

# How Are Playing Cards & the Periodic Table Connected?





By 1860, scientists knew of about 60 elements. However, they had yet to clearly organize their knowledge. A Russian scientist named Dmitri Mendeleev changed that. Mendeleev loved to play solitaire, a type of card game in which playing cards are arranged into patterns according to their properties. One day, Mendeleev decided to make a set of cards on which he wrote the names and properties of the known elements. Then he began to arrange the cards into rows. The result was a table in which certain chemical properties could be seen to occur periodically—that is, to occur in a repeating pattern. In 1869, Mendeleev published his periodic table (seen here in a more advanced version). He left blank spaces in the table where the pattern seemed to call for elements that were not yet known. Over the next several decades, other scientists refined the table, and new elements were added. Modern periodic tables—like the one probably hanging in your classroom—still follow the basic pattern laid out by Mendeleev.

## unit projects

Visit [gpscience.com/unit\\_project](https://gpscience.com/unit_project) to find project ideas and resources.

Projects include:

- **History** Discover the diverse uses of lasers. Compile a class spider map of laser use in different professions.
- **Technology** Research elements and create a 3-dimensional periodic table with characteristics of each element on element cubes.
- **Model** Design and construct a unit review game to include questions, answers, directions, playing pieces, and a creative box.



**Art of Neon** is an investigation of the noble gases and how they are inserted into glass tubes to be used in art and signage.

**BIG Idea**

Matter can be classified by what it is made of, by its physical properties, and by its chemical properties.

**15.1 Composition of Matter****MAIN Idea**

Matter can be either a pure substance (an element or a compound) or a mixture (either heterogeneous or homogeneous).

**15.2 Properties of Matter****MAIN Idea**

A physical property can be observed without changing the identity of the material. A chemical property describes whether it can undergo a chemical change.

**The Art of Mixtures**

When painting, colors can be skillfully mixed to achieve a certain shade, or the artist can show several individual pigments in a single brush stroke. Paint undergoes physical and chemical changes with time that can make the artist's work endure.

**Science Journal**

Describe the changes that take place as the paint dries, particularly which changes are physical and which are chemical.

# Classification of Matter



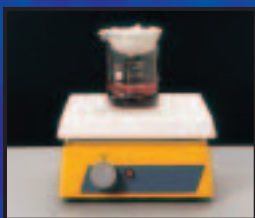


# Start-Up Activities



## Demonstrate the Distillation of Water

Matter is classified according to the different properties that it exhibits. These differences in properties allow drinking water to be obtained from seawater. These properties could be very important to you if you were stranded on a desert island and needed drinking water. Purified water can be obtained through a process called distillation.

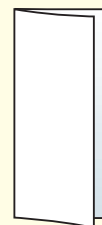


1. Place 75 mL of water in a 200-mL beaker and add 20 drops of red food coloring.
2. Place the beaker on a hot plate.
3. Add ice to an evaporating dish until the dish is half full. Add boiling chips. Place the evaporating dish on the beaker as shown in the photo.
4. Turn on the hot plate and slowly bring the water and food coloring solution to a boil.
5. After boiling the solution for five minutes, carefully remove the evaporating dish using heat-resistant gloves. Touch the drops of liquid on the bottom of the dish to a piece of white paper.
6. Observe the liquid on the paper.
7. **Think Critically** In your Science Journal, write a paragraph explaining where the liquid came from. What was in the beaker that is not in the liquid on the paper?

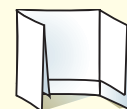
## FOLDABLES™ Study Organizer

**Classification of Matter** Make the following Foldable to ensure that you have understood the content by defining the vocabulary terms from this chapter.

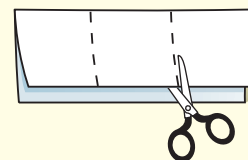
- STEP 1** **Fold** a vertical sheet of paper from side to side. Make the front edge about 1.25 cm shorter than the back edge.



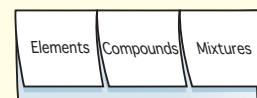
- STEP 2** **Turn** lengthwise, with the fold on top, and **fold** into thirds.



- STEP 3** **Unfold and cut** only the top layer along both folds to make three tabs.



- STEP 4** **Label** the tabs *Elements*, *Compounds*, and *Mixtures* as shown.



