}	Compound	K_{sp}	Compound	K_{sp}
Carbonates		**Halides**		**Hydroxides**	
$BaCO_3$	2.6×10^{-9}	CaF_2	3.5×10^{-11}	$Al(OH)_3$	4.6×10^{-33}
$CaCO_3$	3.4×10^{-9}	$PbBr_2$	6.6×10^{-6}	$Ca(OH)_2$	5.0×10^{-6}
$CuCO_3$	2.5×10^{-10}	$PbCl_2$	1.7×10^{-5}	$Cu(OH)_2$	2.2×10^{-20}
$PbCO_3$	7.4×10^{-14}	PbF_2	3.3×10^{-8}	$Fe(OH)_2$	4.9×10^{-17}
$MgCO_3$	6.8×10^{-6}	PbI_2	9.8×10^{-9}	$Fe(OH)_3$	2.8×10^{-39}
Ag_2CO_3	8.5×10^{-12}	AgCl	1.8×10^{-10}	$Mg(OH)_2$	5.6×10^{-12}
$ZnCO_3$	1.5×10^{-10}	AgBr	5.4×10^{-13}	$Zn(OH)_2$	3×10^{-17}
Hg_2CO_3	3.6×10^{-17}	AgI	8.5×10^{-17}	**Sulfates**	
Chromates		**Phosphates**		$BaSO_4$	1.1×10^{-10}
$BaCrO_4$	1.2×10^{-10}	$AlPO_4$	9.8×10^{-21}	$CaSO_4$	4.9×10^{-5}
$PbCrO_4$	2.3×10^{-13}	$Ca_3(PO_4)_2$	2.1×10^{-33}	$PbSO_4$	2.5×10^{-8}
Ag_2CrO_4	1.1×10^{-12}	$Mg_3(PO_4)_2$	1.0×10^{-24}	Ag_2SO_4	1.2×10^{-5}
Iodates		$FePO_4 \cdot 2H_2O$	9.91×10^{-16}	**Arsenates**	
$Cd(IO_3)_2$	2.3×10^{-8}	$Ni_3(PO_4)_2$	4.7×10^{-32}	$Pb_3(AsO_4)_2$	4.0×10^{-36}

Table R-4 Physical Constants

Quantity	Symbol	Value
Atomic mass unit	amu	1.6605×10^{-27} kg
Avogadro's number	N_A	6.022×10^{23} particles/mole
Ideal gas constant	R	8.31 L•kPa/mol•K 0.0821 L•atm/mol•K 62.4 mm Hg•L/mol•K 62.4 torr•L/mol•K
Mass of an electron	m_e	9.109×10^{-31} kg 5.485799×10^{-4} amu
Mass of a neutron	m_n	1.6749×10^{-27} kg 1.008665 amu
Mass of a proton	m_p	1.6726×10^{-27} kg 1.007276 amu
Molar volume of ideal gas at STP	V	22.414 L/mol
Normal boiling point of water	T_b	373.15 K 100.0°C
Normal freezing point of water	T_f	273.15 K 0.00°C
Planck's constant	h	$6.6260693 \times 10^{-34}$ J•s
Speed of light in a vacuum	c	2.997925×10^{8} m/s

Table R-5 Names and Charges of Polyatomic Ions

1−

- Acetate, CH_3COO^-
- Amide, NH_2^-
- Astatate, AtO_3^-
- Azide, N_3^-
- Benzoate, $C_6H_5COO^-$
- Bismuthate, BiO_3^-
- Bromate, BrO_3^-
- Chlorate, ClO_3^-
- Chlorite, ClO_2^-
- Cyanide, CN^-
- Formate, $HCOO^-$
- Hydroxide, OH^-
- Hypobromite, BrO^-
- Hypochlorite, ClO^-
- Hypophosphite, $H_2PO_2^-$
- Iodate, IO_3^-
- Nitrate, NO_3^-
- Nitrite, NO_2^-
- Perbromate, BrO_4^-
- Perchlorate, ClO_4^-
- Periodate, IO_4^-
- Permanganate, MnO_4^-
- Perrhenate, ReO_4^-
- Thiocyanate, SCN^-
- Vanadate, VO_3^-

2−

- Carbonate, CO_3^{2-}
- Chromate, CrO_4^{2-}
- Dichromate, $Cr_2O_7^{2-}$
- Hexachloroplatinate, $PtCl_6^{2-}$
- Hexafluorosilicate, SiF_6^{2-}
- Molybdate, MoO_4^{2-}
- Oxalate, $C_2O_4^{2-}$
- Peroxide, O_2^{2-}
- Peroxydisulfate, $S_2O_8^{2-}$
- Ruthenate, RuO_4^{2-}
- Selenate, SeO_4^{2-}
- Selenite, SeO_3^{2-}
- Silicate, SiO_3^{2-}
- Sulfate, SO_4^{2-}
- Sulfite, SO_3^{2-}
- Tartrate, $C_4H_4O_6^{2-}$
- Tellurate, TeO_4^{2-}
- Tellurite, TeO_3^{2-}
- Tetraborate, $B_4O_7^{2-}$
- Thiosulfate, $S_2O_3^{2-}$
- Tungstate, WO_4^{2-}

3−

- Arsenate, AsO_4^{3-}
- Arsenite, AsO_3^{3-}
- Borate, BO_3^{3-}
- Citrate, $C_6H_5O_7^{3-}$
- Hexacyanoferrate(III), $Fe(CN)_6^{3-}$
- Phosphate, PO_4^{3-}
- Phosphite, PO_3^{3-}

4−

- Hexacyanoferrate(II), $Fe(CN)_6^{4-}$
- Orthosilicate, SiO_4^{4-}
- Diphosphate, $P_2O_7^{4-}$

1+

- Ammonium, NH_4^+
- Neptunyl(V), NpO_2^+
- Plutonyl(V), PuO_2^+
- Uranyl(V), UO_2^+
- Vanadyl(V), VO_2^+

2+

- Mercury(I), Hg_2^{2+}
- Neptunyl(VI), NpO_2^{2+}
- Plutonyl(VI), PuO_2^{2+}
- Uranyl(VI), UO_2^{2+}
- Vanadyl(IV), VO^{2+}

Table R-6 Ionization Constants

Substance	Ionization Constant	Substance	Ionization Constant	Substance	Ionization Constant
$HCOOH$	1.77×10^{-4}	HBO_3^{2-}	1.58×10^{-14}	HS^-	1.00×10^{-19}
CH_3COOH	1.75×10^{-5}	H_2CO_3	4.5×10^{-7}	HSO_4^-	1.02×10^{-2}
$CH_2ClCOOH$	1.36×10^{-3}	HCO_3^-	4.68×10^{-11}	H_2SO_3	1.29×10^{-2}
$CHCl_2COOH$	4.47×10^{-2}	HCN	6.17×10^{-10}	HSO_3^-	6.17×10^{-8}
CCl_3COOH	3.02×10^{-1}	HF	6.3×10^{-4}	$HSeO_4^-$	2.19×10^{-2}
$HOOCCOOH$	5.36×10^{-2}	HNO_2	5.62×10^{-4}	H_2SeO_3	2.29×10^{-3}
$HOOCCOO^-$	1.55×10^{-4}	H_3PO_4	7.08×10^{-3}	$HSeO_3^-$	4.79×10^{-9}
CH_3CH_2COOH	1.34×10^{-5}	$H_2PO_4^-$	6.31×10^{-8}	$HBrO$	2.51×10^{-9}
C_6H_5COOH	6.25×10^{-5}	HPO_4^{2-}	4.17×10^{-13}	$HClO$	2.9×10^{-8}
H_3AsO_4	6.03×10^{-3}	H_3PO_3	5.01×10^{-2}	HIO	3.16×10^{-11}
$H_2AsO_4^-$	1.05×10^{-7}	$H_2PO_3^-$	2.00×10^{-7}	NH_3	5.62×10^{-10}
H_3BO_3	5.75×10^{-10}	H_3PO_2	5.89×10^{-2}	H_2NNH_2	7.94×10^{-9}
$H_2BO_3^-$	1.82×10^{-13}	H_2S	9.1×10^{-8}	H_2NOH	1.15×10^{-6}

Table R-7 Properties of Elements

Element	Symbol	Atomic Number	Atomic Mass* (amu)	Melting Point (°C)	Boiling Point (°C)	Density (g/cm³) (gases measured at STP)	Atomic Radius (pm)	First Ionization Energy (kJ/mol)	Standard Reduction Potential (V) (for elements from or to oxidation state indicated)	Enthalpy of Fusion	Specific Heat	Enthalpy of Vaporization	Abundance in Earth's Crust	Major Oxidation States
Actinium	Ac	89	[227]	1050	3300	10.07	---	499	(3+)−2.13	14	0.120	400	---	3+
Aluminum	Al	13	26.981539	660.32	2519	2.7	143	577.5	(3+)−1.68	10.789	0.897	294	8.2	3+
Americium	Am	95	[243]	1176	2607	13.67	---	578	(3+)−2.07	14.39	0.110	---	---	2+, 3+, 4+
Antimony	Sb	51	121.760	630.6	1587	6.697	140	834	(3+)+0.15	19.79	0.207	68	2×10^{-5}	3+, 5+
Argon	Ar	18	39.948	−189.3	−185.8	0.001784	98	1521	---	1.18	0.520	6.43	1.5×10^{-4}	---
Arsenic	As	33	74.92160	817	614	5.727	120	947	(3+)+0.24	24.44	0.329	32.4	2.1×10^{-4}	3+, 5+
Astatine	At	85	[210]	302	---	---	140	920	(1−)+0.2	6	---	40	---	1−, 5+
Barium	Ba	56	137.327	727	1870	3.51	222	502.9	(2+)−2.92	7.12	0.204	140	0.034	2+
Berkelium	Bk	97	[247]	986	---	14.78	---	601	(3+)−2.01	---	---	---	---	3+, 4+
Beryllium	Be	4	9.012182	1287	2469	1.848	112	899.5	(2+)−1.97	7.895	1.825	297	2×10^{-4}	2+
Bismuth	Bi	83	208.98040	271.3	1564	9.78	150	703	(3+)+0.317	11.145	0.122	151	3×10^{-7}	3+, 5+
Bohrium	Bh	107	[264]	---	---	---	---	---	---	---	---	---	---	---
Boron	B	5	10.811	2076	3927	2.46	85	800.6	(3+)−0.89	50.2	1.026	480	9×10^{-4}	3+
Bromine	Br	35	79.904	−7.3	59	3.119	114	1139.9	(1−)+1.065	10.57	0.474	29.96	3×10^{-4}	1−, 1+, 3+, 5+
Cadmium	Cd	48	112.411	321.07	767	8.65	151	867.8	(2+)−0.4025	6.21	0.232	99.87	1.5×10^{-5}	2+
Calcium	Ca	20	40.078	842	1484	1.55	197	589.8	(2+)−2.84	8.54	0.647	155	5.00	2+
Californium	Cf	98	[251]	900	---	15.1	---	608	(3+)−1.93	---	---	---	---	3+, 4+
Carbon	C	6	12.0107	3527	4027	2.267	77	1086.5	(4−)+0.132	117	0.709	715	0.018	4−, 2+, 4+
Cerium	Ce	58	140.116	795	3360	6.689	---	534.4	(3+)−2.34	5.46	0.192	350	0.006	3+, 4+
Cesium	Cs	55	132.905451	28.4	671	1.879	265	375.7	(1+)−2.923	2.09	0.242	65	1.9×10^{-4}	1+
Chlorine	Cl	17	35.453	−101.5	−34	0.003	100	1251.2	(1−)+1.358	6.40	0.479	20.41	0.017	1−, 1+, 3+, 5+
Chromium	Cr	24	51.9961	1907	2671	7.14	128	652.9	(3+)−0.74	21.0	0.449	339	0.014	2+, 3+, 6+
Cobalt	Co	27	58.9332	1495	2927	8.9	125	760.4	(2+)−0.28	16.06	0.421	375	0.003	2+, 3+
Copernicium	Cn	112	[285]	---	---	---	---	---	---	---	---	---	---	---
Copper	Cu	29	63.546	1084.62	2570	8.92	128	745.5	(2+)+0.34	12.93	0.385	300	0.0068	1+, 2+
Curium	Cm	96	[247]	1340	3110	13.51	---	581	(3+)−2.06	---	---	---	---	3+, 4+
Darmstadtium	Ds	110	[281]	---	---	---	---	---	---	---	---	---	---	---
Dubnium	Db	105	[262]	---	---	---	---	---	---	---	---	---	---	---
Dysprosium	Dy	66	162.5	1407	2567	8.551	---	573	(3+)−2.29	11.06	0.173	280	6×10^{-4}	2+, 3+
Einsteinium	Es	99	[252]	860	---	---	---	619	(3+)−2	---	---	---	---	3+
Erbium	Er	68	167.259	1497	2868	9.066	---	589.3	(3+)−2.32	19.9	0.168	285	3×10^{-4}	3+
Europium	Eu	63	151.964	826	1527	5.244	---	547.1	(3+)−1.99	9.21	0.182	175	1.8×10^{-4}	2+, 3+
Fermium	Fm	100	[257]	1527	---	---	---	627	(3+)−1.96	---	---	---	---	2+, 3+
Flerovium	Fl	114	[289]	---	---	---	---	---	---	---	---	---	---	---
Fluorine	F	9	18.9984032	−219.62	−188.12	0.001696	71	1681	(1−)+2.87	0.51	0.824	6.62	0.054	1−
Francium	Fr	87	[223]	---	---	---	270	380	(1+)−2.92	2	---	65	---	1+
Gadolinium	Gd	64	157.25	1312	3250	7.901	---	593.4	(3+)−2.28	10.0	0.236	305	5.2×10^{-4}	3+
Gallium	Ga	31	69.723	29.76	2204	5.904	135	578.8	(3+)−0.53	5.576	0.373	254	0.0019	1+, 3+

*[ ] indicates mass of longest-lived isotope

Table R-7 Properties of Elements (continued)

Element	Symbol	Atomic Number	Atomic Mass* (amu)	Melting Point (°C)	Boiling Point (°C)	Density (g/cm³) (gases measured at STP)	Atomic Radius (pm)	First Ionization Energy (kJ/mol)	Standard Reduction Potential (V) (for elements from or to oxidation state indicated)	Enthalpy of Fusion	Specific Heat	Enthalpy of Vaporization	Abundance in Earth's Crust	Major Oxidation States
Germanium	Ge	32	72.64	938.3	2820	5.323	122	762	(4+)+0.124	36.94	0.320	334	1.4×10^{-4}	2+, 4+
Gold	Au	79	196.966569	1064	2856	19.3	144	890.1	(3+)+1.52	12.72	0.129	324	3×10^{-7}	1+, 3+
Hafnium	Hf	72	178.49	2233	4603	13.31	159	658.5	(4+)−1.70	27.2	0.144	630	3×10^{-4}	4+
Hassium	Hs	108	[277]	−272.2	---	0.0001785	---	2372.3	---	---	---	0.083	5.5×10^{-4}	---
Helium	He	2	4.002602	−269.7 (2536 kPa)	−268.93	0.00017847	31	2372	---	0.021	5.193	0.08	---	---
Holmium	Ho	67	164.93032	1461	2720	8.795	---	581	(3+)−2.33	17.0	0.165	265	1.2×10^{-4}	3+
Hydrogen	H	1	1.00794	−259.14	−252.87	0.0000899	37	1312	(1+)0.000	0.12	14.304	0.90	0.15	1−, 1+
Indium	In	49	114.818	156.6	2072	7.31	167	558.3	(3+)−0.3382	3.281	0.233	230	1.6×10^{-5}	1+, 3+
Iodine	I	53	126.90447	113.7	184.3	4.94	133	1008.4	(1−)+0.535	15.52	0.214	41.57	4.9×10^{-5}	1−, 1+, 5+, 7+
Iridium	Ir	77	192.217	2466	4428	22.65	136	880	(4+)+0.926	41.12	0.131	560	4×10^{-7}	3+, 4+, 5+
Iron	Fe	26	55.845	1538	2861	7.874	126	762.5	(3+)−0.04	13.81	0.449	347	6.3	2+, 3+
Krypton	Kr	36	83.798	−157.36	−153.22	0.0037493	112	1350.8	---	1.64	0.248	9.08	1.5×10^{-7}	---
Lanthanum	La	57	138.9055	920	3470	6.146	187	538.1	(3+)−2.38	6.20	0.195	400	0.0034	3+
Lawrencium	Lr	103	[262]	1627	---	---	---	---	(3+)−2	---	---	---	---	3+
Lead	Pb	82	207.2	327.46	1749	11.34	146	715.6	(2+)−0.1251	4.782	0.130	179.5	0.001	2+, 4+
Lithium	Li	3	6.941	180.54	1342	0.535	152	520.2	(1+)−3.040	3.00	3.582	147	0.0017	1+
Livermorium	Lv	116	[291]	---	---	---	---	---	---	---	---	---	---	---
Lutetium	Lu	71	174.967	1652	3402	9.841	160	523.5	(3+)−2.3	22	0.154	415	5.6×10^{-5}	3+
Magnesium	Mg	12	24.305	650	1090	1.738	160	737.7	(2+)−2.356	8.48	1.023	128	2.9	2+
Manganese	Mn	25	54.938045	1246	2061	7.47	127	717.3	(2+)−1.18	12.91	0.479	220	0.11	2+, 3+, 4+, 6+, 7+
Meitnerium	Mt	109	[268]	---	---	---	---	---	---	---	---	---	---	---
Mendelevium	Md	101	[258]	827	---	---	---	635	(3+)−1.7	---	---	---	---	2+, 3+
Mercury	Hg	80	200.59	−38.83	356.73	13.6	151	1007.1	(2+)+0.8535	2.29	0.140	59.11	6.7×10^{-6}	1+, 2+
Molybdenum	Mo	42	95.94	2623	4639	10.28	139	684.3	(6+)+0.114	37.48	0.251	600	1.1×10^{-4}	4+, 5+, 6+
Neodymium	Nd	60	144.24	1024	3100	6.8	---	533.1	(3+)−2.32	7.14	0.190	285	0.0033	2+,3+
Neon	Ne	10	20.1797	−248.59	−246.08	0.0008999	71	2080.7	---	0.328	1.030	1.71	---	---
Neptunium	Np	93	[237]	637	4000	20.45	---	604.5	(4+)−1.30	3.20	0.120	335	---	2+, 3+, 4+, 5+, 6+
Nickel	Ni	28	58.6934	1455	2913	8.908	124	737.1	(2+)−0.257	17.04	0.444	378	0.009	2+, 3+, 4+
Niobium	Nb	41	92.90638	2477	4744	8.57	146	652.1	(5+)−0.65	30	0.265	690	0.0017	4+, 5+
Nitrogen	N	7	14.0067	−210.1	−195.79	0.0012506	75	1402.3	(2−)−0.23	0.71	1.040	5.57	0.002	3−, 2−, 1−, 1+, 2+, 3+, 4+, 5+
Nobelium	No	102	[259]	827	---	---	---	642	(2+)−2.5	---	---	---	---	2+, 3+
Osmium	Os	76	190.23	3033	5012	22.61	135	840	(4+)+0.687	57.85	0.130	630	1.8×10^{-7}	4+, 6+, 8+
Oxygen	O	8	15.9994	−218.79	−182.9	0.001308	73	1313.9	(2−)+1.23	0.44	0.918	6.82	46.0	2−, 1−
Palladium	Pd	46	106.42	1554.9	2963	12.023	137	804.4	(2+)+0.915	16.74	0.246	380	6.3×10^{-7}	2+, 4+
Phosphorus	P	15	30.973462	44.2	277	1.823	110	1011.8	(3−)−0.063	0.66	0.769	12.4	0.10	3−, 3+, 5+

*[ ] indicates mass of longest-lived isotope

Table R-7 Properties of Elements (continued)

Platinum	Pt	78	195.078	1768.3	3825	21.09	138	870	(4+)+1.15	22.17	0.133	490	3.7×10^{-7}	2+, 4+
Plutonium	Pu	94	[244]	639.4	3230	19.816	---	584.7	(4+)−1.25	2.82	0.130	325	---	3+, 4+, 5+, 6+
Polonium	Po	84	[209]	254	962	9.196	168	812.1	(4+)+0.73	13	---	100	---	2−, 2+, 4+, 6+
Potassium	K	19	39.0983	63.38	759	0.856	227	418.8	(1+)−2.925	2.33	0.757	76.9	1.50	1+
Praseodymium	Pr	59	140.90765	935	3290	6.64	---	527	(3+)−2.35	6.89	0.193	330	8.7×10^{-4}	3+, 4+
Promethium	Pm	61	[145]	1100	3000	7.264	---	540	(3+)−2.29	7.7	---	290	---	3+
Protactinium	Pa	91	231.03588	1568	---	15.37	---	568	(5+)−1.19	12.34	---	470	trace	3+, 4+, 5+
Radium	Ra	88	[226]	700	1737	5	220	509.3	(2+)−2.916	8	0.095	125	trace	2+
Radon	Rn	86	[222]	−71	−61.7	0.00973	140	1037	---	3	0.094	17	---	3+
Rhenium	Re	75	186.207	3186	5596	21.02	137	760	(7+)+0.415	60.43	0.137	705	2.6×10^{-7}	3+, 4+, 6+, 7+
Rhodium	Rh	45	102.9055	1964	3695	12.45	134	719.7	(3+)+0.76	26.59	0.243	495	7×10^{-8}	3+, 4+, 5+
Roentgenium	Rg	111	[272]	---	---	---	---	---	---	---	---	---	---	---
Rubidium	Rb	37	85.4678	39.31	688	1.532	248	403	(1+)−2.924	2.19	0.363	72	0.006	1+
Ruthenium	Ru	44	101.07	2334	4150	12.37	134	710.2	(4+)+0.68	38.59	0.238	580	1×10^{-7}	2+, 3+, 4+, 5+
Rutherfordium	Rf	104	[261]	---	---	---	---	---	---	---	---	---	---	---
Samarium	Sm	62	150.36	1072	1803	7.353	---	544.5	(3+)−2.3	8.62	0.197	175	6×10^{-4}	2+, 3+
Scandium	Sc	21	44.95591	1541	2830	2.985	162	633.1	(3+)−2.03	14.1	0.568	318	0.0026	3+
Seaborgium	Sg	106	[266]	---	---	---	---	---	---	---	---	---	---	---
Selenium	Se	34	78.96	221	685	4.819	119	941	(1−)−0.11	6.69	0.321	95.48	5×10^{-6}	2−, 2+, 4+, 6+
Silicon	Si	14	28.0588	1414	2900	2.33	118	786.5	(4−)−0.143	50.21	0.712	359	27.0	2+, 4+
Silver	Ag	47	107.8682	961.78	2162	10.49	144	731	(1+)+0.7991	11.28	0.235	255	8×10^{-6}	1+
Sodium	Na	11	22.989769	97.72	883	0.968	186	495.8	(1+)−2.713	2.60	1.228	97.7	2.3	1+
Strontium	Sr	38	87.62	777	1382	2.63	215	549.5	(2+)−2.89	7.43	0.306	137	0.036	2+
Sulfur	S	16	32.065	115.2	444.7	1.96	103	999.6	(2−)−0.14	1.72	0.708	45	0.042	2−, 4+, 6+
Tantalum	Ta	73	180.9479	3017	5458	16.65	146	761	(5+)−0.81	36.57	0.140	735	1.7×10^{-4}	4+, 5+
Technetium	Tc	43	[98]	2157	4265	11.5	136	702	(6+)+0.83	33.29	0.240	550	---	2+, 4+, 6+, 7+
Tellurium	Te	52	127.60	449.51	988	6.24	142	869.3	(2−)−1.14	17.49	0.202	114.1	1×10^{-7}	2−, 2+, 4+, 6+
Terbium	Tb	65	158.92534	1356	3230	8.219	---	565.8	(3+)−2.31	10.15	0.182	295	1×10^{-4}	3+, 4+
Thallium	Tl	81	204.3822	304	1473	11.85	170	589.4	(1+)−0.3363	4.14	0.129	165	5.3×10^{-5}	1+, 3+
Thorium	Th	90	232.0381	1842	4820	11.72	---	587	(4+)−1.83	13.81	0.118	530	6×10^{-4}	4+
Thulium	Tm	69	168.93421	1545	1950	9.321	---	596.7	(3+)−2.32	16.84	0.160	250	5×10^{-5}	---
Tin	Sn	50	118.710	231.93	2602	7.31	140	708.6	(4+)+0.15	7.173	0.227	290	2.2×10^{-4}	2+, 4+
Titanium	Ti	22	47.867	1668	3287	4.507	147	658.8	(4+)−0.86	14.15	0.523	425	0.66	2+, 3+, 4+
Tungsten	W	74	183.84	3422	5555	19.25	139	770	(6+)−0.09	52.31	0.132	800	1.1×10^{-4}	4+, 5+, 6+
Ununoctium	Uuo	118	[294]	---	---	---	---	---	---	---	---	---	---	---
Ununpentium	Uup	115	[288]	---	---	---	---	---	---	---	---	---	---	---
Ununseptium	Uus	117	[294]	---	---	---	---	---	---	---	---	---	---	---
Ununtrium	Uut	113	[284]	---	---	---	---	---	---	---	---	---	---	---
Uranium	U	92	238.02891	1132.2	3927	19.05	---	597.6	(4+)−1.38	9.14	0.116	420	1.8×10^{-4}	3+, 4+, 5+, 6+
Vanadium	V	23	50.9415	1910	3407	6.11	134	650.9	(5+)−0.236	21.5	0.489	453	0.019	2+, 3+, 4+, 5+
Xenon	Xe	54	131.293	−111.7	−108	0.0058971	131	1170.4	(6+)+2.12	2.27	0.158	12.57	trace	---
Ytterbium	Yb	70	173.04	824	1196	6.57	---	603.4	(3+)−2.22	7.66	0.155	160	2.8×10^{-4}	2+, 3+
Yttrium	Y	39	88.90585	1526	3336	4.472	180	600	(3+)−2.37	11.4	0.298	380	0.0029	3+
Zinc	Zn	30	65.409	419.53	907	7.14	134	906.4	(2+)−0.7926	7.068	0.388	119	0.0079	2+
Zirconium	Zr	40	91.224	1855	4409	6.511	160	640.1	(4+)−1.55	21.00	0.278	580	0.013	4+

*[ ] indicates mass of longest-lived isotope

Reference Tables

Table R-8 Solubility Guidelines

A substance is considered soluble if more than three grams of the substance dissolves in 100 mL of water. The more common rules are listed below.

1. All common salts of the group 1 elements and ammonium ions are soluble.
2. All common acetates and nitrates are soluble.
3. All binary compounds of group 17 elements (other than F) with metals are soluble except those of silver, mercury(I), and lead.
4. All sulfates are soluble except those of barium, strontium, lead, calcium, silver, and mercury(I).
5. Except for those in Rule 1, carbonates, hydroxides, oxides, sulfides, and phoshates are insoluble.

Solubility of Compounds in Water

	Acetate	Bromide	Carbonate	Chlorate	Chloride	Chromate	Hydroxide	Iodide	Nitrate	Oxide	Perchlorate	Phosphate	Sulfate	Sulfide
Aluminum	S	S	—	S	S	—	I	S	S	I	S	I	S	D
Ammonium	S	S	S	S	S	S	S	S	S	—	S	S	S	S
Barium	S	S	P	S	S	I	S	S	S	S	S	I	I	D
Calcium	S	S	P	S	S	S	S	S	S	P	S	P	I	P
Copper(II)	S	S	—	S	S	—	I	—	S	I	S	I	S	I
Hydrogen	S	S	—	S	S	—	—	S	S	S	S	S	S	S
Iron(II)	—	S	P	S	S	—	I	S	S	I	S	I	S	I
Iron(III)	—	S	—	S	S	I	I	S	S	I	S	P	P	D
Lead(II)	S	I	—	S	I	I	P	P	S	P	S	I	I	I
Lithium	S	S	S	S	S	?	S	S	S	S	S	P	S	S
Magnesium	S	S	P	S	S	S	I	S	S	I	S	P	S	D
Manganese(II)	S	S	P	S	S	—	I	S	S	I	S	P	S	I
Mercury(I)	P	I	I	S	I	P	—	I	S	I	S	I	I	I
Mercury(II)	S	S	—	S	S	P	I	P	S	P	S	I	D	I
Potassium	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Silver	P	I	I	S	I	P	—	I	S	P	S	I	I	I
Sodium	S	S	S	S	S	S	S	S	S	D	S	S	S	S
Strontium	S	S	P	S	S	P	S	S	S	S	S	I	I	S
Tin(II)	D	S	—	S	S	O		S	D	I	S	I	S	I
Tin(IV)	S	S	—	—	S	S	I	D	—	I	S	—	S	I
Zinc	S	S	P	S	S	P	P	S	S	P	S	I	S	I

S – soluble P – partially soluble I – insoluble D – decomposes

Table R-9 Specific Heat Values (J/g·K)

Substance	c	Substance	c	Substance	c
AlF_3	0.8948	Fe_3C	0.5898	$NaVO_3$	1.540
$BaTiO_3$	0.79418	$FeWO_4$	0.37735	$Ni(CO)_4$	1.198
BeO	1.020	HI	0.22795	PbI_2	0.1678
CaC_2	0.9785	K_2CO_3	0.82797	SF_6	0.6660
$CaSO_4$	0.7320	$MgCO_3$	0.8957	SiC	0.6699
CCl_4	0.85651	$Mg(OH)_2$	1.321	SiO_2	0.7395
CH_3OH	2.55	$MgSO_4$	0.8015	$SrCl_2$	0.4769
CH_2OHCH_2OH	2.413	MnS	0.5742	Tb_2O_3	0.3168
CH_3CH_2OH	2.4194	Na_2CO_3	1.0595	$TiCl_4$	0.76535
CdO	0.3382	NaF	1.116	Y_2O_3	0.45397
$CuSO_4 \cdot 5H_2O$	1.12				

Table R-10 Molal Freezing Point Depression and Boiling Point Elevation Constants

Substance	K_{fp} (°C/*m*)	Freezing Point (°C)	K_{bp} (°C/*m*)	Boiling Point (°C)
Acetic acid	3.90	16.66	3.22	117.90
Benzene	5.12	5.533	2.53	80.100
Camphor	37.7	178.75	5.611	207.42
Cyclohexane	20.0	6.54	2.75	80.725
Cyclohexanol	39.3	25.15	---	---
Nitrobenzene	6.852	5.76	5.24	210.8
Phenol	7.40	40.90	3.60	181.839
Water	1.86	0.000	0.512	100.000

Table R-11 Heat of Formation Values

ΔH_f° (kJ/mol) (concentration of aqueous solutions is 1*M*)

Substance	ΔH_f°	Substance	ΔH_f°	Substance	ΔH_f°	Substance	ΔH_f°
Ag(s)	0	CsCl(s)	−443.0	H_3PO_4(aq)	−1271.7	NaBr(s)	−361.1
AgCl(s)	−127.0	Cs_2SO_4(s)	−1443.0	H_2S(g)	−20.6	NaCl(s)	−411.2
AgCN(s)	146.0	CuI(s)	−67.8	H_2SO_3(aq)	−608.8	$NaHCO_3$(s)	−950.8
Al_2O_3	−1675.7	CuS(s)	−53.1	H_2SO_4(aq)	−814.0	$NaNO_3$(s)	−467.9
$BaCl_2$(aq)	−855.0	Cu_2S(s)	−79.5	$HgCl_2$(s)	−224.3	NaOH(s)	−425.8
$BaSO_4$	−1473.2	$CuSO_4$(s)	−771.4	Hg_2Cl_2(s)	−265.4	Na_2CO_3(s)	−1130.7
BeO(s)	−609.4	F_2(g)	0	Hg_2SO_4(s)	−743.1	Na_2S(s)	−364.8
$BiCl_3$(s)	−379.1	$FeCl_3$(s)	−399.49	I_2(s)	0	Na_2SO_4(s)	−1387.1
Bi_2S_3(s)	−143.1	FeO(s)	−272.0	K(s)	0	NH_4Cl(s)	−314.4
Br_2	0	FeS(s)	−100.0	KBr(s)	−393.8	O_2(g)	0
CCl_4(l)	−128.2	Fe_2O_3(s)	−824.2	$KMnO_4$(s)	−837.2	P_4O_6(s)	−1640.1
CH_4(g)	−74.6	Fe_3O_4(s)	−1118.4	KOH	−424.6	P_4O_{10}(s)	−2984.0
C_2H_2(g)	227.4	H(g)	218.0	LiBr(s)	−351.2	$PbBr_2$(s)	−278.7
C_2H_4(g)	52.4	H_2(g)	0	LiOH(s)	−487.5	$PbCl_2$(s)	−359.4
C_2H_6(g)	−84.0	HBr(g)	−36.3	Mn(s)	0	SF_6(g)	−1220.5
CO(g)	−110.5	HCl(g)	−92.3	$MnCl_2$(aq)	−555.0	SO_2(g)	−296.8
CO_2(g)	−393.5	HCl(aq)	−167.159	$Mn(NO_3)_2$(aq)	−635.5	SO_3(g)	−395.7
CS_2(l)	89.0	HCN(aq)	108.9	MnO_2(s)	−520.0	SrO(s)	−592.0
Ca(s)	0	HCHO	−108.6	MnS(s)	−214.2	TiO_2(s)	−944.0
$CaCO_3$(s)	−1206.9	HCOOH	−425.0	N_2(g)	0	TlI(s)	−123.8
CaO(s)	−634.9	HF(g)	−273.3	NH_3(g)	−45.9	UCl_4(s)	−1019.2
$Ca(OH)_2$(s)	−985.2	HI(g)	26.5	NH_4Br(s)	−270.8	UCl_6(s)	−1092.0
Cl_2(g)	0	H_2O(l)	−285.8	NO(g)	91.3	Zn(s)	0
Co_3O_4(s)	−891.0	H_2O(g)	−241.8	NO_2(g)	33.2	$ZnCl_2$(aq)	−415.1
CoO(s)	−237.9	H_2O_2(l)	−187.8	N_2O(g)	81.6	ZnO(s)	−350.5
Cr_2O_3(s)	−1139.7	H_3PO_2(l)	−595.4	Na(s)	0	$ZnSO_4$(s)	−982.8

Reference Tables

Safety Symbols

Safety symbols in the following table are used in the lab activities to indicate possible hazards. Learn the meaning of each symbol. **It is recommended that you wear safety goggles and apron at all times in the lab. This might be required in your school district.**

Safety Symbols	Hazard	Examples	Precaution	Remedy
Disposal	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
Biological	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
Extreme Temperature	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
Sharp Object	Use of tools or glassware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
Fume	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Be sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
Electrical	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus. Use GFI-protected outlets.	Do not attempt to fix electrical problems. Notify your teacher immediately.
Irritant	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
Chemical	Chemicals that can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
Toxic	Substance may be poisonous if touched, inhaled, or swallowed.	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
Flammable	Flammable chemicals may be ignited by open flame, spark, or exposed heat.	alcohol, kerosene, potassium permanganate	Avoid open flames and heat when using flammable chemicals.	Notify your teacher immediately. Use fire safety equipment if applicable.
Open Flame	Open flame in use, may cause fire.	hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instruction on lighting and extinguishing flames.	Notify yourteacher immediately. Use fire safety equipment if applicable.

Eye Safety
Proper eye protection should be worn at all times by anyone performing or observing science activities.

Clothing Protection
This symbol appears when substances could stain or burn clothing.

Animal Safety
This symbol appears when safety of animals must be ensured.

Radioactivity
This symbol appears when radioactive materials are used.

Handwashing
After the lab, wash hands with soap and water before removing goggles.

PERIODIC TABLE OF THE ELEMENTS

Element	Hydrogen
Atomic number	1
Symbol	H
Atomic mass	1.008
State of matter	Gas

Gas
Liquid
Solid
Synthetic

	1	2	3	4	5	6	7	8	9
1	Hydrogen 1 **H** 1.008								
2	Lithium 3 **Li** 6.941	Beryllium 4 **Be** 9.012							
3	Sodium 11 **Na** 22.990	Magnesium 12 **Mg** 24.305							
4	Potassium 19 **K** 39.098	Calcium 20 **Ca** 40.078	Scandium 21 **Sc** 44.956	Titanium 22 **Ti** 47.867	Vanadium 23 **V** 50.942	Chromium 24 **Cr** 51.996	Manganese 25 **Mn** 54.938	Iron 26 **Fe** 55.847	Cobalt 27 **Co** 58.933
5	Rubidium 37 **Rb** 85.468	Strontium 38 **Sr** 87.62	Yttrium 39 **Y** 88.906	Zirconium 40 **Zr** 91.224	Niobium 41 **Nb** 92.906	Molybdenum 42 **Mo** 95.94	Technetium 43 **Tc** (98)	Ruthenium 44 **Ru** 101.07	Rhodium 45 **Rh** 102.906
6	Cesium 55 **Cs** 132.905	Barium 56 **Ba** 137.327	Lanthanum 57 **La** 138.905	Hafnium 72 **Hf** 178.49	Tantalum 73 **Ta** 180.948	Tungsten 74 **W** 183.84	Rhenium 75 **Re** 186.207	Osmium 76 **Os** 190.23	Iridium 77 **Ir** 192.217
7	Francium 87 **Fr** (223)	Radium 88 **Ra** (226)	Actinium 89 **Ac** (227)	Rutherfordium 104 **Rf** (261)	Dubnium 105 **Db** (262)	Seaborgium 106 **Sg** (266)	Bohrium 107 **Bh** (264)	Hassium 108 **Hs** (277)	Meitnerium 109 **Mt** (268)

The number in parentheses is the mass number of the longest lived isotope for that element.

Lanthanide series	Cerium 58 **Ce** 140.115	Praseodymium 59 **Pr** 140.908	Neodymium 60 **Nd** 144.242	Promethium 61 **Pm** (145)	Samarium 62 **Sm** 150.36	Europium 63 **Eu** 151.965
Actinide series	Thorium 90 **Th** 232.038	Protactinium 91 **Pa** 231.036	Uranium 92 **U** 238.029	Neptunium 93 **Np** (237)	Plutonium 94 **Pu** (244)	Americium 95 **Am** (243)

Metal

Metalloid

Nonmetal

Recently observed

10	11	12	13	14	15	16	17	18
								Helium 2 **He** 4.003
			Boron 5 **B** 10.811	Carbon 6 **C** 12.011	Nitrogen 7 **N** 14.007	Oxygen 8 **O** 15.999	Fluorine 9 **F** 18.998	Neon 10 **Ne** 20.180
			Aluminum 13 **Al** 26.982	Silicon 14 **Si** 28.086	Phosphorus 15 **P** 30.974	Sulfur 16 **S** 32.066	Chlorine 17 **Cl** 35.453	Argon 18 **Ar** 39.948
Nickel 28 **Ni** 58.693	Copper 29 **Cu** 63.546	Zinc 30 **Zn** 65.39	Gallium 31 **Ga** 69.723	Germanium 32 **Ge** 72.61	Arsenic 33 **As** 74.922	Selenium 34 **Se** 78.96	Bromine 35 **Br** 79.904	Krypton 36 **Kr** 83.80
Palladium 46 **Pd** 106.42	Silver 47 **Ag** 107.868	Cadmium 48 **Cd** 112.411	Indium 49 **In** 114.82	Tin 50 **Sn** 118.710	Antimony 51 **Sb** 121.757	Tellurium 52 **Te** 127.60	Iodine 53 **I** 126.904	Xenon 54 **Xe** 131.290
Platinum 78 **Pt** 195.08	Gold 79 **Au** 196.967	Mercury 80 **Hg** 200.59	Thallium 81 **Tl** 204.383	Lead 82 **Pb** 207.2	Bismuth 83 **Bi** 208.980	Polonium 84 **Po** 208.982	Astatine 85 **At** 209.987	Radon 86 **Rn** 222.018
Darmstadtium 110 **Ds** (281)	Roentgenium 111 **Rg** (272)	Copernicium 112 **Cn** (285)	Ununtrium * 113 **Uut** (284)	Flerovium 114 **Fl** (289)	Ununpentium * 115 **Uup** (288)	Livermorium 116 **Lv** (293)	Ununseptium * 117 **Uus** (294)	Ununoctium * 118 **Uuo** (294)

* The names and symbols for elements 113, 115, 117, and 118 are temporary. Final names will be approved by IUPAC (International Union of Pure and Applied Chemistry).