**Define** As you read the chapter, define each term and list examples of each under the appropriate tab.



Preview this chapter's content and activities at [gpscience.com](http://gpscience.com)

# Composition of Matter

## Reading Guide

### What You'll Learn

- **Define** substances and mixtures.
- **Identify** elements and compounds.
- **Compare and contrast** solutions, colloids, and suspensions.

### Why It's Important

You can form a better picture of your world when you understand the concepts of elements and compounds.

### Review Vocabulary

**property:** characteristic or essential quality

### New Vocabulary

- substance
- element
- compound
- heterogeneous mixture
- homogeneous mixture
- solution
- colloid
- Tyndall effect
- suspension

**Figure 1** All the atoms of an element are alike.



## Pure Substances

Have you ever seen a picture hanging on a wall that looked just like a real painting? Did you have to touch it to find out? If so, the rough or smooth surface told you which it was. Each material has its own properties. The properties of materials can be used to classify them into general categories.

Materials are made of a pure substance or a mixture of substances. A pure **substance**, or simply a substance, is a type of matter with a fixed composition. A substance can be either an element or a compound. Some substances you might recognize are helium, aluminum, water, and salt.

**Elements** All substances are built from atoms. If all the atoms in a substance have the same identity, that substance is an **element**. The graphite in your pencil point and the copper coating of most pennies are examples of elements. In graphite all the atoms are carbon atoms, and in a copper sample, all the atoms are copper atoms. The metal substance beneath the copper in the penny is another element—zinc. About 90 elements are found on Earth. More than 20 others have been made in laboratories, but most of these are unstable and exist only for short periods of time. Some elements you might recognize are shown in **Figure 1**. Some less common elements and their properties are shown in **Figure 2**.

**Figure 2**

**M**ost of us think of gold as a shiny yellow metal used to make jewelry. However, it is an element that is also used in more unexpected ways, such as in spacecraft parts. On the other hand, some less common elements, such as americium (am uh REE see um), are used in everyday objects. Some elements and their uses are shown here.



▲ **TITANIUM** (tie TAY nee um) Parts of the exterior of the Guggenheim Museum in Bilbao, Spain, are made of titanium panels. Strong and lightweight, titanium is also used for body implants.



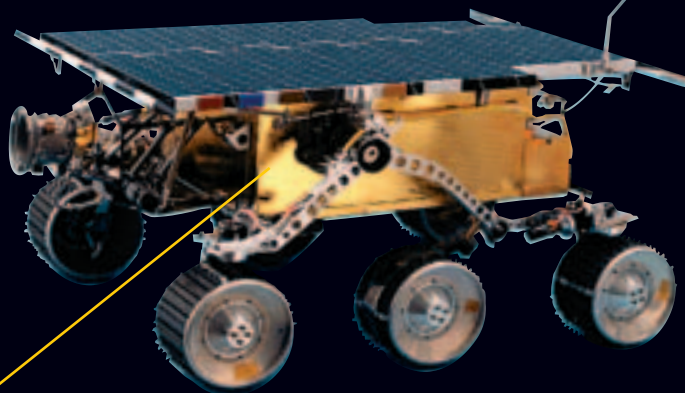
▲ **LEAD** Because lead has a high density, it is a good barrier to radiation. Dentists drape lead aprons on patients before taking X rays of the patient's teeth to reduce radiation exposure.



▲ **ALUMINUM** Aluminum is an excellent reflector of heat. Here, an aluminum plastic laminate is used to retain the body heat of a newborn baby.



▲ **TUNGSTEN** Although tungsten can be combined with steel to form a very durable metal, in its pure form it is soft enough to be stretched to form the filament of a lightbulb. Tungsten has the highest melting point of any metal.