Gadolinium 64 **Gd** 157.25	Terbium 65 **Tb** 158.925	Dysprosium 66 **Dy** 162.50	Holmium 67 **Ho** 164.930	Erbium 68 **Er** 167.259	Thulium 69 **Tm** 168.934	Ytterbium 70 **Yb** 173.04	Lutetium 71 **Lu** 174.967
Curium 96 **Cm** (247)	Berkelium 97 **Bk** (247)	Californium 98 **Cf** (251)	Einsteinium 99 **Es** (252)	Fermium 100 **Fm** (257)	Mendelevium 101 **Md** (258)	Nobelium 102 **No** (259)	Lawrencium 103 **Lr** (262)

Safety Symbols

Safety symbols in the following table are used in the lab activities to indicate possible hazards. Learn the meaning of each symbol. **It is recommended that you wear safety goggles and apron at all times in the lab. This might be required in your school district.**

Safety Symbols	Hazard	Examples	Precaution	Remedy
Disposal	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
Biological	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
Extreme Temperature	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
Sharp Object	Use of tools or glassware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
Fume	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Be sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
Electrical	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus. Use GFI-protected outlets.	Do not attempt to fix electrical problems. Notify your teacher immediately.
Irritant	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
Chemical	Chemicals that can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
Toxic	Substance may be poisonous if touched, inhaled, or swallowed.	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
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Open Flame	Open flame in use, may cause fire.	hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instruction on lighting and extinguishing flames.	Notify your teacher immediately. Use fire safety equipment if applicable.

Eye Safety	Clothing Protection	Animal Safety	Radioactivity	Handwashing
Proper eye protection should be worn at all times by anyone performing or observing science activities.	This symbol appears when substances could stain or burn clothing.	This symbol appears when safety of animals must be ensured.	This symbol appears when radioactive materials are used.	After the lab, wash hands with soap and water before removing goggles.

GLOSSARY • القاموس

مفتاح النطق

استخدم المفتاح التالي لمساعدتك على نطق المفردات الواردة في القاموس:

a	back (BAK)	ew	food (FEWD)
ay	day (DAY)	yoo	pure (PYOOR)
ah	father (FAH thur)	yew	few (FYEW)
ow	flower (FLOW ur)	uh	comma (CAHM uh)
ar	car (CAR)	u (+con)	rub (RUB)
e	less (LES)	sh	shelf (SHELF)
ee	leaf (LEEF)	ch	nature (NAY chur)
ih	trip (TRIHP)	g	gift (GIHFT)
i (i+con+e)	idea, life (i DEE uh, life)	j	gem (JEM)
oh	go (GOH)	ing	sing (SING)
aw	soft (SAWFT)	zh	vision (VIHZH un)
or	orbit (OR but)	k	cake (KAYK)
oy	coin (COYN)	s	seed, cent (SEED, SENT)
oo	foot (FOOT)	z	zone, raise (ZOHN, RAYZ)

الإنجليزية | A | العربية

absolute zero Zero on the Kelvin scale, which represents the lowest possible theoretical temperature; atoms are all in the lowest possible energy state.

accuracy Refers to how close a measured value is to an accepted value.

acid-base indicator A chemical dye whose color is affected by acidic and basic solutions.

acidic solution Contains more hydrogen ions than hydroxide ions.

acid ionization constant The value of the equilibrium constant expression for the ionization of a weak acid.

actinide series In the periodic table, the f-block elements from period 7 that follow the element actinium.

activated complex A short-lived, unstable arrangement of atoms that can break apart and re-form the reactants or can form products; also sometimes referred to as the transition state.

activation energy The minimum amount of energy required by reacting particles in order to form the activated complex and lead to a reaction.

active site The pocket or crevice to which a substrate binds in an enzyme-catalyzed reaction.

actual yield The amount of product produced when a chemical reaction is carried out.

addition polymerization Occurs when all the atoms present in the monomers are retained in the polymer product.

الصفر المطلق هو الصفر على مقياس كلفن، والذي يمثل أقل درجة حرارة نظرية ممكنة حيث تكون جميع ذرات المادة عند أقل مستوى ممكن من الطاقة.

الدقة تشير إلى مدى تقارب قيمة مقيسة مع قيمة مقبولة.

الكاشف هو صبغة كيميائية يتأثر لونها بالمحاليل الحمضية والقاعدية.

المحلول حمضي يحتوي على أيونات هيدروجين أكثر من أيونات الهيدروكسيد.

ثابت تأين الحمض هي قيمة تعبر عن ثابت اتزان تأين حمض ضعيف.

سلسلة الأكتنيدات في الجدول الدوري، هي عناصر المجمع f من الدورة السابعة التي تلي عنصر الأكتنيوم.

المعقد المنشط هو ترتيب قصير الأجل وغير مستقر للذرات، إعادة تكوين المواد المتفاعلة أو يمكنه تكوين النواتج؛ كما يشار إليه أيضا في بعض الأحيان بالحالة الانتقالية.

طاقة التنشيط الحد الأدنى من الطاقة التي تلزم لتحويل المتفاعلات إلى معقد منشط وتؤدي إلى حدوث تفاعل.

الموقع النشط هو التجويف أو الفتحة التي ترتبط بها ركيزة في أحد التفاعلات المحفزة للإنزيم.

الناتج الفعلي يشير إلى كمية الناتج الذي يتكون عند إجراء تفاعل كيميائي.

البلمرة بالإضافة تحدث عندما يتم الاحتفاظ بجميع الذرات، الموجودة في المونومرات، داخل البوليمر الناتج.

addition reaction A reaction that occurs when other atoms bond to each of two atoms bonded by double or triple covalent bonds.

alcohol An organic compound in which a hydroxyl group replaces a hydrogen atom of a hydrocarbon.

aldehyde An organic compound containing the structure in which a carbonyl group at the end of a carbon chain is bonded to a carbon atom on one side and a hydrogen atom on the other side.

aliphatic compounds (a luh FA tihk • KAHM pownd) Nonaromatic hydrocarbons, such as the alkanes, alkenes, and alkynes.

alkali metals Group 1 elements, except for hydrogen, they are reactive and usually exist as compounds with other elements.

alkaline earth metals Group 2 elements in the modern periodic table and are highly reactive.

alkane Hydrocarbon that contains only single bonds between atoms.

alkene An unsaturated hydrocarbon, such as ethene (C_2H_4), with one or more double covalent bonds between carbon atoms in a chain.

alkyl halide An organic compound containing a halogen atom covalently bonded to an aliphatic carbon atom.

alkyne An unsaturated hydrocarbon, such as ethyne (C_2H_2), with one or more triple bonds between carbon atoms in a chain.

allotrope One of two or more forms of an element with different structures and properties when they are in the same state—solid, liquid, or gas.

alloy A mixture of elements that has metallic properties; most commonly forms when the elements are either similar in size (substitutional alloy) or the atoms of one element are much smaller than the atoms of the other (interstitial alloy).

alpha particle A particle with two protons and two neutrons, with a 2+ charge; is equivalent to a helium-4 nucleus, can be represented by α; and is emitted during radioactive decay.

alpha radiation Radiation that is made up of alpha particles; is deflected toward a negatively charged plate when radiation from a radioactive source is directed between two electrically charged plates.

amide (AM ide) An organic compound in which the –H group of a carboxylic acid is replaced by a nitrogen atom bonded to other atoms.

amines (A meen) Organic compounds that contain nitrogen atoms bonded to carbon atoms in aliphatic chains or aromatic rings and have the general formula RNH_2.

amino acid An organic molecule that has both an amino group (–NH_2) and a carboxyl group (–COOH).

تفاعل الإضافة هو تفاعل يحدث عندما ترتبط ذرات أخرى بكل من الذرتين المرتبطتين بروابط تساهمية ثنائية أو ثلاثية.

الكحول مركب عضوي حلت فيه مجموعة هيدروكسيل محل ذرة هيدروجين في الهيدروكربون.

الألدهيد مركب عضوي يحتوي على مجموعة CHO- كمجموعة وظيفية.

المركبات الأليفاتية تشير إلى مركبات الهيدروكربونات غير الأروماتية، مثل الألكانات والألكينات والألكاينات.

الفلزات القلوية تشير إلى عناصر المجموعة الأولى، باستثناء الهيدروجين، وهي عناصر نشطة كيميائيًا وتتواجد عادةً في صورة مركبات مع عناصر أخرى.

الفلزات القلوية الأرضية تشير إلى عناصر المجموعة الثانية في الجدول الدوري الحديث، وهي عناصر نشطة كيميائيًا بشكل كبير.

الألكان هو مركب هيدروكربوني يحتوي على روابط أحادية فقط بين الذرات.

الألكين هيدروكربون غير مشبع، مثل الإثيلين (C_2H_4)، مع رابطة تساهمية واحدة أو أكثر بين ذرات الكربون في سلسلة.

هاليد الألكيل هو مركب عضوي يحتوي على ذرة هالوجين مرتبطة تساهميًا بذرة كربون أليفاتية.

الألكاين هو هيدروكربون غير مشبع، مثل الإيثاين (C_2H_2)، رابطة تساهمية ثلاثية واحدة أو أكثر بين ذرات الكربون في سلسلة.

التآصل عدة صور للعنصر نفسه مختلفة في التركيب والخواص عندما تكون في الحالة الفيزيائية نفسها (صلبة، سائلة، غازية).

السبيكة هي خليط من عناصر ذات خصائص فلزية، وتتكون غالبًا عندما تتشابه العناصر في الحجم (السبيكة الاستبدالية)، أو عندما تكون ذرات عنصر واحد أصغر كثيرًا من ذرات العنصر الآخر (السبيكة الفراغية).

جسيم ألفا هو جسيم يتكون من بروتونين ونيوترونين، بشحنة موجبة مقدارها 2، ويعادل نواة ذرة الهيليوم4- ويمثله الرمز α، وينبعث خلال الانحلال الإشعاعي.

إشعاع ألفا إشعاع يتكون من جسيمات ألفا وينحرف نحو الصفيحة سالبة الشحنة عند توجيه الأشعة الناتجة عن مصدر مشع بين إثنتين من الصفائح المشحونة كهربائيًا.

الأميد مركب عضوي يتم فيه استبدال مجموعة OH للحمض الكربوكسيلي بذرة نيتروجين مرتبطة بذرات أخرى.

الأمينات هي مركبات عضوية تحتوي على ذرات نيتروجين مرتبطة بذرات الكربون في سلاسل أليفاتية أو حلقات أروماتية وصيغتها العامة هي RNH_2.

الحمض الأميني هو جزيء عضوي يتكون من مجموعة أمين (NH_2-) ومجموعة كربوكسيل (COOH-).

القاموس • Glossary

amorphous solid A solid in which particles are not arranged in a regular, repeating pattern that often is formed when molten material cools too quickly to form crystals.

amphoteric (AM foh TAR ihk) Describes water and other substances that can act as both acids and bases.

amplitude The height of a wave from the origin to a crest, or from the origin to a trough.

anabolism (ah NAB oh lih zum) Refers to the metabolic reactions through which cells use energy and small building blocks to build large, complex molecules needed to carry out cell functions and for cell structures.

anion (AN i ahn) An ion that has a negative charge.

anode In an electrochemical cell, the electrode where oxidation takes place.

applied research A type of scientific investigation that is undertaken to solve a specific problem.

aqueous solution A solution in which the solvent is water.

aromatic compounds Organic compounds that contain one or more benzene rings as part of their molecular structure.

Arrhenius model (ah REE nee us • MAH dul) A model of acids and bases; states that an acid is a substance that contains hydrogen and ionizes to produce hydrogen ions in aqueous solution and a base is a substance that contains a hydroxide group and dissociates to produce a hydroxide ion in aqueous solution.

aryl halide An organic compound that contains a halogen atom bonded to a benzene ring or another aromatic group

asymmetric carbon A carbon atom that has four different atoms or groups of atoms attached to it; occurs in chiral compounds.

atmosphere The unit that is often used to report air pressure.

atom The smallest particle of an element that retains all the properties of that element; is electrically neutral, spherically shaped, and composed of electrons, protons, and neutrons.

atomic emission spectrum A set of frequencies of electromagnetic waves given off by atoms of an element; consists of a series of fine lines of individual colors.

atomic mass The weighted average mass of the isotopes of that element.

atomic mass unit (amu) One-twelfth the mass of a carbon-12 atom.

atomic number The number of protons in an atom.

atomic orbital A three-dimensional region around the nucleus of an atom that describes an electron's probable location.

الصلب غير المتبلور هي جسم صلب لا تكون الجسيمات فيه بنمط متكرر أو منتظم، ويتكون غالبًا عندما يتم تبريد المادة المنصهرة بسرعة شديدة لتكوين البلورات.

الأمفوتيري صفة تصف مادة كالماء، لها خصائص الأحماض والقواعد.

السعة هي ارتفاع موجة من الأصل إلى القمة أو من الأصل إلى القاع.

الأيض البنائي مصطلح يشير إلى التفاعلات الأيضية التي تقوم الخلايا من خلالها باستخدام الطاقة ووحدات البناء الصغيرة لبناء الجزيئات الكبيرة والمعقدة المطلوبة لأداء وظائف الخلية واللازمة لتركيبات الخلية.

الأنيون هو أيون سالب الشحنة.

الأنود هو القطب الكهربائي الذي تحدث عنده عملية الأكسدة في خلية كهروكيميائية.

البحث التطبيقي هو نوع من التحقيق العلمي يتم إجراؤه لحل مشكلة معينة.

المحلول المائي هو محلول يكون فيه المذيب هو الماء.

المركبات الأروماتية هي مركبات عضوية تحتوي على حلقة بنزين واحدة أو أكثر كجزء من تركيبها الجزيئي.

نموذج أرهينيوس نموذج للأحماض والقواعد؛ ينص على أن الحمض هو مادة تحتوي على الهيدروجين وتتأين لإنتاج أيونات الهيدروجين في محلول مائي. أما القاعدة فهي مادة تحتوي على مجموعة هيدروكسيد وتتفكك لإنتاج أيون هيدروكسيد في محلول مائي.

هاليد الأرايل مركب عضوي يحتوي على ذرة هالوجين مرتبطة بحلقة بنزين أو مجموعة أروماتية أخرى

ذرة الكربون غير المتماثلة هي ذرة كربون تتصل بها أربع ذرات أو مجموعات مختلفة من الذرات؛ وتحدث في المركبات عديمة التناظر المرآتي.

الضغط الجوي هو الوحدة المستخدمة غالبًا للإشارة إلى ضغط الهواء.

الذرة هي جزء من العنصر للعنصر، وهو جزء من العنصر يحتفظ بجميع خواص ذلك العنصر، ومتعادل كهربائيًا، وله شكل كروي ويتألف من الإلكترونات والبروتونات والنيوترونات.

طيف الانبعاث الذري هو مجموعة من ترددات الموجات الكهرومغناطيسية التي تنبعث من ذرات أحد العناصر، وهي تتكون من سلسلة من الخطوط الواضحة للألوان الفردية.

الكتلة الذرية متوسط الكتلة الذرية لنظائر ذلك العنصر.

وحدة الكتلة الذرية (amu) تساوي 12/1 من كتلة ذرة الكربون-12.

العدد الذري هو عدد البروتونات الموجودة في الذرة.

الفلك الذري هو منطقة ثلاثية الأبعاد حول نواة الذرة تصف الموقع المحتمل لوجود الإلكترون.

القاموس • Glossary

ATP Adenosine triphosphate—a nucleotide that functions as the universal energy-storage molecule in living cells.

أدينوسين ثلاثي الفوسفات ATP الأدينوسين ثلاثي الفوسفات هو نكليوتيد يقوم بدور الجزيء الشامل الذي تختزن فيه الطاقة في الخلايا الحية.

aufbau principle States that each electron occupies the lowest energy orbital available.

مبدأ أوفباو ينص هذا المبدأ على أن كل إلكترون يشغل المستوى الأقل طاقة المتوفر.

Avogadro's number The number 6.0221367×10^{23}, which is the number of representative particles in a mole, and ca n be rounded to three significant digits 6.02×10^{23}.

عدد أفوجادرو هو العدد 6.0221367×10^{23} وهو عدد الجسيمات الممثلة في المول. ويمكن تقريبه إلى ثلاثة أرقام ذات دلالة وهي 6.02×10^{23}.

Avogadro's principle States that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.

مبدأ أفوجادرو ينص على أن الأحجام المتساوية من الغازات عند نفس درجة الحرارة والضغط تحتوي على عدد متساوٍ من الجسيمات.

B

band of stability The region on a graph within which all stable nuclei are found when plotting the number of neutrons versus the number of protons.

نطاق الاستقرار هو المنطقة الموجودة في الرسم البياني، والتي يوجد بها جميع النوى المستقرة عند عمل رسم بياني لعدد النيوترونات مقابل عدد البروتونات.

barometer An instrument that is used to measure atmospheric pressure.

البارومیتر هو جهاز يستخدم لقياس الضغط الجوي.

base ionization constant The value of the equilibrium constant expression for the ionization of a base.

ثابت تأين القاعدة قيمة ثابت الاتزان لتفاعل تأين قاعدة ضعيف ويرمز له Kb.

base unit A defined unit in a system of measurement that is based on an object or event in the physical world and is independent of other units.

الوحدة الأساسية هي وحدة محددة في أحد أنظمة القياس، تعتمد على موضوع أو حدث، وهي مستقلة عن الوحدات الأخرى.

basic solution Contains more hydroxide ions than hydrogen ions.

المحلول القاعدي يحتوي على أيونات هيدروكسيد أكثر من أيونات هيدروجين.

battery One or more electrochemical cells in a single package that generates electrical current.

البطارية مصطلح يشير إلى واحدة أو أكثر من الخلايا الكهروكيميائية الموجودة في علبة واحدة يتولد عنها التيار الكهربائي.

beta particle A high-speed electron with a 1− charge that is emitted during radioactive decay.

جسيم بيتا هو إلكترون عالي السرعة بشحنة واحدة تنبعث خلال الانحلال الإشعاعي.

beta radiation Radiation that is made up of beta particles; is deflected toward a positively charged plate when radiation from a radioactive source is directed between two electrically charged plates.

إشعاع بيتا إشعاع يتكون من جسيمات بيتا وينحرف نحو الصفيحة موجبة الشحنة عند توجيه الأشعة الناتجة عن مصدر مشع بين إثنتين من الصفائح المشحونة كهربائيًا.

boiling point The temperature at which a liquid's vapor pressure is equal to the external or atmospheric pressure.

درجة الغليان هي درجة الحرارة التي يتساوى عندها ضغط البخار الخاص بالسائل مع الضغط الخارجي أو الجوي.

boiling-point elevation The temperature difference between a solution's boiling point and a pure solvent's boiling point.

الارتفاع في درجة الغليان هو الفرق في درجة الحرارة بين درجة غليان المحلول ودرجة غليان المذيب النقي.

Boyle's law States that the volume of a fixed amount of gas held at a constant temperature varies inversely with the pressure.

قانون بويل ينص على أن حجم كمية محددة من الغاز عند درجة حرارة ثابتة يتناسب عكسيًا مع الضغط الواقع عليه.

breeder reactor A nuclear reactor that is able to produce more fuel than it uses.

المفاعل المولد هو مفاعل نووي يمكنه إنتاج كمية وقود أكثر من الكمية التي يستهلكها.

Brønsted-Lowry model A model of acids and bases in which an acid is a hydrogen-ion donor and a base is a hydrogen-ion acceptor.

نموذج برونشتد – لوري هو نموذج من الأحماض والقواعد يكون فيه الحمض هو المادة المانحة لأيون الهيدروجين والقاعدة هي المادة المستقبلة لهذا الأيون.

Brownian motion The erratic, random, movements of colloid particles that results from collisions of particles of the dispersion medium with the dispersed particles.

الحركة البراونية تشير إلى الحركات العشوائية وغير المنتظمة للجسيمات الغروية الناشئة عن حالات اصطدام جسيمات وسط التشتت مع الجسيمات المبعثرة.

buffer A solution that resists changes in pH when limited amounts of acid or base are added.

المحلول المنظم هو المحلول الذي يقاوم التغيرات في الرقم الهيدروجيني عند إضافة كميات محدودة من الحمض أو القاعدة.

buffer capacity The amount of acid or base a buffer solution can absorb without a significant change in pH.

سعة المحلول المنظم هي كمية الحمض أو القاعدة التي يمكن أن يمتصها محلول منظم دون تغير كبير في pH.

C

calorie The amount of heat required to raise the temperature of one gram of pure water by one degree Celsius.

السعر الحراري هو كمية الحرارة اللازمة لرفع درجة حرارة جرام واحد من الماء النقي بمعدل درجة سيليزية واحدة.

calorimeter An insulated device that is used to measure the amount of heat released or absorbed during a physical or chemical process.

المُسعر هو جهاز معزول يستخدم لقياس كمية الحرارة التي يتم إصدارها أو امتصاصها أثناء إحدى العمليات الفيزيائية أو الكيميائية.

carbohydrates Compounds that contain multiple hydroxyl groups, plus an aldehyde or a ketone functional group, and function in living things to provide immediate and stored energy.

الكربوهيدرات هي مركبات تحتوي على مجموعات هيدروكسيل متعددة بالإضافة إلى مجموعة وظيفية تتألف من الألدهيد أو الكيتون وتعمل على توفير الطاقة المباشرة والمخزونة للكائنات الحية.

carbonyl group Arrangement in which an oxygen atom is double-bonded to a carbon atom.

مجموعة الكربونيل هي الترتيب الذي ترتبط فيه ذرة أكسجين برابطة ثنائية بذرة كربون.

carboxyl group Consists of a carbonyl group bonded to a hydroxyl group.

مجموعة الكربوكسيل تتكون من مجموعة كربونيل مرتبطة بمجموعة هيدروكسيل.

carboxylic acid An organic compound that contains a carboxyl group and is polar and reactive.

حمض كربوكسيلي هو مركب عضوي يحتوي على مجموعة كربوكسيل وهو أحد المركبات القطبية والنشطة.

catabolism (kuh TAB oh lih zum) Refers to metabolic reactions that break down complex biological molecules for the purpose of forming smaller building blocks and extracting energy.

الأيض الهدمي يشير إلى التفاعلات الأيضية التي تفتت الجزيئات البيولوجية المعقدة بغرض تكوين وحدات بناء أصغر حجما واستخراج الطاقة.

catalyst A substance that increases the rate of a chemical reaction by lowering activation energies but is not itself consumed in the reaction.

الحفّاز هو مادة تعمل على زيادة معدل التفاعل الكيميائي عن طريق خفض طاقات التنشيط دون استهلاك هذه المادة في التفاعل.

cathode In an electrochemical cell, the electrode where reduction takes place.

الكاثود هو القطب الكهربائي الذي تحدث فيه عملية الاختزال في أي خلية كهروكيميائية.

cathode ray Radiation that originates from the cathode and travels to the anode of a cathode-ray tube.

أشعة الكاثود الأشعة التي تنشأ من الكاثود وتنتقل إلى أنود أنبوبة أشعة الكاثود.

cation (KAT i ahn) An ion that has a positive charge.

الكاتيون هو أيون موجب الشحنة.

cellular respiration The process in which glucose is broken down in the presence of oxygen gas to produce carbon dioxide, water, and energy.

التنفس الخلوي هو عملية يتم فيها تفتيت الجلوكوز في وجود غاز الأكسجين لإنتاج ثاني أكسيد الكربون والماء والطاقة.

Charles's law States that the volume of a given mass of gas is directly proportional to its kelvin temperature at constant pressure.

قانون شارل ينص على أن حجم كتلة معينة من الغاز يتناسب بشكل مباشر مع درجة حرارتها على مقياس كلفن تحت ضغط ثابت.

chemical bond The force that holds two atoms together; may form by the attraction of a positive ion for a negative ion or by sharing electrons.

الرابطة الكيميائية هي القوة التي تجذب ذرتين معا، وقد تتكون عن طريق جذب أيون موجب لأيون سالب أو عن طريق تشارك الإلكترونات.

chemical change A process involving one or more substances changing into new substances; also called a chemical reaction.

التغير الكيميائي هو عملية تتضمن تغير مادة أو أكثر إلى مواد جديدة وتسمى أيضا التفاعل الكيميائي.

chemical equation A statement using chemical formulas to describe the identities and relative amounts of the reactants and products involved in the chemical reaction.

المعادلة الكيميائية تمثيل بالرموز والصيغ للمتفاعلات والنواتج وكمياتها النسبية في التفاعل.

chemical equilibrium The state in which forward and reverse reactions balance each other because they occur at equal rates.

الاتزان الكيميائي الحالة التي تكون فيها سرعة التفاعل الأمامي مساوية لسرعة التفاعل العكسي وتبقى فيها تراكيز المواد المتفاعلة والناتجة ثابتة.

chemical potential energy The energy stored in a substance because of its composition; most is released or absorbed as heat during chemical reactions or processes.

الطاقة الكيميائية الكامنة هي الطاقة التي يتم تخزينها في مادة بسبب تركيبتها، ويتم إطلاق أو امتصاص معظمها كطاقة حرارية أثناء التفاعلات أو العمليات الكيميائية.

chemical property The ability or inability of a substance to combine with or change into one or more new substances.

الخاصية الكيميائية قابلية المادة على التفاعل أو التغير إلى مادة جديدة أو أكثر.

القاموس • Glossary

chemical reaction The process by which the atoms of one or more substances are rearranged to form different substances; occurrence can be indicated by changes in temperature, color, odor, and physical state.

chemistry The study of matter and the changes that it undergoes.

chirality A property of a compound to exist in both left (l–) and right (d–) forms; occurs whenever a compound contains an asymmetric carbon.

chromatography A technique that is used to separate the components of a mixture based on the tendency of each component to travel or be drawn across the surface of a fixed substrate.

coefficient In a chemical equation, the number written in front of a reactant or product; in a balanced equation describes the lowest whole-number ratio of the amounts of all reactants and products.

colligative property **(kol LIHG uh tihv • PRAH pur tee)** A physical property of a solution that depends on the number, but not the identity, of the dissolved solute particles.

collision theory States that atoms, ions, and molecules must collide in order to react.

colloids A heterogeneous mixture of intermediate-sized particles (between atomic-size of solution particles and the size of suspension particles).

combined gas law A single law combining Boyle's, Charles's, and Gay-Lussac's laws that states the relationship among pressure, volume, and temperature of a fixed amount of gas.

combustion reaction A chemical reaction that occurs when a substance reacts with oxygen, releasing energy in the form of heat and light.

common ion An ion that is common to two or more ionic compounds.

common ion effect The lowering of the solubility of a substance by the presence of a common ion.

complete ionic equation An ionic equation that shows all the particles in a solution as they realistically exist.

complex reaction A chemical reaction that consists of two or more elementary steps.

compound A chemical combination of two or more different elements; can be broken down into simpler substances by chemical means and has properties different from those of its component elements.

concentration A measure of how much solute is dissolved in a specific amount of solvent or solution.

conclusion A judgment based on the information obtained.

condensation The energy-releasing process by which a gas or vapor becomes a liquid.

condensation polymerization Occurs when monomers containing at least two functional groups combine with the loss of a small by-product, usually water.

condensation reaction Occurs when two smaller organic molecules combine to form a more complex molecule, accompanied by the loss of a small molecule such as water.

التفاعل الكيميائي هو عملية يتم من خلالها إعادة ترتيب ذرات مادة واحدة أو أكثر لتكوين مواد جديدة. ويمكن ملاحظة حدوثها عن طريق التغيرات التي تحدث في درجة الحرارة واللون والرائحة والحالة الفيزيائية.

الكيمياء هي دراسة المادة والتغيرات التي تطرأ عليها.

عدم التناظر المرآتي(الكيرالي) خاصية لمركب تسمح له بالوجود في الأشكال اليسرى (l–) واليمنى (d–) على حد سواء؛ ويحدث ذلك في أي وقت يحتوي فيه المركب على ذرة كربون غير متماثلة.

الكروماتوجرافيا هي تقنية تستخدم لفصل مكونات خليط ما اعتمادًا على ميل كل مكون للانتقال أو السحب عبر سطح ركيزة ثابتة.

المعامل هو الرقم الذي يُكتب أمام مادة متفاعلة أو ناتج في المعادلة الكيميائية؛ وفي المعادلة الموزونة يصف أقل نسبة عددية صحيحة لكميات جميع المواد المتفاعلة والنواتج.

الخاصية التجميعية هي خاصية فيزيائية للمحلول تعتمد على عدد جسيمات المادة المذابة ولا تعتمد على نوعها.

نظرية التصادم تنص على وجوب تصادم الذرات والأيونات والجزيئات لحدوث التفاعل.

الغرويات هي خليط غير متجانس من الجسيمات متوسطة الحجم (ما بين الحجم الذري لجسيمات المحلول وحجم الجسيمات المعلقة).

القانون العام للغازات هو قانون واحد يشمل قانون بويل وقانون شارل وقانون جاي لوساك، ويوضح العلاقة بين الضغط والحجم ودرجة الحرارة لكمية ثابتة من الغاز.

تفاعل الاحتراق هو تفاعل كيميائي يحدث عندما تتفاعل مادة مع الأكسجين وينتج عنها طاقة في شكل حرارة وضوء.

الأيون المشترك هو أيون يشترك فيه اثنان أو أكثر من المركبات الأيونية.

تأثير الأيون المشترك هو انخفاض ذائبية أو تأين مادة ما بسبب وجود أيون مشترك.

المعادلة الأيونية الكاملة هي معادلة أيونية تظهر كافة الجسيمات في المحلول كما هي في الواقع.

التفاعل المعقد هو تفاعل كيميائي يتكون من اثنتين أو أكثر من الخطوات الأولية.

المركب مادة تتكون من عنصرين مختلفين أو أكثر، يمكن تقسيمها إلى مواد أبسط من خلال وسائل كيميائية، وتختلف خصائصها عن خصائص العناصر التي تتكون منها.

التركيز هو قياس لتعيين كمية المواد المذابة في كمية محددة من المذيب أو المحلول.

الاستنتاج هو تقدير قائم على المعلومات التي تم الحصول عليها.

التكثيف هو عملية اطلاق الطاقة التي يتحول الغاز أو البخار من خلالها إلى سائل.

بلمرة التكثيف هي عملية تحدث عندما تتحد المونومرات التي تحتوي على مجموعتين وظيفيتين على الأقل مع فقدان ناتج ثانوي صغير، عادةً ما يكون الماء.

تفاعل التكاثف هو تفاعل يحدث عندما يتحد جزيئان عضويان أصغر حجما لتكوين جزيء أكثر تعقيدًا مصحوبًا بفقدان جزيء صغير مثل الماء.

القاموس • Glossary

conjugate acid The species produced when a base accepts a hydrogen ion from an acid.

الحمض المرافق يشير إلى الأنواع التي تنتج عند قبول قاعدة لأيون هيدروجين من أحد الأحماض.

conjugate acid-base pair Consists of two substances related to each other by the donating and accepting of a single hydrogen ion.

زوج مرافق من حمض وقاعدة يتكون من مادتين مرتبطتين ببعضهما عن طريق منح وقبول أيون هيدروجين واحد.

conjugate base The species produced when an acid donates a hydrogen ion to a base.

القاعدة المرافقة تشير إلى الأنواع التي تنتج عندما يقوم أحد الأحماض بمنح أيون هيدروجين لقاعدة ما.

control In an experiment, the standard that is used for comparison.

الضابط "المراقبة" هي المعيار الذي يستعمل للمقارنة في أي تجربة.

conversion factor A ratio of equivalent values used to express the same quantity in different units; is always equal to 1 and changes the units of a quantity without changing its value.

معامل التحويل هو نسبة من القيم المتساوية تستخدم للتعبير عن نفس الكمية في وحدات مختلفة، ويساوي 1 دائما، ويغير وحدات الكمية دون تغيير قيمتها.

coordinate covalent bond Forms when one atom donates a pair of electrons to be shared with an atom or ion that needs two electrons to become stable.

الرابطة التساهمية التناسقية رابطة تتكون عندما تمنح ذرة زوجا من الإلكترونات لتتشارك مع ذرة (أو أيون) تحتاج إلى إلكترونين لتصبح مستقرة.

corrosion The loss of metal that results from an oxidation-reduction reaction of the metal with substances in the environment.

التآكل عملية طبيعية تحول الفلز عن طريق تفاعلات الأكسدة والاختزال إلى مواد أخرى مثل الأكاسيد.

covalent bond A chemical bond that results from the sharing of valence electrons.

الرابطة التساهمية هي رابطة كيميائية تنتج عن مشاركة إلكترونات تكافؤ.

cracking The process by which heavier fractions of petroleum are converted to gasoline by breaking their large molecules into smaller molecules.

التكسير هو العملية التي من خلالها يتم تحويل الأجزاء الثقيلة من البترول (النفط) إلى جازولين عن طريق تفتيت جزيئاتها الكبيرة إلى جزيئات أصغر.

critical mass The minimum mass of a sample of fissionable material necessary to sustain a nuclear chain reaction.

الكتلة الحرجة هي أقل كتلة من عينة مادة قابلة للانشطار، لازمة لاستمرار تفاعل نووي متسلسل.

crystal lattice A three-dimensional geometric arrangement of particles in which each positive ion is surrounded by negative ions and each negative ion is surrounded by positive ions; vary in shape due to sizes and relative numbers of the ions bonded.

الشبكة البلورية هي ترتيب هندسي ثلاثي الأبعاد للجسيمات يحاط فيها كل أيون موجب بأيونات سالبة، ويحاط فيها كل أيون سالب بأيونات موجبة، وهي متنوعة في الشكل بسبب أحجام الأيونات المرتبطة بها وأعدادها النسبية.

crystalline solid A solid whose atoms, ions, or molecules are arranged in an orderly, geometric, three-dimensional structure.

الجسم البلوري الصلب هو جسم صلب يتم ترتيب ذراته وأيوناته وجزيئاته في تركيب هندسي منتظم ثلاثي الأبعاد.

crystallization A separation technique that produces pure solid crytsals of a substance from a solution that contains the dissolved substance.

التبلور هي طريقة للفصل تنتج عنها بلورات نقية صلبة لمادة من محلول يحتوي على المادة المذابة.

cyclic hydrocarbon An organic compound that contains a hydrocarbon ring.

الهيدروكربون الحلقي هو هيدروكربون عضوي يحتوي على حلقة هيدروكربونية.

cycloalkane Cyclic hydrocarbons that contain single bonds only and can have rings with three, four, five, six, or more carbon atoms.

الألكان الحلقي هو عبارة عن هيدروكربونات حلقية تحتوي على روابط احادية بين الذرات، ويمكنها أن تحتوي على حلقات بها ثلاث ذرات من الكربون أو أربع أو خمس أو ست أو أكثر من ذلك.

D

Dalton's atomic theory States that matter is composed of extremely small particles called atoms; atoms are invisible and indestructable; atoms of a given element are identical in size, mass, and chemical properties; atoms of a specific element are different from those of another element; different atoms combine in simple whole-number ratios to form compounds; in a chemical reaction, atoms are separated, combined, or rearranged.

نظرية دالتون الذرية تنص على أن المادة تتألف من جسيمات صغيرة جدًا تسمى الذرات، ولا يمكن رؤية الذرات ولا تقسيمها، وتتشابه ذرات العنصر الواحد في الحجم والكتلة والخصائص الكيميائية، وتختلف ذرات أي عنصر عن ذرات عنصر آخر، وتتحد الذرات المختلفة بنسب بسيطة من الأعداد الصحيحة لتكوين المركبات، وتكون الذرات منفصلة أو متحدة أو مرتبة في التفاعل الكيميائي.

Dalton's law of partial pressures States that the total pressure of a mixture of gases is equal to the sum of the pressures of all the gases in the mixture.

قانون دالتون للضغوط الجزئية ينص على أن إجمالي الضغط لخليط من الغازات يتساوى مع ناتج جمع ضغوط جميع الغازات الموجودة في الخليط.

de Broglie equation Predicts that all moving particles have wave characteristics and relates each particle's wavelength to its frequency, its mass, and Planck's constant.

معادلة دي بروغلي تتوقع هذه المعادلة أن جميع الجسيمات المتحركة تتمتع بخصائص موجية، كما أنها تربط الطول الموجي لكل جسيم بتردده وكتلته وثابت بلانك.

decomposition reaction A chemical reaction that occurs when a single compound breaks down into two or more elements or new compounds.

تفاعل الانحلال (التفكك) هو تفاعل كيميائي يحدث عندما يتفتت مركب واحد إلى عنصرين أو أكثر أو إلى مركبات جديدة.

dehydration reaction An elimination reaction in which the atoms removed form water.

تفاعل نزع الماء هو تفاعل حذف يتم فيه إزالة جزيء الماء.

dehydrogenation reaction A reaction that eliminates two hydrogen atoms, which form a hydrogen molecule of gas.

تفاعل نزع الهيدروجين هو تفاعل يعمل على إزالة ذرتين من الهيدروجين وتكوين جزيء هيدروجين.

delocalized electrons The electrons involved in metallic bonding that are free to move easily from one atom to the next throughout the metal and are not attached to a particular atom.

إلكترونات غير متموضعة الإلكترونات المشاركة في الرابطة الفلزية وتنتقل بسهولة من ذرة إلى أخرى خلال الفلز وليست مرتبطة بذرة معينة.

denaturation The process in which a protein's natural, intricate three-dimensional structure is disrupted.

تمسخ البروتين هي العملية التي يحدث فيها خلل في التركيب الطبيعي والمعقد والثلاثي الأبعاد للبروتيين.

density The amount of mass per unit volume; a physical property.

الكثافة مقدار كتلة المادة في وحدة الحجم وهي خاصية فيزيائية.

dependent variable In an experiment, the variable whose value depends on the independent variable.

المتغير التابع هو المتغير الذي تعتمد قيمته في إحدى التجارب على المتغير المستقل.

deposition The energy-releasing process by which a substance changes from a gas or vapor to a solid without first becoming a liquid.

الترسيب هو عملية انتاج الطاقة التي تتحول المادة من خلالها من حالة غازية أو بخارية إلى حالة صلبة دون مرورها بالحالة السائلة .

derived unit A unit defined by a combination of base units.

الوحدة المشتقة هي الوحدة التي يتم تحديدها عن طريق مجموعة من الوحدات الأساسية.

diffusion The movement of one material through another from an area of higher concentration to an area of lower concentration.

الانتشار يشير إلى انتقال مادة خلال مادة أخرى من منطقة عالية التركيز إلى منطقة منخفضة التركيز.

dimensional analysis A systematic approach to problem solving that uses conversion factors to move from one unit to another.

التحليل البعدي هو أسلوب منهجي لحل المشكلات يستخدم معاملات التحويل للانتقال من وحدة لأخرى.

dipole-dipole forces The attractions between oppositely charged regions of polar molecules.

القوى ثنائية القطب هي حالات التجاذب بين المناطق ذات الشحنات المختلفة من الجزيئات القطبية.

disaccharide Forms when two monosaccharides bond together.

السكر الثنائي يتكون عندما يترابط سكران أحاديان مع بعضهما البعض.

dispersion forces The weak forces resulting from temporary shifts in the density of electrons in electron clouds.

قوى التشتت هي القوى الضعيفة الناتجة عن حالات الإزاحة المؤقتة في كثافة الإلكترونات في سحب الإلكترونات.

distillation A technique that can be used to physically separate most homogeneous mixtures based on the differences in the boiling points of the substances.

التقطير هو تقنية يمكن استخدامها للفصل فيزيائيًا بين معظم المحاليل بناءً على الاختلافات في درجات غليان المواد.

double-replacement reaction A chemical reaction that involves the exchange of ions between two compounds and produces either a precipitate, a gas, or water.

تفاعل استبدال ثنائي (مزدوج) هو تفاعل كيميائي يتطلب تبادل الأيونات بين مركبين ويكون الناتج إما راسبًا أو غازًا أو ماءً.

dry cell An electrochemical cell that contains a moist electrolytic paste inside a zinc shell.

الخلية الجافة هي خلية كهروكيميائية تحتوي على معجون إلكتروليتي رطب داخل عبوة خارصين.

E

elastic collision Collision in which no kinetic energy is lost; kinetic energy can be transferred between the colliding particles, but the total kinetic energy of the two particles remains the same.

التصادم المرن هو التصادم الذي لا تفقَد فيه الطاقة الحركية، كما يمكن تحويل الطاقة الحركية إلى جسيمات متصادمة، ولكن يظل إجمالي الطاقة الحركية للجسيمين ثابت.