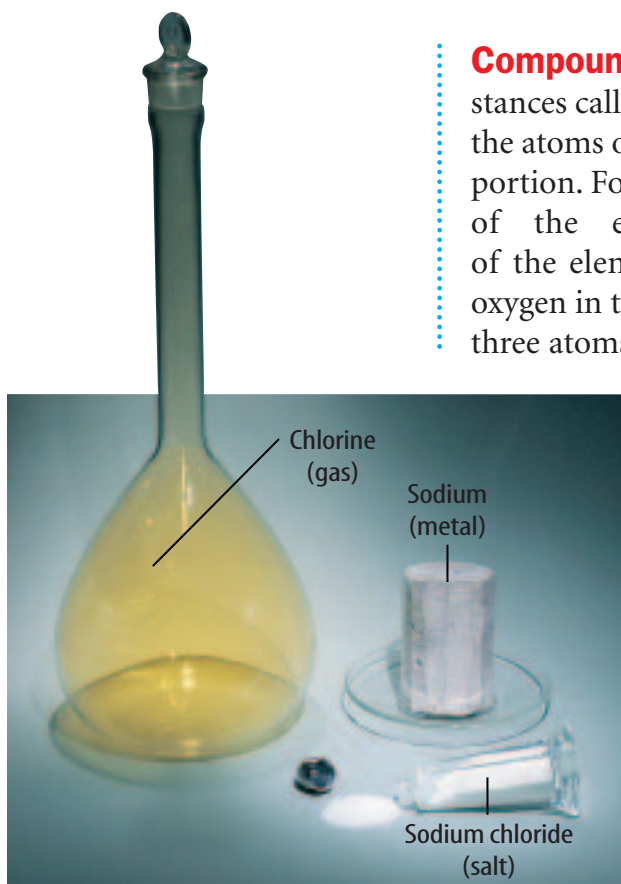


▲ **GOLD** Gold's resistance to corrosion and its ability to reflect infrared radiation make it an excellent coating for space vehicles. The electronic box on the six-wheel Sojourner Rover, above, part of NASA's Pathfinder 1997 mission to Mars, is coated with gold.



◀ **AMERICIUM** Named after America, where it was first produced, americium is a component of this smoke detector. It is a radioactive metal that must be handled with care to avoid contact.





**Figure 3** Chlorine gas and sodium metal combine dramatically in the ratio of one to one to form sodium chloride.

**Compounds** Two or more elements can combine to form substances called compounds. A **compound** is a substance in which the atoms of two or more elements are combined in a fixed proportion. For example, water is a compound in which two atoms of the element hydrogen combine with one atom of the element oxygen. Chalk contains calcium, carbon, and oxygen in the proportion of one atom of calcium and carbon to three atoms of oxygen.

### ✓ Reading Check

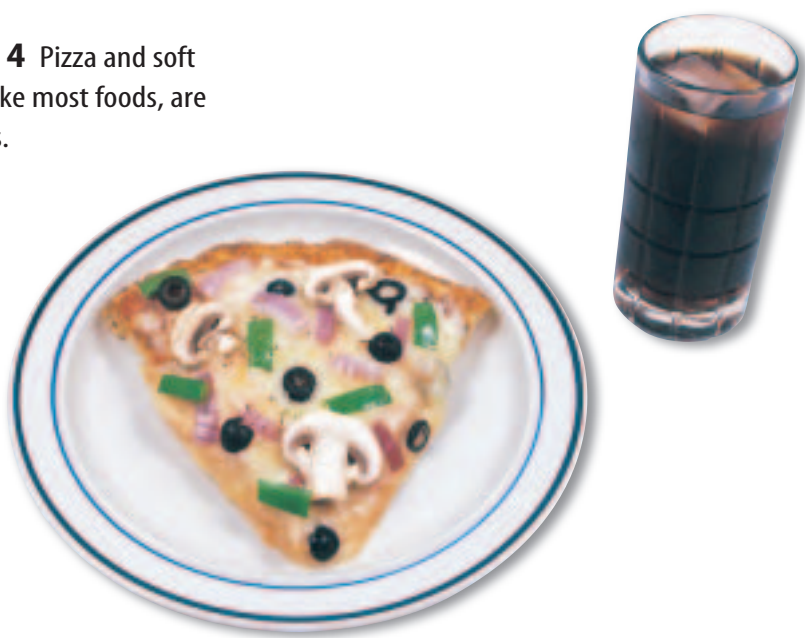
*How are elements and compounds related?*

Can you imagine yourself putting something made from a silvery metal and a greenish-yellow, poisonous gas on your food? You might have shaken some on your food today—table salt is a chemical compound that fits this description. Even though it looks like white crystals and adds flavor to food, its components—sodium and chlorine—are neither white nor salty, as shown in **Figure 3**. Like salt, compounds usually look different from the elements in them.

## Mixtures

Are pizza and a soft drink one of your favorite lunches? If so, you enjoy two foods that are classified as mixtures—but two different kinds of mixtures. A mixture, such as the pizza or soft drink shown in **Figure 4**, is a material made up of two or more substances that can be easily separated by physical means.