التماموس • Glossary

electrochemical cell An apparatus that uses a redox reaction to produce electrical energy or uses electrical energy to cause a chemical reaction.

electrolysis The process that uses electrical energy to bring about a chemical reaction.

electrolyte An ionic compound whose aqueous solution conducts an electric current.

electrolytic cell An electrochemical cell in which electrolysis occurs.

electromagnetic radiation A form of energy exhibiting wavelike behavior as it travels through space; can be described by wavelength, frequency, amplitude, and speed.

electromagnetic spectrum Includes all forms of electromagnetic radiation; the types of radiation differ in their frequencies and wavelengths.

electron A negatively charged, fast-moving particle with an extremely small mass that is found in all forms of matter and moves through the empty space surrounding an atom's nucleus.

electron capture A radioactive decay process that occurs when an atom's nucleus draws in its own surrounding electron, which combines with a proton to form a neutron, resulting in an X-ray photon being emitted.

electron configuration The arrangement of electrons in an atom, which is prescribed by three rules—the aufbau principle, the Pauli exclusion principle, and Hund's rule.

electron-dot structure Consists of an element's symbol, representing the atomic nucleus and inner-level electrons, that is surrounded by dots, representing the atom's valence electrons.

electron sea model Proposes that all metal atoms in a metallic solid contribute their valence electrons to form a "sea" of electrons, and can explain properties of metallic solids such as malleability, conduction, and ductility.

electronegativity Indicates the relative ability of an element's atoms to attract electrons in a chemical bond.

element A pure substance that cannot be broken down into simpler substances by physical or chemical means.

elimination reaction A reaction of organic compounds that occurs when a combination of atoms is removed from two adjacent carbon atoms forming an additional bond between the atoms.

empirical formula A formula that shows the smallest whole-number mole ratio of the elements of a compound, and might or might not be the same as the actual molecular formula.

endothermic A chemical reaction or process in which a greater amount of energy is required to break the existing bonds in the reactants than is released when the new bonds form in the product molecules.

end point The point at which the indicator that is used in a titration changes color.

الخلية الكهروكيميائية هي جهاز يستخدم أحد تفاعلات الأكسدة – الاختزال لإنتاج طاقة كهربائية أو يستخدم طاقة كهربائية لإحداث تفاعل كيميائي.

التحليل الكهربائي هي العملية التي تستخدم طاقة كهربائية لإحداث تفاعل كيميائي.

الإلكتروليت هو مركب أيوني يقوم محلوله المائي بتوصيل تيار كهربائي.

الخلية الإلكتروليتية هي خلية كهروكيميائية يحدث فيها التحليل الكهربائي.

الأشعة الكهرومغناطيسية هو أحد أشكال الطاقة الذي يُظهر السلوك الموجي حيث ينتقل عبر الفضاء ويمكن وصفه بالطول الموجي والتردد والسعة والسرعة.

الطيف الكهرومغناطيسي يشمل جميع أشكال الإشعاع الكهرومغناطيسي، وتختلف أنواع الإشعاع في تردداتها وأطوالها الموجية.

الإلكترون هو جسيم سالب الشحنة وسريع الانتقال له كتلة صغيرة للغاية يوجد في جميع أشكال المادة ويتحرك خلال الحيز الفارغ المحيط بنواة الذرة.

أسر الإلكترون هو عملية الانحلال الإشعاعي التي تحدث عندما تقوم نواة الذرة بسحب إلكترون من فلك داخلي للذرة نفسها، والذي يتحد مع أحد البروتونات لتكوين نيوترون مما يؤدي إلى انبعاث فوتون الأشعة السينية.

الترتيب الإلكتروني هو عملية ترتيب الإلكترونات في ذرة ما، والتي يتم وصفها بثلاث قواعد وهي مبدأ أوفباو ومبدأ باولي للاستبعاد وقاعدة هوند.

الترميز النقطي للإلكترون يتكون من رمز أحد العناصر الذي يمثل النواة الذرية والمستوى الداخلي للإلكترونات التي تحيط بها مجموعة نقاط تمثل إلكترونات تكافؤ الذرة.

نموذج بحر الإلكترونات يقترح هذا النموذج أن جميع ذرات الفلز في أي مادة فلزية صلبة تساهم بإلكترونات التكافؤ فيما بينها لتكوين «بحر» من الإلكترونات، كما يوضح كذلك خصائص المواد الفلزية الصلبة مثل قابلية السحب والتوصيل والطرق.

السالبية الكهربائية تشير إلى القدرة النسبية لذرات أحد العناصر على جذب الإلكترونات في رابطة كيميائية.

العنصر هو مادة نقية لا يمكن تفتيتها إلى مواد أصغر منها بواسطة وسائل فيزيائية أو كيميائية.

تفاعل الحذف هو تفاعل للمركبات العضوية يحدث عند إزالة مجموعة من الذرات من ذرتي كربون متجاورتين لتكوين رابطة إضافية بين الذرتين.

الصيغة الأولية هي صيغة تبين أصغر نسبة مولية برقم صحيح لعناصر مركب ما وقد تكون نفس الصيغة الجزيئية الفعلية وقد لا تكون كذلك.

التفاعل الماص للحرارة هو تفاعل أو عملية كيميائية تتطلب وجود كمية من الطاقة لتفتيت الروابط الموجودة بين المواد المتفاعلة أكثر من الكمية الناتجة عند تكوين الروابط الجديدة في جزيئات النواتج.

نقطة النهاية هي النقطة التي يتغير عندها لون الكاشف المستخدم في المعايرة.

التاموس • Glossary

energy The capacity to do work or produce heat; exists as potential energy, which is stored in an object due to its composition or position, and kinetic energy, which is the energy of motion.

الطاقة القدرة على بذل مجهود أو إنتاج حرارة؛ وتوجد في صورة طاقة كامنة يتم تخزينها في الجسم بسبب تركيبتها أو موضعها، وفي صورة طاقة حركية تشير إلى طاقة الحركة.

energy sublevels The energy levels contained within a principal energy level.

مستويات الطاقة الفرعية (تحت المستويات) مستويات الطاقة التي يحتويها مستوى الطاقة الرئيس.

enthalpy The heat content of a system at constant pressure.

المحتوى الحراري هو محتوى الحرارة لأي نظام تحت ضغط ثابت.

enthalpy (heat) of combustion The enthalpy change for the complete burning of one mole of a given substance.

المحتوى الحراري (حرارة) للاحتراق هو تغير المحتوى الحراري للاحتراق الكامل لمول واحد لمادة معينة.

enthalpy (heat) of reaction The change in enthalpy for a reaction—the difference between the enthalpy of the substances that exist at the end of the reaction and the enthalpy of the substances present at the start .

المحتوى الحراري (حرارة) للتفاعل هو تغير المحتوى الحراري لأي تفاعل؛ أي الفرق بين المحتوى الحراري للمواد الموجودة في نهاية التفاعل والمحتوى الحراري للمواد الموجودة في البداية.

entropy A measure of the number of possible ways that the energy of a system can be distributed; related to the freedom of the system's particles to move and the number of ways they can be arranged.

الإنتروبي هو مقياس عدد الطرق الممكنة التي يمكن من خلالها توزيع طاقة أحد الأنظمة؛ وارتباطها بحرية انتقال جسيمات النظام وعدد الطرق التي يمكن ترتيبها.

enzyme A biological catalyst.

الإنزيم هو حفّاز بيولوجي.

equilibrium constant K_{eq} is the numerical value that describes the ratio of product concentrations to reactant concentrations, with each raised to the power corresponding to its coefficient in the balanced equation.

ثابت الاتزان Keq نسبة حاصل ضرب تراكيز المواد الناتجة إلى حاصل ضرب تراكيز المواد المتفاعلة . كل مرفوع إلى أس يساوي معامل المادة التابعة له في المعادلة الكيميائية الموزونة.

equivalence point The point at which the moles of H^+ ions from the acid equals moles of OH^- ions from the base.

نقطة التكافؤ هي النقطة التي تتساوى عندها مولات أيونات الهيدروجين الموجبة من الحمض مع مولات أيونات الهيدروكسيد السالبة من القاعدة.

error The difference between an experimental value and an accepted value

الخطأ هو الفرق بين قيمة تجريبية وقيمة مقبولة.

ester An organic compound with a carboxyl group in which the hydrogen of the hydroxyl group is replaced by an alkyl group; may be volatile and sweet-smelling and is polar.

الإستر هو مركب عضوي مع مجموعة من الكربوكسيل يتم فيه استبدال الهيدروجين الموجود في مجموعة الهيدروكسيل بمجموعة ألكيل؛ وقد يكون متطايرًا وذا رائحة طيبة وهو مركب قطبي.

ether An organic compound that contains an oxygen atom bonded to two carbon atoms.

الإيثر هو مركب عضوي يحتوي على ذرة أكسجين مرتبطة بذرتي كربون.

evaporation The process in which vaporization occurs only at the surface of a liquid.

التبخر هو العملية التي يحدث فيها التبخير على سطح سائل فقط.

excess reactant A reactant that remains after a chemical reaction stops.

المتفاعل الفائض هو مادة تتبقى بعد توقف أي تفاعل كيميائي.

exothermic A chemical reaction or process in which more energy is released than is required to break bonds in the initial reactants.

التفاعل الطارد للحرارة ، هو تفاعل كيميائي أو عملية يتم فيها إنتاج طاقة أكثر من الطاقة المطلوبة لكسر الروابط في المواد المتفاعلة الأولية.

experiment A set of controlled observations that test a hypothesis.

التجربة هي مجموعة من الملاحظات المُحكمة التي تختبر الفرضية.

extensive property A physical property, such as mass, length, and volume, that is dependent upon the amount of substance present.

الخاصية التوسعية هي خاصية فيزيائية مثل الكتلة والطول والحجم، وتعتمد على كمية المادة الموجودة.

F

fatty acid A long-chain carboxylic acid that usually has between 12 and 24 carbon atoms and can be saturated (no double bonds), or unsaturated (one or more double bonds).

الحمض الدهني هو حمض كربوكسيلي ذي سلسلة طويلة يوجد به عادةً من 12 إلى 24 ذرة كربون ويمكن أن يكون مشبعا (لا يحتوي على روابط ثنائية) أو غير مشبع (يحتوي على رابطة أو رابطتين ثنائيتين).

fermentation The process in which glucose is broken down in the absence of oxygen, producing either ethanol, carbon dioxide, and energy (alcoholic fermentation) or lactic acid and energy (lactic acid fermentation).

التخمُّر هي العملية التي يتم فيها تفتيت الجلوكوز في غياب الأكسجين، مما يؤدي إلى إنتاج إيثانول وثاني أكسيد كربون وطاقة (تخمر كحولي) أو حمض اللاكتيك وطاقة (تخمر حمض اللاكتيك).

filtration A technique that uses a porous barrier to separate a solid from a liquid.

الترشيح هي تقنية تستخدم حاجزًا مساميًا للفصل بين جسم صلب وسائل.

formula unit The simplest ratio of ions represented in an ionic compound.

وحدة الصيغة هي أبسط نسبة من الأيونات التي توجد في مركب أيوني.

fractional distillation The process by which petroleum can be separated into simpler components, called fractions, as they condense at different temperatures.

التقطير التجزيئي هو العملية التي يمكن من خلالها فصل البترول إلى مكونات أبسط، تسمى المشتقات، حيث تتكاثف تحت درجات حرارة مختلفة.

free energy The energy available to do work—the difference between the change in enthalpy and the product of the entropy change and the kelvin temperature.

الطاقة الحرة الطاقة المتوفرة للقيام بالشغل وتساوي الفرق بين التغيير الذي يحدث في المحتوى الحراري (ΔH) وناتج التغيير الذي يحدث في الإنتروبي (ΔS) مضروبًا بدرجة الحرارة على مقياس كلفن.

freezing point The temperature at which a liquid is converted into a crystalline solid.

درجة التجمد هي درجة الحرارة التي يتحول عندها السائل إلى جسم بلوري صلب.

freezing-point depression The difference in temperature between a solution's freezing point and the freezing point of its pure solvent.

انخفاض درجة التجمد هو الاختلاف في درجة الحرارة بين درجة تجمد محلول ما ودرجة تجمد مذيبه النقي.

frequency The number of waves that pass a given point per second.

التردد هو عدد الموجات التي تعبر نقطة معينة في كل ثانية.

fuel cell A voltaic cell in which the oxidation of a fuel, such as hydrogen gas, is used to produce electric energy.

خلية الوقود هي خلية فولتية يتم فيها استخدام أكسدة الوقود، مثل غاز الهيدروجين، لإنتاج طاقة كهربائية.

functional group An atom or group of atoms that always reacts in a certain way in an organic molecule.

المجموعة الوظيفية هي ذرة أو مجموعة من الذرات تتفاعل دائما بطريقة معينة في جزيء عضوي.

G

galvanization The process in which an iron object is dipped into molten zinc or electroplated with zinc to make the iron more resistant to corrosion.

الجلفنة العملية التي يتم فيها وضع جسم من الحديد في مصهور الخارصين أو طلائه كهربائيًا بالخارصين لجعل الحديد أكثر مقاومة للصدأ.

gamma rays High-energy radiation that has no electrical charge and no mass, is not deflected by electric or magnetic fields, usually accompanies alpha and beta radiation, and accounts for most of the energy lost during radioactive decay.

أشعة جاما هي إشعاع عالي الطاقة لا توجد به شحنة كهربائية ولا كتلة، كما أنه لا ينحرف بواسطة المجالات الكهربائية أو المغناطيسية، ويصحبه عادة إشعاع ألفا وبيتا وهو المسؤول عن معظم الطاقة المفقودة أثناء الانحلال الإشعاعي.

gas A form of matter that flows to conform to the shape of its container, fills the container's entire volume, and is easily compressed.

الغاز أحد حالات المادة التي تنساب لتأخذ شكل وحجم الوعاء الذي يحتويها وتكون سهلة الانضغاط.

Gay-Lussac's law States that the pressure of a fixed mass of gas varies directly with the kelvin temperature when the volume remains constant.

قانون جاي لوساك ينص على أن ضغط كتلة محددة من الغاز يتناسب طرديًا مع درجة الحرارة بالكلفن عند ثبات الحجم.

geometric isomers A category of stereoisomers that results from different arrangements of groups around a double bond.

أيزومرات هندسية فئة من الأيزومرات الفراغية تنتج عن ترتيبات مختلفة للمجموعات حول رابطة ثنائية.

Graham's law of effusion States that the rate of effusion for a gas is inversely proportional to the square root of its molar mass.

قانون جراهام للتدفق ينص على أن معدل تدفق الغاز يتناسب عكسيًا مع الجذر التربيعي للكتلة المولية له.

graph A visual display of data.

الرسم البياني هو عرض مرئي للبيانات.

ground state The lowest allowable energy state of an atom.

حالة الاستقرار هي أقل حالة طاقة مسموح بها لذرة ما.

group A vertical column of elements in the periodic table arranged in order of increasing atomic number; also called a family.

المجموعة عمود رأسي للعناصر في الجدول الدوري مرتبة تصاعديًا تبعًا للعدد الذري وتسمى العائلة أيضا.

H

half-cells The two parts of an electrochemical cell in which the separate oxidation and reduction reactions occur.

half-life The time required for one-half of a radioisotope's nuclei to decay into its products.

half-reaction One of two parts of a redox reaction—the oxidation half, which shows the number of electrons lost when a species is oxidized, or the reduction half, which shows the number of electrons gained when a species is reduced.

halocarbon Any organic compound containing a halogen substituent.

halogen A highly reactive group 17 element.

halogenation A process by which hydrogen atoms are replaced by halogen atoms.

heat A form of energy that flows from a warmer object to a cooler object.

heat of solution The overall energy change that occurs during the solution formation process.

Heisenberg uncertainty principle States that it is not possible to know precisely both the velocity and the position of a particle at the same time.

Henry's law States that at a given temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.

Hess's law States that if two or more thermochemical equations can be added to produce a final equation for a reaction, then the sum of the enthalpy changes for the individual reactions is the enthalpy change for the final reaction.

heterogeneous catalyst A catalyst that exists in a different physical state than the reaction it catalyzes.

heterogeneous equilibrium A state of equilibrium that occurs when the reactants and products of a reaction are present in more than one physical state.

heterogeneous mixture One that does not have a uniform composition and in which the individual substances remain distinct.

homogeneous catalyst A catalyst that exists in the same physical state as the reaction it catalyzes.

homogeneous equilibrium A state of equilibrium that occurs when all the reactants and products of a reaction are in the same physical state.

homogeneous mixture One that has a uniform composition throughout and always has a single phase; also called a solution.

homologous series Describes a series of compounds that differ from one another by a repeating unit.

Hund's rule States that single electrons with the same spin must occupy each equal-energy orbital before additional electrons with opposite spins can occupy the same orbitals.

الخلايا النصفية قسما الخلية الكهروكيميائية تحدث في أحدهما الأكسدة وفي الثاني الاختزال.

عمر النصف الزمن اللازم لانحلال نصف كمية ذرات نويدة مشعة.

التفاعل النصفي أحد نصفي تفاعل الأكسدة – اختزال وهما نصف الأكسدة ويبين عدد الإلكترونات المفقودة عند أكسدة المادة أو نصف الاختزال ويبين عدد الإلكترونات المكتسبة عند اختزال المادة.

الكربون الهالوجيني هو مركب عضوي يحتوي على ذرة هالوجين.

الهالوجينات المجموعة 17 في الجدول الدوري وهي نشطة كيميائيًا.

الهلجنة هي عملية يتم من خلالها استبدال ذرات الهالوجين بذرات الهيدروجين.

الحرارة هي أحد أشكال الطاقة تتدفق من تنتقل من جسم دافئ إلى جسم بارد.

حرارة المحلول هي إجمالي تغير الطاقة الذي يحدث أثناء عملية تكوين المحلول.

مبدأ الشك لهايزنبرج ينص على أنه لا يمكن التعرف بدقة على كلاً من السرعة المتجهة وموضع الجزيء في الوقت ذاته.

قانون هنري ينص على أن قابلية ذوبان الغاز في سائل ما تحت درجة حرارة معينة تتناسب عكسيًا مع ضغط الغاز فوق السائل.

قانون هس ينص على أنه إذا كان من الممكن إضافة اثنتين أو أكثر من المعادلات الكيميائية الحرارية لإنتاج معادلة نهائية لأحد التفاعلات، فإن مجموع التغيرات التي تطرأ على المحتوى الحراري للمعادلات المنفردة هو التغير في المحتوى الحراري للمعادلة النهائية.

حفاز غير متجانس حفاز يكون في حالة فيزيائية مختلفة عن حالة المتفاعلات الفيزيائية.

الاتزان غير المتجانس حالة الاتزان التي تكون فيه المواد المتفاعلة والناتجة في أكثر من حالة فيزيائية.

الخليط غير المتجانس الخليط الذي لا يوجد له تركيبة متماثل وتظل فيه مكوناته مستقلة.

حفاز متجانس هو حفاز يوجد بنفس الحالة الفيزيائية التي يكون عليها التفاعل الذي يحفزه.

الاتزان المتجانس حالة الاتزان التي تكون فيه جميع المواد المتفاعلة والناتجة في حالة فيزيائية واحدة.

الخليط المتجانس هو خليط له تركيب متماثل في جميع أجزائه، وله طور واحد دائمًا. ويسمى محلولاً أيضا.

سلسلة متجانسة تصف مجموعة من المركبات يختلف كل منها عن الآخر بوحدة متكررة.

قاعدة هوند لا يحدث تزاوج بين إلكترونين في تحت مستوى معين إلا بعد أن تشغل أفلاكه فرادى أولاً.

hybridization A process in which atomic orbitals are mixed to form new, identical hybrid orbitals.

التهجين العملية التي يتم فيها دمج لفلكين أو أكثر للذرة لتكوين أفلاك جديدة ذات طاقة متساوية وأشكال متشابهة.

hydrate A compound that has a specific number of water molecules bound to its atoms.

الهيدرات هي مركب يحتوي على عدد معين من جزيئات الماء مرتبطة بذراته.

hydration reaction An addition reaction in which a hydrogen atom and a hydroxyl group from a water molecule add to a double or triple bond.

تفاعل إضافة الماء هو تفاعل إضافة يتم فيه إضافة ذرة هيدروجين ومجموعة هيدروكسيل من جزيء ماء إلى رابطة ثنائية أو ثلاثية.

hydrocarbon Simplest organic compound composed only of the elements carbon and hydrogen.

الهيدروكربون هو أبسط مركب عضوي يتكون من عناصر الكربون والهيدروجين فقط.

hydrogenation reaction An addition reaction in which hydrogen is added to atoms in a double or triple bond; usually requires a catalyst.

تفاعل الهدرجة هو تفاعل إضافة يضاف الهيدروجين خلاله إلى الذرات المرتبطة برابطة ثنائية أو ثلاثية، ويحتاج عادة إلى حفاز.

hydrogen bond A strong dipole-dipole attraction between molecules that contain a hydrogen atom bonded to a small, highly electronegative atom.

الرابطة الهيدروجينية رابطة ثنائية القطب - ثنائية القطب قوية تحدث بين الجزيئات التي تحتوي على ذرة هيدروجين مرتبطة بذرة صغيرة ذات سالبية كهربائية كبيرة.

hydroxyl group An oxygen-hydrogen group covalently bonded to a carbon atom.

مجموعة الهيدروكسيل مجموعة OH مرتبطة بذرة كربون بصورة تساهمية.

hypothesis A tentative, testable statement or prediction about what has been observed.

الفرضية هي عبارة أو استنتاج تجريبي وقابل للاختبار حول ما تمت ملاحظته.

I

ideal gas constant (R) An experimentally determined constant whose value in the ideal gas equation depends on the units that are used for pressure.

ثابت الغاز المثالي (R) هو ثابت محدد تجريبيًا تستند قيمته في معادلة الغاز المثالي إلى الوحدات المستخدمة للضغط.

ideal gas law Describes the physical behavior of an ideal gas in terms of pressure, volume, temperature, and number of moles of gas.

قانون الغاز المثالي هو قانون يصف سلوك غاز مثالي فيما يتعلق بالضغط والحجم ودرجة الحرارة وعدد مولات الغاز.

immiscible (ih MIHS ih bul) Describes two liquids that can be mixed together but separate shortly after you cease mixing them.

غير قابل للامتزاج (ih MIHS ih bul) هي خاصية تصف سائلين يمكنهما الامتزاج معا ولكنهما ينفصلان بعد وقف المزج بينهما بفترة قليلة.

independent variable In an experiment, the variable that the experimenter plans to change.

المتغير المستقل هو المتغير الذي يقرر المُختبر تغييره أثناء التجربة.

induced transmutation The process in which nuclei are bombarded with high-velocity charged particles in order to create new elements.

تحول نووي اصطناعي هو عملية يتم خلالها قذف النواة بجسيمات مشحونة عالية السرعة لتكوين عناصر جديدة.

inhibitor A substance that slows down the reaction rate of a chemical reaction or prevents a reaction from happening.

المثبط هو مادة تبطئ معدل التفاعل الكيميائي أو تمنع حدوث التفاعل.

inner transition metal A type of group B element that is contained in the f-block of the periodic table and is characterized by a filled outermost orbital, and filled or partially filled 4f and 5f orbitals.

الفلز الانتقالي الداخلي أحد أنواع عناصر المجموعة B الموجود في المجمع -f في الجدول الدوري ويتميز بوجود الأفلاك الخارجية الممتلئة و أفلاك 4f و 5f الممتلئة أو شبه الممتلئة.

insoluble Describes a substance that cannot be dissolved in a given solvent.

عديم الذوبان هي خاصية تصف المادة التي لا يمكن إذابتها في مذيب محدد.

instantaneous rate The rate of decomposition at a specific time, calculated from the rate law, the specific rate constant, and the concentrations of all the reactants.

السرعة اللحظية هو معدل التفكك في وقت محدد ويحسب من قانون سرعة التفاعل وثابت السرعة النوعية وتراكيز جميع المواد المتفاعلة.

intensive property A physical property that remains the same no matter how much of a substance is present.

الخاصية المكثفة هي خاصية فيزيائية تبقى كما هي دون النظر إلى كمية المادة الموجودة.

intermediate A substance produced in one elementary step of a complex reaction and consumed in a subsequent elementary step.

المادة الوسيطة هي مادة تنتج خلال خطوة أولية واحدة من تفاعل معقد وتستهلك في خطوة لاحقة.

التاموس • Glossary

ion An atom or bonded group of atoms with a positive or negative charge.
ionic bond The electrostatic force that holds oppositely charged particles together in an ionic compound.
ionic compounds Compounds that contain ionic bonds.
ionization energy The energy required to remove an electron from a gaseous atom; generally increases in moving from left-to-right across a period and decreases in moving down a group.

ionizing radiation Radiation that is energetic enough to ionize matter it collides with.
ion product constant for water The value of the equilibrium constant expression for the self-ionization of water.
isomers Two or more compounds that have the same molecular formula but have different molecular structures.
isotopes Atoms of the same element with different numbers of neutrons.

الأيون هو ذرة أو مجموعة مترابطة من الذرات موجبة أو سالبة الشحنة.
الرابطة الأيونية هي قوى إلكتروستاتية تربط بين جسيمات مشحونة مختلفة الشحنة في مركب أيوني.
المركبات الأيونية هي مركبات تحتوي على روابط أيونية.
طاقة التأين هي الطاقة اللازمة لنزع إلكترون من ذرة غازية؛ وتزداد عموما عند الانتقال من اليسار إلى اليمين في الدورة وتقل عند الانتقال من الأعلى إلى الأسفل في المجموعة.
إشعاع التأين هو إشعاع ذو طاقة كافية لتأيين المادة التي تصطدم به.
ثابت تأين الماء K_W حاصل الإتزان للتعبير عن التأين الذاتي للماء.
الأيزومرات مركبات لها الصيغة الجزيئية نفسها لكنها تختلف في صيغها البنائية.
النظائر هي ذرات نفس العنصر التي تحتوي على أعداد مختلفة من النيوترونات.

J

joule The SI unit of heat and energy.

الجول وحدة الحرارة والطاقة في نظام الوحدات الدولي SI.

K

kelvin The SI base unit of temperature.

ketone An organic compound in which the carbon of the carbonyl group is bonded to two other carbon atoms.
kilogram The SI base unit for mass.

kinetic-molecular theory Describes the behavior of gases in terms of particles in motion; makes several assumptions about size, motion, and energy of gas particles.

الكلفن وحدة درجة الحرارة في نظام الوحدات الدولي SI.
الكيتون هو مركب عضوي يتميز باحتوائه على مجموعة كربونيل ترتبط بذرتي كربون أخريين.
الكيلوجرام وحدة الكتلة في نظام الوحدات الدولي SI.
النظرية الحركية الجزيئية تصف سلوك الغازات من حيث حركة الجسيمات وإجراء عدة افتراضات حول حجم وحركة وطاقة جسيمات الغاز.

L

lanthanide series In the periodic table, the f-block elements from period 6 that follow the element lanthanum.
lattice energy The energy required to separate one mole of the ions of an ionic compound, which is directly related to the size of the ions bonded and is also affected by the charge of the ions.
law of chemical equilibrium States that at a given temperature, a chemical system may reach a state in which a particular ratio of reactant and product concentrations has a constant value.
law of conservation of energy States that in any chemical reaction or physical process, energy may change from one form to another, but it is neither created nor destroyed.
law of conservation of mass States that mass is neither created nor destroyed during a chemical reaction but is conserved.

سلسلة اللانثينيدات في الجدول الدوري، تتمثل في عناصر المجمع f من الدورة السادسة التي تلي عنصر اللانثانيوم.
طاقة الشبكة البلورية هي الطاقة اللازمة لفصل مول واحد من أيونات مركب أيوني، وترتبط مباشرةً بحجم الأيونات التي تحتوي عليها وتتأثر أيضا بشحنة الأيونات.
قانون الاتزان الكيميائي هو قانون ينص على أن النظام الكيميائي عند درجة حرارة محددة قد يصل إلى حالة تكون فيها نسبة محددة من تراكيز المواد المتفاعلة والناتجة ذات قيمة ثابتة.
قانون حفظ الطاقة هو قانون ينص على إمكانية تغير الطاقة من شكل إلى آخر أثناء أي تفاعل كيميائي أو عملية فيزيائية، ولكنها لا تفنى ولا تستحدث من العدم.
قانون حفظ الكتلة هو قانون ينص على أن الكتلة لا تفنى ولا تستحدث من العدم أثناء التفاعل الكيميائي، ولكن يتم الحفاظ عليها.

law of definite proportions States that, regardless of the amount, a compound is always composed of the same elements in the same proportion by mass.

قانون النسب الثابتة هو قانون ينص على أن المركب، بغض النظر عن الكمية، دائما ما يتكون من نفس العناصر وبنفس النسبة الكتلية.

law of multiple proportions States that when different compounds are formed by the combination of the same elements, different masses of one element combine with the same fixed mass of the other element in a ratio of small whole numbers.

قانون النسب المتضاعفة هو قانون ينص على أنه في حالة تكوين المركبات المختلفة باتحاد نفس العناصر، فإن الكُتل المختلفة لأحد العناصر تتحد مع نفس الكتلة الثابتة لعنصر آخر بنسبة عددية صحيحة وصغيرة.

Le Châtelier's principle **(luh SHAHT uh lee yays • PRIHN sih puhl)** States that if a stress is applied to a system at equilibrium, the system shifts in the direction that relieves the stress.

مبدأ لو شاتيليه ينص على أنه إذا تعرض نظام متزن لتوتر فإن النظام ينزاح في الاتجاه الذي يحد من هذا التوتر.

Lewis model A Lewis acid is an electron-pair acceptor and a Lewis base is an electron-pair donor.

نموذج لويس حمض لويس هو مستقبل لزوج من الإلكترونات وقاعدة لويس هي مانح لزوج من الإلكترونات.

Lewis structure A model that uses electron-dot structures to show how electrons are arranged in molecules. Pairs of dots or lines represent bonding pairs.

بنى لويس هو نموذج يستخدم لعرض كيفية ترتيب الإلكترونات في الجزيئات بحيث يبين الإلكترونات غير المشتركة حول كل ذرة ممثلة بالنقط، والمعترضة تبين الإلكترونات بين الذرتين المترابطتين برابطة تساهمية.

limiting reactant A reactant that is totally consumed during a chemical reaction, limits the extent of the reaction, and determines the amount of product.

المتفاعل المحدد هي مادة متفاعلة يتم استهلاكها بالكامل أثناء التفاعل الكيميائي وتحدد مدى التفاعل وكمية الناتج.

lipids Large, nonpolar biological molecules that vary in structure, store energy in living organisms, and make up most of the structure of cell membranes.

الدهون هي جزيئات بيولوجية كبيرة لاقطبية تختلف في التركيب، وتقوم بتخزين الطاقة في الكائنات الحية. وتكوّن أغلب تركيب أغشية الخلية.

liquid A form of matter that flows, has constant volume, and takes the shape of its container.

السائل حالة المادة التي تنساب ولها حجم ثابت وتأخذ شكل الإناء الذي تحتويه.

liter The metric unit for volume equal to one cubic decimeter.

اللتر هو وحدة قياس مترية لحجم يعادل واحد ديسيمتر مكعب.

M

mass A measure that reflects the amount of matter.

الكتلة هي وحدة قياس تعكس كمية المادة.

mass defect The difference in mass between a nucleus and its component nucleons.

نقص الكتلة هو الفرق في الكتلة بين النواة والنويّات التي تتكون منها.

mass number The number after an element's name, representing the sum of its protons and neutrons.

العدد الكتلي هو العدد الموجود بعد اسم العنصر ويمثل مجموع عدد بروتوناته ونيوتروناته.

matter Anything that has mass and takes up space.

المادة هي أي شيء له كتلة ويشغل حيزًا.

melting point For a crystalline solid, the temperature at which the forces holding a crystal lattice together are broken and it becomes a liquid.

درجة الانصهار بالنسبة إلى مادة صلبة بلورية، هي درجة الحرارة التي تنكسر عندها القوى التي تربط الشبكة البلورية ببعضها وتتحول إلى مادة سائلة.

metabolism The sum of the many chemical reactions that occur in living cells.

الأيض البنائي هو مجموع التفاعلات الكيميائية الكثيرة التي تحدث في الخلايا الحية.

metal An element that is solid at room temperature, a good conductor of heat and electricity, and generally is shiny; most metals are ductile and malleable.

الفلز هو عنصر صلب بدرجة حرارة الغرفة، وموصل جيد للحرارة والكهرباء، ويكون لامعا في العموم بالإضافة إلى أن معظم الفلزات قابلة للسحب والطرق.

metallic bond The attraction of a metallic cation for delocalized electrons.

الرابطة الفلزية هي تجاذب الأيونات الموجبة الفلزية مع الإلكترونات غير المتموضعة (بحر الإلكترونات).

metalloid An element that has physical and chemical properties of both metals and nonmetals.

شبه الفلز هو عنصر له خصائص فيزيائية وكيميائية من الفلزات واللا فلزات.

meter The SI base unit for length.

المتر وحدة الطول في نظام الوحدات الدولي SI.

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method of initial rates Determines the reaction order by comparing the initial rates of a reaction carried out with varying reactant concentrations.

طريقة المعدّلات الأولية هي طريقة تحدد رتبة التفاعل من خلال مقارنة المعدلات الأولية للتفاعل الذي تم إجراؤه بتراكيز مواد التفاعل المختلفة.

miscible Describes two liquids that are soluble in each other.

قابل للامتزاج يصف مادتين سائلتين قابلتين للذوبان معا.

mixture A physical blend of two or more pure substances in any proportion in which each substance retains its individual properties; can be separated by physical means.

الخليط هو خليط فيزيائي لمادتين نقيتين أو أكثر بأي نسبة، تحتفظ خلاله كل مادة بخصائصها الفردية ويمكن الفصل بينهما بوسائل فيزيائية.

model A visual, verbal, and/or mathematical explanation of data collected from many experiments.

النموذج هو توضيح مرئي ولفظي و/أو رياضي للبيانات التي تم تجميعها من العديد من التجارب.

molality The ratio of the number of moles of solute dissolved in one kilogram of solvent; also known as molal concentration.

المولالية هي نسبة عدد المولات المذابة في كيلو جرام واحد من المذيب، والمعروفة أيضا بالتركيز المولالي.

molar enthalpy (heat) of fusion The amount of heat required to melt one mole of a solid at its melting point.

الحرارة المولية للانصهار هو كمية الحرارة اللازمة لصهر مول واحد من مادة صلبة عند درجة انصهارها.

molar enthalpy (heat) of vaporization The amount of heat required to vaporize one mole of a at its boiling point.

الحرارة المولية للتبخير هو كمية الحرارة اللازمة لتبخر مول واحد من المادة السائلة عند درجة غليانها..

molarity The number of moles of solute dissolved per liter of solution; also known as molar concentration.

المولارية هي عدد المولات المذابة في كل لتر من المحلول والمعروفة أيضا بالتركيز المولاري.

molar mass The mass in grams of one mole of any pure substance.

الكتلة المولية الكتلة بالجرام لمول واحد من أي مادة نقية.

molar volume For a gas, the volume that one mole occupies at 0.00°C and 1.00 atm pressure.

حجم مولي الحجم الذي يشغله مول واحد من أي غاز عند درجة حرارة 0.0 °C وضغط 1.00 atm

mole The SI base unit used to measure the amount of a substance, abbreviated mol; the number of carbon atoms in exactly 12 g of pure carbon; one mole is the amount of a pure substance that contains 6.02×10^{23} representative particles.

المول الوحدة الأساسية في النظام الدولي للوحدات (SI) لقياس كمية المادة، يرمز له «mol».أو عدد ذرات الكربون في 12 جراما من الكربون النقي ، أو هو كمية مادة نقية تحتوي على 6.02×10^{23} من الجسيمات.

molecular formula A formula that specifies the actual number of atoms of each el ement in one molecule of a substance.

الصيغة الجزيئية هي صيغة تحدد العدد الفعلي لذرات كل عنصر في أحد جزيئات المادة.

molecule Forms when two or more atoms covalently bond and is lower in potential energy than its constituent atoms.

الجزيء يتكون عند ارتباط ذرتين أو أكثر، وتنخفض طاقته الكامنة عن الذرات المكونة له.

mole fraction The ratio of the number of moles of solute in solution to the total number of moles of solute and solvent.

الكَسر المولِيّ هو نسبة عدد المولات المذابة في محلول بالنسبة لإجمالي عدد مولات المذاب والمذيب.

mole ratio In a balanced equation, the ratio between the numbers of moles of any two substances.

النسبة المولية هي النسبة، في معادلة متوازنة، بين عدد المولات الموجودة في أي مادتين.

monatomic ion An ion formed from only one atom.

الأيون أحادي الذرة هو أيون يتكون من ذرة واحدة فقط.

monomer A molecule from which a polymer is made.

المونومر هو جزيء ينتج منه البوليمر.

monosaccharides The simplest carbohydrates, also called simple sugars.

السكريات الأحادية هي أبسط أنواع الكربوهيدرات، وتسمى أيضا بالسكريات البسيطة.

N

net ionic equation An ionic equation that includes only the particles that participate in the reaction.

المعادلة الأيونية الصرفة هي معادلة أيونية تتضمن الجسيمات التي تشترك في التفاعل.

neutralization reaction A reaction in which an acid and a base react in aqueous solution to produce a salt and water.

تفاعل التعادل هو تفاعل يحدث بين حمض وقاعدة في محلول مائي لإنتاج ملح وماء.

القاموس • Glossary

neutron A neutral, subatomic particle in an atom's nucleus that has a mass nearly equal to that of a proton.

النيوترون جسيم دون ذري متعادل الشحنة يوجد في نواة الذرة وله كتلة مساوية لكتلة البروتون تقريبًا.

noble gas An extremely unreactive group 18 element.

الغاز النبيل عنصر غير نشط كيميائيًا ويقع في المجموعة 18 من الجدول الدوري.

nonmetals Elements that are generally gases or dull, brittle solids that are poor conductors of heat and electricity.

اللا فلزات عناصر عامةً ما تكون غازات أو أجساما صلبة باهتة اللون أو هشة وتعد موصلات رديئة للحرارة والكهرباء.

nuclear equation A type of equation that shows the atomic number and mass number of the particles involved.

المعادلة النووية هي أحد أنواع المعادلات التي توضح العدد الذري والعدد الكتلي للجسيمات.

nuclear fission The splitting of a nucleus into smaller, more stable fragments, accompanied by a large release of energy.

الانشطار النووي هو انقسام النواة إلى عناصر أصغر وأكثر استقرارًا ويصاحبها إطلاق الطاقة بكمية كبيرة.

nuclear fusion The process of binding smaller atomic nuclei into a single, larger, and more stable nucleus.

الاندماج النووي تفاعل يتم بين أنوية خفيفة تندمج معا لتكون أنوية أثقل مع إطلاق كميات هائلة من الطاقة.

nuclear reaction A reaction that involves a change in the nucleus of an atom.

التفاعل النووي هو تفاعل يتضمن حدوث تغيير في نواة الذرة.

nucleic acid A nitrogen-containing biological polymer that is involved in the storage and transmission of genetic information.

الحمض النووي بوليمر بيولوجي يحتوي على النيتروجين ويشترك في تخزين المعلومات الوراثية ونقلها.

nucleons The positively charged protons and neutral neutrons contained in an atom's nucleus.

النويّات هي البروتونات موجبة الشحنة والنيوترونات متعادلة الشحنة الموجودة في نواة الذرة.

nucleotide The monomer that makes up a nucleic acid; consists of a nitrogen base, an inorganic phosphate group, and a five-carbon monosaccharide sugar.

النوكليوتيد هو المونومر الذي يكون الحمض النووي، والذي يتكون من قاعدة نيتروجينية ومجموعة فوسفات غير عضوية وسكر أحادي يحتوي على خمس ذرات كربون.

nucleus The extremely small, positively charged, dense center of an atom that contains positively charged protons and neutral neutrons.

النواة هي المركز الكثيف موجب الشحنة ومتناهي الصغر لأي ذرة تحتوي على بروتونات موجبة الشحنة ونيوترونات متعادلة الشحنة.

O

octet rule States that atoms lose, gain, or share electrons in order to acquire the stable electron configuration of a noble gas.

قاعدة الثمانية تنص على أن الذرة تفقد أو تكتسب أو تشارك إلكترونات للوصول إلى الترتيب الإلكتروني المستقر للغاز النبيل.

optical isomers Result from different arrangements of four different groups around the same carbon atom and have the same physical and chemical properties except in chemical reactions where chirality is important.

أيزومرات ضوئية تنشأ عن الترتيب المختلف للأربع مجموعات المتنوعة حول ذرة الكربون ذاتها ولها نفس الخصائص الفيزيائية والكيميائية باستثناء في التفاعلات الكيميائية التي يعد عدم التناظر المرآتي(الكيرالي) خلالها أمرًا ذا أهمية.

optical rotation An effect that occurs when polarized light passes through a solution containing an optical isomer and the plane of polarization is rotated to the right by a d-isomer or to the left by an l-isomer.

التدوير الضوئي تأثير يحدث عند مرور ضوء مستقطب خلال محلول يحتوي على أيزومر ضوئي ويتم تدوير مستوى الاستقطاب إلى اليمين بـ (+)D– أيزومر أو إلى اليسار بـ (–)L– أيزومر.

organic compounds All compounds that contain carbon with the primary exceptions of carbon oxides, carbides, and carbonates, all of which are considered inorganic.

المركبات العضوية هي جميع المركبات التي تحتوي على كربون باستثناء باستثناء أكاسيد الكربون والكربيدات والكربونات حيث تعد مركبات غير عضوية.

osmosis The diffusion of solvent particles across a semipermeable membrane from an area of higher solvent concentration to an area of lower solvent concentration.