**Figure 4** Pizza and soft drinks, like most foods, are mixtures.



**Heterogeneous Mixtures** Unlike compounds, mixtures do not always contain the same proportions of the substances that make them up—the pizza chef doesn’t measure precisely how much of each topping is sprinkled on. You easily can see most of the toppings on a pizza. A mixture in which different materials can be distinguished easily is called a **heterogeneous** (he tuh ruh JEE nee us) **mixture**. Granite, concrete, and dry soup mixes are other heterogeneous mixtures you can recognize.

You might be wearing another heterogeneous mixture—clothing made of permanent-press fabric like that seen in **Figure 5A**. Such fabric contains fibers of two materials—polyester and cotton. The amounts of polyester and cotton can vary from one article of clothing to another, as shown by the label. Though you might not be able to distinguish the two fibers just by looking at them with your naked eye, you probably could tell using a microscope, as shown in **Figure 5B**. Therefore, a permanent-press fabric is also a heterogeneous mixture.

Most of the substances you come in contact with every day are heterogeneous mixtures. Some components are easy to see, like the ingredients in pizza, but others are not. In fact, the component you see can be a mixture itself. For example, the cheese in pizza is also a mixture, but you cannot see the individual components. Cheese contains many compounds, such as milk proteins, butterfat, colorings, and other food additives.



## Separating Mixtures

### Procedure

1. Put equal amounts of **soil, clay, sand, gravel, and pebbles** in a **clear-plastic container**. Add **water** until the container is almost full. Wash your hands well after handling the materials.
2. Stir or shake the mixture thoroughly. Predict the order in which the materials will settle.
3. Observe what happens and compare your observations to your predictions.

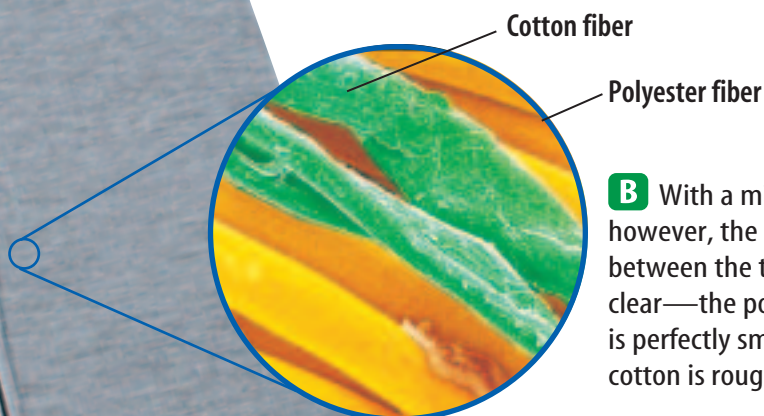
### Analysis

1. In what order did the materials settle?
2. Explain why the materials settled in the order they did.



**Figure 5** Heterogeneous mixtures can be hard to detect.

**A** You can’t tell at a glance that this fabric is a mixture of cotton and polyester.

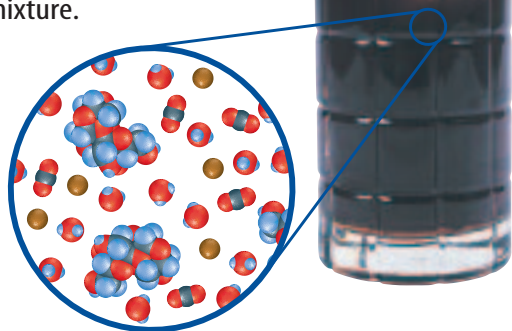


Magnification: 600×

**B** With a microscope however, the difference between the two fibers is clear—the polyester fiber is perfectly smooth and the cotton is rough.



**Figure 6** A soft drink can be either heterogeneous or homogeneous. As carbon dioxide fizzes out it is a heterogeneous mixture.



The resulting flat soft drink is a homogeneous mixture of water, sugar, flavor, color, and some remaining carbon dioxide.