الأسموزية انتشار جسيمات الماء أو المذيب من المحلول الأقل تركيز (المذاب) إلى المحلول الأكثر تركيز (المذاب) عبر غشاء منفذ بالنسبة للمذيب.

osmotic pressure The pressure caused when water molecules move into or out of a solution.

الضغط الأسموزي هو الضغط الناتج عن دخول جزيئات الماء إلى المحلول أو خروجها منه.

oxidation The complete or partial loss of electrons from a reacting substance; increases an atom's oxidation number.

الأكسدة عملية فقد إلكترون أو أكثر من مادة بحيث يزداد عدد أكسدتها.

oxidation number The positive or negative charge of a monatomic ion.

عدد التأكسد هو الشحنة الموجبة أو السالبة الموجودة على الأيون أحادي الذرة.

oxidation-number method The technique that can be used to balance more difficult redox reactions, based on the fact that the number of electrons or ions transferred from atoms must equal the number of electrons or ions accepted by other atoms.

طريقة عدد التأكسد طريقة يمكن استخدامها في وزن معادلات الأكسدة والاختزال الأكثر صعوبة استنادًا إلى حقيقة أن عدد الإلكترونات المكتسبةمن الذرات أو الأيونات يجب أن تعادل عدد الإلكترونات المفقودة من الذرات أو الأيونات الأخرى.

oxidation-reduction reaction Any chemical reaction in which electrons are transferred from one substance to another; also called a redox reaction.

تفاعل الأكسدة-الاختزال هو أي تفاعل كيميائي تنتقل خلاله الإلكترونات من مادة إلى أخرى.

oxidizing agent The substance that oxidizes another substance by accepting its electrons.

العامل المؤكسد هو المادة التي تؤكسد مادة أخرى بكسبها إلكترونات تلك المادة..

oxyacid Any acid that contains hydrogen and an oxyanion.

الحمض الأكسجيني هو أي حمض يحتوي على هيدروجين وأيون أكسجيني.

oxyanion **(ahk see AN i ahn)** A polyatomic ion composed of an element, usually a nonmetal, bonded to one or more oxygen atoms.

الأيون الأكسجيني هو أيون متعدد الذرات يتكون من عنصر، يكون لا فلزي غالبًا، يرتبط مع ذرة أو أكثر من ذرات الأكسجين.

P

parent chain The longest continuous chain of carbon atoms in a branched-chain alkane, alkene, or alkyne.

السلسلة الأم هي أطول سلسلة متصلة لذرات الكربون في سلسلة متفرعة من ألكان أو ألكين أو ألكاين.

pascal The SI unit of pressure; one pascal (Pa) is equal to a force of one newton per square meter.

الباسكال وحدة قياس الضغط في نظام SI ؛ و يساوي الضغط الذي تؤثر به قوة مقدارها نيوتن واحد على مساحة مقدارها متر مربع.

Pauli exclusion principle States that a maximum of two electrons can occupy a single atomic orbital but only if the electrons have opposite spins.

مبدأ باولي للاستبعاد ينص على أن الفلك الذري الواحد يتسع إلكترونين كحد أقصى بشرط أن يغزلا بعكس بعضهما.

penetrating power The ability of radiation to pass through matter.

قوة الاختراق مقدرة الأشعة على المرور خلال المادة.

peptide A chain of two or more amino acids linked by peptide bonds.

الببتيدات هي سلسلة من حمضين أو أكثر من الأحماض الأمينية المتصلة برابطة ببتيدية.

peptide bond The amide bond that joins two amino acids.

الرابطة الببتيدية هي رابطة أميدية تربط بين حمضين من الأحماض الأمينية.

percent by mass A percentage determined by the ratio of the mass of each element to the total mass of the compound.

النسبة المئوية لكتلة العنصر في المركب هي نسبة مئوية تتحدد بنسبة كتلة كل عنصر إلى إجمالي كتلة المركب.

percent composition The percent by mass of each element in a compound.

النسبة المئوية للتركيب هو النسبة المئوية بكتلة كل عنصر في المركب.

percent error The ratio of an error to an accepted value.

النسبة المئوية للخطأ هي نسبة الخطأ في أي قيمة مقبولة.

percent yield The ratio of actual yield (from an experiment) to theoretical yield (from stoichiometric calculations) expressed as a percent.

النسبة المئوية للناتج هي النسبة المئوية للناتج الفعلي (من تجربة) بالنسبة للناتج النظري (من حسابات نظرية) الموضحة كنسبة مئوية.

period A horizontal row of elements in the modern periodic table.

الدورة هي صف أفقي من العناصر الموجودة في الجدول الدوري الحديث.

periodic law States that when the elements are arranged by increasing atomic number, there is a periodic repetition of their properties.

القانون الدوري ينص على أنه في حالة ترتيب العناصر تصاعديًا تبعا لعددها الذري، فإنه يوجد تكرار دوري لخواصها.

periodic table A chart that organizes all known elements into a grid of horizontal rows (periods) and vertical columns (groups or families) arranged by increasing atomic number.

الجدول الدوري هو جدول ينظم جميع العناصر المعروفة في شبكة من الصفوف الأفقية (الدورات) والأعمدة الرأسية (مجموعات أو عائلات) يتم ترتيبها تصاعديًا تبعا لعددها الذري.

pH The negative logarithm of the hydrogen ion concentration of a solution; acidic solutions have pH values between 0 and 7, basic solutions have values between 7 and 14, and a solution with a pH of 7.0 is neutral.

الرقم الهيدروجيني سالب لوغاريتم تركيز أيونات الهيدروجين في المحلول؛ فالمحاليل الحمضية تكون pH بين 0 و 7 والمحاليل القاعدية تكون pH بين 7 و 14 والمحلول الذي تكون فيه pH تساوي 7.0 يكون متعادلاً.

phase change A transition of matter from one physical state to another.

تغير الطور تغير المادة من حالة فيزيائية إلى أخرى.

phase diagram A graph of pressure versus temperature that shows which phase a substance exists in under different conditions of temperature and pressure.

مخطط بياني للأطوار رسم بياني للضغط مقابل درجة الحرارة التي توضح الطور الذي توجد به المادة تحت ظروف درجة الحرارة والضغط المختلفة.

phospholipid A triglyceride in which one of the fatty acids is replaced by a polar phosphate group.

الدهن الفوسفوري هو ثلاثي الجليسريد الذي يتم خلاله استبدال أحد الأحماض الدهنية بمجموعة فوسفات قطبية.

photoelectric effect A phenomenon in which photoelectrons are emitted from a metal's surface when light of a certain frequency shines on the surface.

التأثير الكهروضوئي ظاهرة انبعاث إلكترونات من سطح فلز عند سقوط ضوء بتردد معين عليه.

photon A particle of electromagnetic radiation with no mass that carries a quantum of energy.

الفوتون هو جسيم من الأشعة الكهرومغناطيسية عديم الكتلة يحمل كما من الطاقة.

photosynthesis The complex process that converts energy from sunlight to chemical energy in the bonds of carbohydrates.

البناء الضوئي هو عملية معقدة تعمل على تحويل طاقة ضوء الشمس لطاقة كيميائية في روابط الكربوهيدرات.

physical change A type of change that alters the physical properties of a substance but does not change its composition.

التغير الفيزيائي هو نوع من التغيرات يقوم بتغيير الخواص الفيزيائية للمادة ولكنه لا يغير تركيبتها.

physical property A characteristic of matter that can be observed or measured without changing the sample's composition—for example, density, color, taste, hardness, and melting point.

الخاصية الفيزيائية هي صفات المادة التي يمكن ملاحظتها أو قياسها دون تغيير تركيبة العينة—على سبيل المثال، الكثافة واللون والمذاق والصلابة ونقطة الانصهار .

pi bond A bond that is formed when parallel orbitals overlap to share electrons.

رابطة باي هي رابطة يتم تكوينها عند تداخل أفلاك متوازية للتشارك بالإلكترونات.

Planck's constant (*h*) 6.626×10^{-34} J·s, where J is the symbol for the joule.

ثابت بلانك مقدار فيزيائي ثابت يساوي 6.626×10^{-34} J·s. حيث J ترمز للجول.

plastic A polymer that can be heated and molded while relatively soft.

البلاستيك هو بوليمر يمكن تسخينه وتشكيله عند ليونته نسبيًا.

pOH The negative logarithm of the hydroxide ion concentration of a solution; a solution with a pOH above 7.0 is acidic, a solution with a pOH below 7.0 is basic, and a solution with a pOH of 7.0 is neutral.

الرقم الهيدروكسيدي pOH سالب اللوغاريتم للأساس 10 لتركيز أيون الهيدروكسيد في المحلول ؛ فالمحلول الذي فيه pOH أكبر من 7.0 يكون حمضي والمحلول الذي فيه pOH أقل من 7.0 يكون قاعدي والذي فيه pOH تساوي 7.0 هو متعادل.

polar covalent bond A type of bond that forms when electrons are not shared equally.

الروابط التساهمية القطبية رابطة تساهمية تكون فيها قوة جذب الذرات للإلكترونات متفاوتة.

polyatomic ion An ion made up of two or more atoms bonded together that acts as a single unit with a net charge.

الأيون متعدد الذرات هو أيون يتكون من ذرتين أو أكثر يرتبطان معا كوحدة واحدة.

polymerization reaction A reaction in which monomer units are bonded together to form a polymer.

تفاعل البلمرة هو تفاعل ترتبط خلاله وحدات المونومر معا لتكوين البوليمر.

polymers Large molecules formed by combining many repeating structural units (monomers); are synthesized through addition or condensation reactions.

البوليمرات جزيئات كبيرة تتكون من عدد كبير من الوحدات البنائية الصغيرة (مونمرات) التي تترابط خلال تفاعلات الإضافة أو التكاثف.

polysaccharide A complex carbohydrate, which is a polymer of simple sugars that contains 12 or more monomer units.

السكريات المتعددة كربوهيدرات معقدة وهي بوليمر لسكريات بسيطة تحتوي على 12 وحدة أو أكثر من المونومر.

positron A particle that has the same mass as an electron but an opposite charge.

البوزترون هو جسيم له نفس كتلة الإلكترون ولكن بشحنة موجبة.

positron emission A radioactive decay process in which a proton in the nucleus is converted into a neutron and a positron, and then the positron is emitted from the nucleus.

انبعاث البوزيترون هو عملية انحلال إشعاعي يتم تحويل البروتون خلالها إلى نيوترون وبوزِتْرون، وبعد ذلك ينبعث البُوزِتْرون من النواة.

القاموس • Glossary

precipitate A solid produced during a chemical reaction in a solution.
precision Refers to how close a series of measurements are to one another; precise measurements show little variation over a series of trials but might not be accurate.
pressure Force applied per unit area.
primary battery A type of battery that produces electric energy by redox reactions that are not easily reversed, delivers current until the reactants are gone, and then is discarded.
principal energy levels The major energy levels of an atom.
principal quantum number (n) Assigned by the quantum mechanical model to indicate the relative sizes and energies of atomic orbitals.
product A substance formed during a chemical reaction.
protein An organic polymer made up of animo acids linked together by peptide bonds that can function as an enzyme, transport important chemical substances, or provide structure in organisms.
proton A subatomic particle in an atom's nucleus that has a positive charge of 1+.
pure research A type of scientific investigation that seeks to gain knowledge for the sake of knowledge itself.

الراسب هو مادة صلبة تتكون أثناء حدوث تفاعل كيميائي في محلول.
الضبط يشير إلى مدى تقارب سلسلة القياسات مع بعضها و قد تكون القياسات مضبوطة ولكن غير دقيقة.
الضغط هو القوة التي يتم تطبيقها على كل وحدة مساحة.
بطارية غير قابلة لإعادة الشحن نوع من البطاريات التي تنتج طاقة كهربائية بتفاعلات أكسدة واختزال لا يسهل عكسها وتقوم بإنتاج التيارالكهربائي حتى تستهلك المواد المتفاعلة ويتم التخلص منها بعد ذلك.
مستويات الطاقة الرئيسة هي مستويات الطاقة الرئيسة للذرة.
عدد الكم الرئيس (ورمزه *n*) هو عدد يحدده النموذج الميكانيكي الكمي للإشارة إلى الأحجام والطاقات النسبية للأفلاك الذرية.
الناتج هو مادة تتكون أثناء تفاعل كيميائي.
البروتين هو بوليمر عضوي يتكون من أحماض أمينية مرتبطة مع بعضها بواسطة روابط بِبْتيديَّة التي يمكنها العمل كإنزيم، ويقوم بنقل المواد الكيميائية المهمة أو توفير التركيب في الكائنات الحية.
البروتون جسيم دون ذري يوجد في نواة الذرة ويحمل شحنة موجبة 1+.
بحث أساسي البحث هو أحد أنواع الاستقصاء العلمي الذي يهدف إلى اكتساب معرفة بغرض المعرفة ذاتها.

Q

qualitative data Information describing color, odor, shape, or some other physical characteristic.
quantitative data Numerical information describing how much, how little, how big, how tall, or how fast.
quantum The minimum amount of energy that can be gained or lost by an atom.
quantum mechanical model of the atom An atomic model in which electrons are treated as waves; also called the wave mechanical model of the atom.
quantum number The number assigned to each orbit of an electron.

البيانات النوعية هي معلومات تصف اللون أو الترتيب أو الشكل أو بعض الخصائص الفيزيائية الأخرى.
البيانات الكمية هي معلومات رقمية تصف مدى الكثرة أو القلة أو الضخامة أو الطول أو السرعة.
الكم الحد الأدنى من كمية الطاقة التي يمكن تكتسبها الذرة أو تفقدها.
النموذج الميكانيكي الكمي للذرة هو نموذج ذري تتم معاملة الإلكترونات خلاله كموجات؛ ويسمى أيضا بالنموذج الميكانيكي الموجي للذرة.
عدد الكم هو العدد المحدد لكل فلك لأي الإلكترون.

R

radiation The rays and particles—alpha and beta particles and gamma rays—that are emitted by radioactive materials.
radioactive decay A spontaneous process in which unstable nuclei lose energy by emitting radiation.
radioactive decay series A series of nuclear reactions that starts with an unstable nucleus and results in the formation of a stable nucleus.
radioactivity The process in which some substances spontaneously emit radiation.
radiochemical dating The process that is used to determine the age of an object by measuring the amount of a certain radioisotope remaining in that object.

إشعاع نووي هو الأشعة والجسيمات —ألفا وبيتا وأشعة جاما—التي تنبعث من خلال المواد المشعة.
انحلال إشعاعي هو عملية تلقائية تفقد النويات غير المستقرة خلالها الطاقة بانبعاث جسيمات أو أشعة كهرومغناطيسية أو كليهما.
سلسلة انحلال إشعاعي هي سلسلة تفاعلات نووية تبدأ بنواة غير مستقرة وينتج عنها تكوين نواة مستقرة.
النشاط الإشعاعي هو عملية ينبعث فيها الأشعة تلقائيًا من بعض المواد.
التأريخ بالإشعاع طريقة يحدد فيها العمر التقريبي لجسم ما، بالاعتماد على كمية النويدات المشعة الموجودة فيه.

radioisotopes Isotopes of atoms that have unstable nuclei and emit radiation to attain more stable atomic configurations.

النظائر المشعة نظائر للذرات تكون بها النواة غير مستقرة وتصدر أشعة لتصبح مستقرة.

radiotracer An isotope that emits non-ionizing radiation and is used to signal the presence of an element or specific substance; can be used to analyze complex chemical reactions mechanisms and to diagnose disease.

المتتبع المُشع هو نظير يصدر إشعاع غير مؤين. ويستخدم للدلالة على وجود عنصر أو مادة محددة. ويمكن استخدامه لتحليل آليات تفاعلات كيميائية معقدة ولتشخيص المرض.

rate-determining step The slowest elementary step in a complex reaction; limits the instantaneous rate of the overall reaction.

الخطوة المحددة للسرعة هي الخطوة التي لها السرعة الأبطأ في تفاعل متعدد الخطوات ، والتي تحدد سرعة التفاعل الكلي.

rate law The mathematical relationship between the rate of a chemical reaction at a given temperature and the concentrations of reactants.

قانون سرعة التفاعل هو العلاقة الرياضية بين معدل التفاعل الكيميائي في درجة حرارة محددة وتراكيز المواد المتفاعلة.

reactant The starting substance in a chemical reaction.

المادة المتفاعلة هي مادة التي يبدأ بها التفاعل الكيميائي.

reaction mechanism The complete sequence of elementary steps that make up a complex reaction.

آلية التفاعل هي الطريقة التي يحدث فيها تفاعل كيميائي ويعبر عنها بسلسلة من الخطوات أو المعادلات الكيميائية.

reaction order For a reactant, describes how the rate is affected by the concentration of that reactant.

رتبة التفاعل بالنسبة للمادة المتفاعلة، هي درجة تصف مدى تأثير تركيز هذه المادة على سرعة التفاعل.

reaction rate The change in concentration of a reactant or product per unit time, generally calculated and expressed in moles per liter per second.

سرعة التفاعل هو التغير في تركيز المادة المتفاعلة أو الناتجة في وحدة الزمن، وغالبًا يعبر عنها بالمول لكل لتر في الثانية.

redox reaction An oxidation-reduction reaction.

reducing agent The substance that reduces another substance by losing electrons.

العامل المختزل هو المادة التي تختزل مادة أخرى عن طريق فقد الإلكترونات.

reduction The complete or partial gain of electrons by a reacting substance; decreases an atom's oxidation number.

الاختزال العملية التي يتم فيها كسب إلكترونات ويقل عدد التأكسد.

reduction potential The tendency of a substance to gain electrons.

جهد الاختزال هو ميل المادة إلى اكتساب الإلكترونات.

representative elements Elements from grou, 2, and 13–18 in the modern periodic table, possessing a wide range of chemical and physical properties.

العناصر الرئيسة هي عناصر المجموعات 1 و 2 ومن 13–18 الموجودة في الجدول الدوري الحديث، تتميز بنطاق واسع من الخصائص الكيميائية والفيزيائية.

resonance Condition that occurs when more than one valid Lewis structure exists for the same molecule.

الرنين حالة تحدث عند وجود أكثر من بنية صحيحة من بنى لويس للجزيء نفسه.

reversible reaction A reaction that can take place in both the forward and reverse directions; leads to an equilibrium state where the forward and reverse reactions occur at equal rates and the concentrations of reactants and products remain constant.

التفاعل الانعكاسي هو تفاعل يمكن أن يحدث في اتجاهات أمامية وعكسية، ويؤدي إلى حالة اتزان حيث تحدث التفاعلات الأمامية والعكسية بمعدلات متساوية وتظل تراكيز المواد المتفاعلة والناتجة ثابتة.

S

salt An ionic compound made up of a cation from a base and an anion from an acid.

المِلح هو مركب أيوني يتكون من أيون موجب من القاعدة وأيون سالب من الحمض.

salt bridge A pathway constructed to maintain solution neutrality by allowing positive and negative ions to move from one solution to another.

القنطرة الملحية أنبوب زجاجي على شكل حرف U يحتوي على محلول مادة إلكتروليتية قوية، تعمل على المحافظة على التوازن الأيوني للمحلول بالسماح للأيونات الموجبة والسالبة بالانتقال من محلول إلى آخر.

salt hydrolysis The process in which anions of the dissociated salt accept hydrogen ions from water, or the cations of the dissociated salt donate hydrogen ions to water.

التميؤ هو عملية تستقبل خلالها أيونات الملح المتفككة أيونات الهيدروجين من الماء، أو تمنح خلالها أيونات الملح المتفككة الموجبة أيونات الهيدروجين للماء.

القاموس • Glossary

saponification (**suh pahn ih fih KAY shuhn**) The hydrolysis of the ester bonds of a triglyceride using an aqueous solution of a strong base to form carboxylate salts and glycerol.

التصبن تحلل مائي لروابط الإستر في ثلاثي الجليسريد في محلول قلوي لتكوين ملح الحمض الدهني والجليسرول.

saturated hydrocarbon A hydrocarbon that contains only single bonds.

الهيدروكربون المشبع هو هيدروكربون يحتوي على روابط أحادية فقط.

saturated solution Contains the maximum amount of dissolved solute for a given amount of solvent at a specific temperature and pressure.

المحلول المُشبع يحتوي على أعلى كمية ذائبة من المذاب في كمية محددة من المذيب عند درجة حرارة وضغط محددين.

scientific law Describes a relationship in nature that is supported by many experiments.

القانون العلمي هو قانون يصف العلاقة الموجودة في الطبيعة مدعومة بالعديد من التجارب.

scientific methods A systematic approach used in scientific study; an organized process used by scientists to do research and to verify the work of others.

المنهجية العلمية هي طريقة منهجية تستخدم في الدراسة العلمية؛ وهي عملية منظمة يستخدمها العلماء لإجراء الأبحاث والتحقق من عمل الآخرين.

scientific notation Expresses any number as a number between 1 and 10 (known as a coefficient) multiplied by 10 raised to a power (known as an exponent).

الترميز العلمي يعبر عن أي رقم ما بين 1 إلى 10(يعرف بالمعامل) مضروبًا في 10 ومرفوعاً إلى قوة (معروفة بالأس).

second The SI base unit for time.

الثانية وحدة الزمن في نظام الوحدات الدولي SI.

second law of thermodynamics The spontaneous processes always proceed in such a way that the entropy of the universe increases.

قانون الديناميكا الحراري الثاني تستمر العمليات التلقائية دائما في الحالة التي تزداد بها الانتروبي في الكون.

secondary battery A rechargeable battery that depends on reversible redox reactions.

بطارية قابلة لإعادة الشحن بطارية يمكن إعادة شحنها وتعتمد على تفاعلات أكسدة واختزال انعكاسية.

sigma bond A single covalent bond that is formed when an electron pair is shared by the direct overlap of bonding orbitals.

رابطة سيخما هي رابطة تساهمية أحادية تتكون عند مشاركة زوج من الإلكترونات عن طريق تداخل مباشر بين الأفلاك المترابطة.

significant figures The number of all known digits reported in measurements plus one estimated digit.

الأرقام المعنوية هي عدد جميع الأرقام المعروفة التي تشير إليها أدوات القياس بالإضافة إلى رقم مقدر واحد.

single-replacement reaction A chemical reaction that occurs when the atoms of one element replace the atoms of another element in a compound.

تفاعل استبدال أحادي هو تفاعل كيميائي يحدث عند استبدال ذرات أحد العناصر بذرات عنصر آخر في المركب.

solid A form of matter that has its own definite shape and volume, is incompressible, and expands only slightly when heated.

الجسم الصلب حالة المادة التي يكون شكلها وحجمها محددين وغير قابل للانضغاط وتتمدد قليلاً عند تسخينها فقط.

solubility The maximum amount of solute that will dissolve in a given amount of solvent at a specific temperature and pressure.

الذائبية الحد الأقصى لكمية من المذاب التي ستذوب عند وضعها في كمية محددة من المُذيب بدرجة حرارة وضغط محددين.

solubility product constant K_{sp}, which is an equilibrium constant for the dissolving of a sparingly soluble ionic compound in water.

ثابت حاصل الإذابة K_{sp}، حاصل ضرب التراكيز المولارية لأيونات مادة معينة في محلول مشبع .

soluble Describes a substance that can be dissolved in a given solvent.

قابل للذوبان هي خاصية تصف المادة التي يمكن إذابتها في مذيب محدد.

solute One or more substances dissolved in a solution.

المُذاب هو مادة واحدة أو أكثر مذابة في محلول.

solution A uniform mixture that can contain solids, liquids, or gases; also called a homogeneous mixture.

المحلول هو خليط متماثل يمكن أن يحتوي على مواد صلبة أو سائلة أو غازية ويسمى أيضا بالخليط المتجانس.

solvation The process of surrounding solute particles with solvent particles to form a solution; occurs only where and when the solute and solvent particles come in contact with each other.

الإذابة هي عملية إحاطة جزيئات المُذاب بجزيئات المُذيب لتكوين محلول؛ ولا تحدث إلا حينما تتلامس جزيئات المُذاب والمُذيب مع بعضها البعض.

solvent The substance that dissolves a solute to form a solution; the most plentiful substance in the solution.

المُذيب هو المادة التي تعمل على إذابة المُذاب لتكوين محلول، وهو المادة الأكثر وفرة في المحلول.

species Any kind of chemical unit involved in a process.

الأنواع هو أي نوع من أنواع الوحدات الكيميائية المشتركة في العملية.

specific heat The amount of heat required to raise the temperature of one gram of a given substance by one degree Celsius.

specific rate constant A numerical value that relates reaction rate and concentration of reactant at a specific temperature.

spectator ion Ion that does not participate in a reaction.

spontaneous process A physical or chemical change that occurs without outside intervention and may require energy to be supplied to begin the process.

standard enthalpy (heat) of formation The change in enthalpy that accompanies the formation of one mole of a compound in its standard state from its constituent elements in their standard states.

standard hydrogen electrode The standard electrode against which the reduction potential of all electrodes can be measured.

states of matter The physical forms in which all matter naturally exists on Earth—most commonly as a solid, a liquid, or a gas.

stereoisomers A class of isomers whose atoms are bonded in the same order but are arranged differently in space.

steroids Lipids that have multiple cyclic rings in their structures.

stoichiometry The study of quantitative relationships between the amounts of reactants used and products formed by a chemical reaction; is based on the law of conservation of mass.

strong acid An acid that ionizes completely in aqueous solution.

strong base A base that dissociates entirely into metal ions and hydroxide ions in aqueous solution.

strong nuclear force A force that acts on subatomic particles that are extremely close together.

structural formula A molecular model that uses symbols and bonds to show relative positions of atoms; can be predicted for many molecules by drawing the Lewis structure.

structural isomers A class of isomers whose atoms are bonded in different orders with the result that they have different chemical and physical properties despite having the same formula.

sublimation The energy-requiring process by which a solid changes directly to a gas without first becoming a liquid.

substance Matter that has a definite composition; also known as a chemical.

substituent groups The side branches that extend from the parent chain; they appear to substitute for a hydrogen atom in the straight chain.

substitution reaction A reaction of organic compounds in which one atom or group of atoms in a molecule is replaced by another atom or group of atoms.

الحرارة النوعية هي كمية الحرارة اللازمة لرفع درجة حرارة واحد جرام من مادة محددة درجة سيليزية واحدة.

ثابت السرعة النوعية ثابت تناسب يربط بين سرعة التفاعل وتركيز المواد المتفاعلة عند درجة حرارة محددة.

الأيون المُتفرج هو الأيون الذي لا يشارك في التفاعل.

العملية التلقائية هي تغير كيميائي أو فيزيائي يحدث دون تدخل خارجي وقد يستلزم توفير طاقة لبدء العملية.

حرارة التكوين القياسية هو التغير في المحتوى الحراري الذي يصاحب تكوين مول واحد من المركب في حالته القياسية من العناصر المكونة له في حالاتها القياسية.

قطب الهيدروجين القياسي هو القطب القياسي الذي يمكن قياس الجهد الاختزالي لجميع الأقطاب مقارنة به.

حالات المادة هي الأشكال التي تكون عليها جميع المواد الموجودة على الأرض—وأكثرها شيوعاً الحالة الصلبة والسائلة والغازية.

أيزومرات فراغية أيزومرات يتشابه فيها ترتيب الروابط بين الذرات ويختلف فيها ترتيب الذرات في الفضاء.

الستيرويد هي الدهون التي تحتوي على حلقات متعددة في تركيباتها.

الحسابات الكيميائية المعتمدة على التفاعل هي دراسة العلاقات الكمية بين كميات المواد المتفاعلة المستخدمة والمواد الناتجة التي كوّنها تفاعل كيميائي، وهي تعتمد على قانون حفظ الكتلة.

الحمض القوي هو حمض يتأين بشكل كامل في المحلول المائي.

القاعدة القوية قاعدة تتأين بشكل تام إلى أيونات الفلز والهيدروكسيد في المحلول المائي.

القوة النووية الشديدة هي قوة تؤثر على الجسيمات دون الذرية القريبة جدًا من بعضها البعض.

الصيغة البنائية هي نموذج جزيئي يستخدم رموز وروابط لعرض الأوضاع نموذج جزيئي يستخدم الرموز و الروابط ليوضح المواقع النسبية للذرات ، ويمكن توقعها للعديد من الجزيئات برسم بنى لويس.

الأيزومرات البنائية هي مجموعة من الأيزومرات التي ترتبط ذراتها بترتيبات مختلفة مما ينتج عنه اختلاف خصائصها الكيميائية والفيزيائية رغم اشتراكها في نفس الصيغة.

التسامي هو عملية تحتاج إلى طاقة تتحول خلالها المادة من الحالة الصلبة إلى الحالة الغازية دون دون المرور في الحالة السائلة.

مادة كيميائية هي مادة لها تركيب محدد.

مجموعات الاستبدال هي التفرعات الجانبية التي تمتد من السلسلة الأصلية، وتَظهر لاستبدال ذرة هيدروجين في السلسلة المتتالية.

تفاعل الاستبدال هو تفاعل عضوي يتم خلاله استبدال ذرة واحدة أو مجموعة من الذرات في جزيء بذرة أخرى أو مجموعة أخرى من الذرات.

substrate A reactant in an enzyme-catalyzed reaction that binds to specific sites on enzyme molecules.

الركيزة هي مادة متفاعلة خلال تفاعل محفز الإنزيم، وهي ترتبط بمواقع محددة في جزيئات الإنزيم.

supersaturated solution Contains more dissolved solute than a saturated solution at the same temperature.

محلول فوق المشبع يحتوي على كمية من المذاب أكبر من المحلول المشبع عند درجة الحرارة نفسها.

surface tension The energy required to increase the surface area of a liquid by a given amount; results from an uneven distribution of attractive forces.

التوتر السطحي هو الطاقة اللازمة لزيادة مساحة سطح المادة السائلة بكمية محددة، وهو ينشأ عن التوزيع غير المتساوي لقوى الجذب.

surfactant A compound, such as soap, that lowers the surface tension of water by disrupting hydrogen bonds between water molecules; also called a surface active agent.

خافض التوتر السطحي هو مركب، مثل الصابون، يعمل على خفض التوتر السطحي للماء بإحداث خلل في الروابط الهيدروجينية بين جزيئات الماء، ويسمى أيضا بالعامل السطحي الفعال.

surroundings In thermochemistry, includes everything in the universe except the system.

الأشياء المحيطة في الكيمياء الحرارية، تتضمن جميع الموجودات في الكون باستثناء النظام.

suspension A type of heterogeneous mixture whose particles settle out over time and can be separated from the mixture by filtration.

المُعلّق هو نوع من الخليط غير المتجانس تستقر جزيئاته مع مرور الوقت ويمكن فصله عن الخليط بالترشيح.

synthesis reaction A chemical reaction in which two or more substances react to yield a single product.

تفاعل التركيب "الاتحاد" هو تفاعل كيميائي يتفاعل خلاله مادتان أو أكثر للحصول على ناتج واحد.

system In thermochemistry, the specific part of the universe containing the reaction or process being studied.

النظام في الكيمياء الحرارية، هو جزء محدد من الكون يتضمن تفاعلاً أو عملية قيد الدراسة.

T

technology The practical use of scientific information.

التكنولوجيا هي الاستخدام العملي للمعلومات العلمية.

temperature A measure of the average kinetic energy of the particles in a sample of matter.

درجة الحرارة هي مقياس متوسط الطاقة الحركية للجزيئات في عينة من المادة.

theoretical yield In a chemical reaction, the maximum amount of product that can be produced from a given amount of reactant.

الناتج النظري في التفاعل الكيميائي هو الحد الأقصى لكمية الناتج التي يمكن إنتاجها من كمية محددة من المادة المتفاعلة.

theory An explanation supported by many experiments; is still subject to new experimental data, can be modified, and is considered valid if it can be used to make predictions that are proven true.

النظرية هي تفسير مدعم بالعديد من التجارب، ولا تزال خاضعة لبيانات تجريبية جديدة، ويمكن تعديلها، وتعد صحيحة إذا أمكن استخدامها لبناء استنتاجات ثبتت صحتها.

thermochemical equation A balanced chemical equation that includes the physical states of all the reactants and the energy change, usually expressed as the change in enthalpy.

المعادلة الكيميائية الحرارية معادلة كيميائية موزونة تتضمن الحالات الفيزيائية لجميع المواد المتفاعلة والناتجة وتغير الطاقة وعادةً ما يعبر عنها بالتغير في المحتوى الحراري.

thermochemistry The study of heat changes that accompany chemical reactions and phase changes.

الكيمياء الحرارية هي دراسة التغيرات الحرارية التي تصاحب التفاعلات الكيميائية وتغيرات الحالة الفيزيائية.

thermonuclear reaction A nuclear fusion reaction.

التفاعل النووي الحراري هو تفاعل اندماج نووي.

thermoplastic A type of polymer that can be melted and molded repeatedly into shapes that are retained when it is cooled.

بوليمر غير ثابت حـــراريًا هو أحد أنواع البوليمرات الذي يمكن صهره وتشكيله مرارًا وتكرارًا بأشكال يمكن الاحتفاظ بها عند تبريدها.

thermosetting A type of polymer that can be molded when it is first prepared but when cool cannot be remelted.

بوليمر ثابت حراريًا هي أحد أنواع البوليمرات التي يمكن تشكيلها عند إعدادها للمرة الأولى ولكن لا يمكن إعادة تشكيلها بعد التبريد.

titrant A solution of known concentration used to titrate a solution of unknown concentration; also called the standard solution.

المحلول المعاير هو محلول بتركيز معروف يستخدم في معايرة محلول بتركيز غير معروف ويسمى أيضا بالمحلول القياسي.

titration The process in which an acid-base neutralization reaction is used to determine the concentration of a solution of unknown concentration.

المعايرة عملية يستخدم خلالها تفاعل تعادل حمض- قاعدة لتحديد تركيز غير معروف لمحلول.

transition elements Elements in grou–12 of the modern periodic table and are further divided into transition metals and inner transition metals.
transition metal An element in grou–12 that is contained in the d-block of the periodic table and, with some exceptions, is characterized by a filled outermost s orbital of energy level n, and filled or partially filled d orbitals of energy level $n - 1$.
transition state Term used to describe an activated complex because the activated complex is as likely to form reactants as it is to form products.
transmutation The conversion of an atom of one element to an atom of another element.
transuranium element An element with an atomic number of 93 or greater in the periodic table.
triglyceride Forms when three fatty acids are bonded to a glycerol backbone through ester bonds; can be either solid or liquid at room temperature.
triple point The point on a phase diagram representing the temperature and pressure at which the three phases of a substance (solid, liquid, and gas) can coexist.
Tyndall effect **(TIHN duhl • ee FEKT)** The scattering of light by colloidal particles.

العناصر الانتقالية هي عناصر توجد في المجموعات من 3–12 في الجدول الدوري الحديث وتنقسم فلزات انتقالية وفلزات انتقالية داخلية.
الفلز الانتقالي عنصر موجود في المجموعات من 3 – 12 في المجمع d- في الجدول الدوري الحديث، يوجد بعض الاستثناءات، يتميز بامتلاء الفلك s في مستوى الطاقة n ويكون الفلك d ممتلئ أو شبه الممتلئ في مستوى الطاقة n-1.
الحالة الانتقالية هي مصطلح يصف معقدًا نشطا لأن هذا المعقد النشط قد يعمل على تكوين المواد المتفاعلة وكذلك النواتج.
تحول نووي هو تحويل ذرة أحد العناصر إلى ذرة عنصر آخر ينتج عن تغير في عدد بروتوناتها.
عنصر ما بعد اليورانيوم هو عنصر بعدد ذري يبلغ 93 أو أكبر في الجدول الدوري.
ثلاثي الجليسريد يتكون عند اتحاد ثلاثة أحماض دهنية مع الجليسرول ويوجد إما في الحالة الصلبة أو السائلة بدرجة حرارة الغرفة.
النقطة الثلاثية نقطة توجد في المخطط البياني للأطوار حيث تمثل درجة الحرارة والضغط التي يمكن أن توجد بها الحالات الثلاث (الصلبة والسائلة والغازية).
ظاهرة تندال تشتيت الضوء بواسطة الجسيمات الغروية.

U

unit cell The smallest arrangement of atoms in a crystal lattice that has the same symmetry as the whole crystal; a small representative part of a larger whole.
universe In thermochemistry, is the system plus the surroundings.
unsaturated hydrocarbon A hydrocarbon that contains at least one double or triple bond between carbon atoms.
unsaturated solution Contains less dissolved solute for a given temperature and pressure than a saturated solution; has further capacity to hold more solute.

وحدة الخلية هي أصغر ترتيب للذرات في شبكة بلورية تتمتع بتناظر الوحدة البلورية الكاملة ذاته. وهي جزء تمثيلي صغير لوحدة أكبر.
الكون في الكيمياء الحرارية هو النظام بالإضافة إلى الأشياء المحيطة.
الهيدروكربون غير المشبع هو هيدروكربون يحتوي على رابطة واحدة ثنائية أو ثلاثية على الأقل بين ذرات الكربون.
المحلول غير المشبع يحتوي على نسبة مذاب ذائب عند درجة حرارة وضغط محددين أقل من المحلول المشبع، ويتمتع بسعة إضافية للاحتفاظ بمزيد من المذاب.

V

valence electrons The electrons in an atom's outermost orbitals; determine the chemical properties of an element.
vapor Gaseous state of a substance that is a liquid or a solid at room temperature.
vaporization The energy-requiring process by which a liquid changes to a gas or vapor.
vapor pressure The pressure exerted by a vapor over a liquid.
vapor pressure lowering The lowering of vapor pressure of a solvent by the addition of a nonvolatile solute to the solvent.
viscosity A measure of the resistance of a liquid to flow, which is affected by the size and shape of particles, and generally increases as the temperature decreases and as intermolecular forces increase.

إلكترونات التكافؤ إلكترونات تقع في مستوى الطاقة الخارجي للذرة، وتحدد الخصائص الكيميائية للعنصر.
البخار هو الحالة الغازية لمادة سائلة أو صلبة عند درجة حرارة الغرفة.
التبخير هو عملية تتطلب وجود طاقة يتحول من خلالها السائل إلى غاز أو بخار.
ضغط البخار هو الضغط الذي ينشأ عن بخار فوق سطح سائل.
انخفاض ضغط البخار انخفاض ضغط البخار لمذيب ما عند إضافة مذاب غير متطاير له.
اللزوجة هي مقياس لمقاومة سائل ما للإنسياب، وهي تتأثر بحجم الجسيمات وشكلها، وتتزايد بصفة عامة مع انخفاض درجة الحرارة ومع زيادة القوى بين الجزيئات.

voltaic cell A type of electrochemical cell that converts chemical energy into electrical energy by a spontaneous redox reaction.

الخلية الفولتية نوع من الخلايا الكهروكيميائية تقوم بتحويل الطاقة الكيميائية إلى طاقة كهربائية عن طريق تفاعل أكسدة-اختزال تلقائي.

VSEPR model Valence Shell Electron Pair Repulsion model, which is based on an arrangement that minimizes the repulsion of shared and unshared pairs of electrons around the central atom.

نظرية تنافر أزواج إلكترونات التكافؤ تعتمد على ترتيب يقلل تنافر أزواج الإلكترونات المشاركة وغير المشاركة حول الذرة المركزية.

W

wavelength The shortest distance between equivalent points on a continuous wave; is usually expressed in meters, centimeters, or nanometers.

طول الموجة هو أقصر مسافة بين نقاط متكافئة في موجة مستمرة ويقاس عادةً بالمترات أو السنتيمترات أو النانومترات.

wax A type of lipid that is formed by combining a fatty acid with a long-chain alcohol; is made by both plants and animals.

الشمع نوع من الدهون التي تتكون عن طريق اتحاد حمض دهني مع كحول مكون من سلسلة طويلة وتنتجه النباتات والحيوانات.

weak acid An acid that ionizes only partially in dilute aqueous solution.

الحمض الضعيف هو حمض يتأين جزئيًا فقط في المحلول المائي.

weak base A base that ionizes only partially in dilute aqueous solution to form the conjugate acid of the base and hydroxide ion.

القاعدة الضعيفة هي قاعدة تتأين جزئيًا فقط في محلول مائي مخفف لتكوين حمض مرافق للقاعدة وأيون الهيدروكسيد.

weight A measure of an amount of matter and also the effect of Earth's gravitational pull on that matter.

الوزن قياس لقوة الجاذبية الأرضية المطبقة على المادة المكونة لجسم ما.

X

X-ray A form of high-energy, penetrating electromagnetic radiation emitted from some materials that are in an excited electron state.

اشعة أكس أحد أشكال الأشعة الكهرومغناطيسية عالية الطاقة والقادرة على النفاذ وتنبعث من ذرات المواد المستثارة.

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