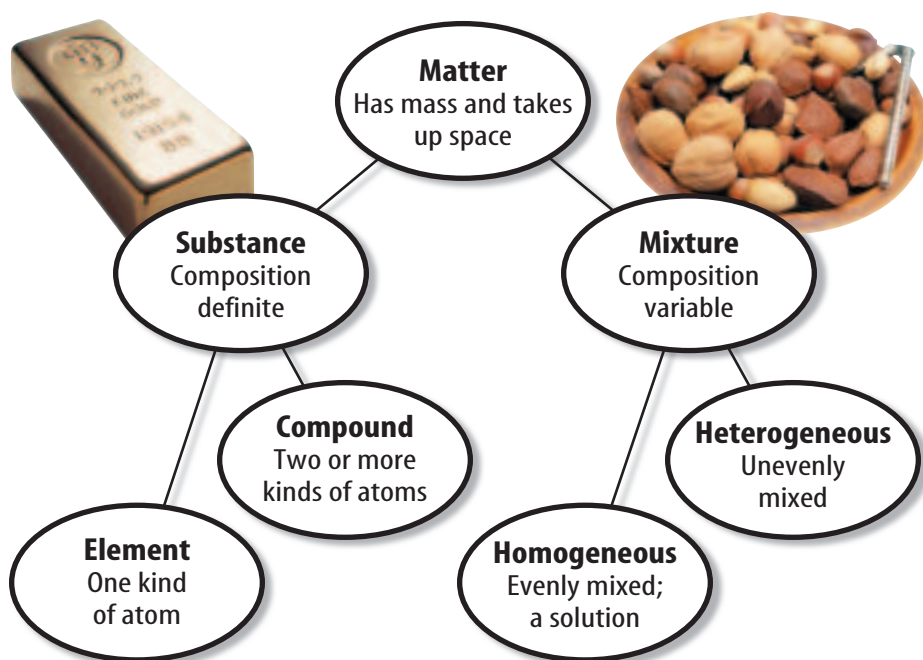
**Homogeneous Mixtures** Remember that soft drink you had with your pizza? Soft drinks contain water, sugar, flavoring, coloring, and carbon dioxide gas. **Figure 6** will help you to visualize these particles in a liquid soft drink.

Soft drinks in sealed bottles are examples of homogeneous mixtures. A **homogeneous** (hoh muh JEE nee us) **mixture** contains two or more gaseous, liquid, or solid substances blended evenly throughout. However, a soft drink in which you can see bubbles of carbon dioxide gas and ice cubes is a heterogeneous mixture.

Vinegar is another homogeneous mixture. It appears clear even though it is made up of particles of acetic acid mixed with water. Another name for homogeneous mixtures like vinegar and a cold soft drink is solution. A **solution** is a homogeneous mixture of particles so small that they cannot be seen with a microscope and will never settle to the bottom of their container. Solutions remain constantly and uniformly mixed. The differences between substances and mixtures are summarized in **Figure 7**.

**Reading Check** What kind of mixture is a solution?

**Figure 7** All matter can be divided into substances and mixtures.



**Colloids** Milk is an example of a specific kind of mixture called a colloid. Like a heterogeneous mixture, it contains water, fats, and proteins in varying proportions. Like a solution, its components won't settle if left standing. A **colloid** (KAH loyd) is a type of mixture with particles that are larger than those in solutions but not heavy enough to settle out. The word *colloid* comes from a Greek word for glue. The first colloids studied were in gelatin, a source of some types of glue.

Paint is an example of a liquid with suspended colloid particles. Gases and solids can contain colloidal particles, too. For example, fog consists of particles of liquid water suspended in air, and smoke contains solids suspended in air.

**Figure 8** Fog is a colloid composed of water droplets suspended in air.

The light from the headlights is scattered by fog.



The same colloid allows you to see the sunlight as it streams through the trees.

**Detecting Colloids** One way to distinguish a colloid from a solution is by its appearance. Fog appears white because its particles are large enough to scatter light as shown in **Figure 8**. Sometimes it is not so obvious that a liquid is a colloid. For example, some shampoos and gelatins are colloids called gels that appear almost clear. You can tell for certain if a liquid is a colloid by passing a beam of light through it, as shown in **Figure 9**. A light beam is invisible as it passes through a solution, but can be seen readily as it passes through a colloid. This occurs because the particles in the colloid are large enough to scatter light, but those in the solution are not. This scattering of light by colloidal particles is called the **Tyndall effect**.



#### Reading Check

*How can you distinguish a colloid from a solution?*



**Figure 9** Because of the Tyndall effect, a light beam is scattered by the colloid suspension on the right, but passes invisibly through the solution on the left.





**Figure 10** The mud deposited by the Mississippi River is said to be more than 10,000 m thick.

**Table 1 Comparing Solutions, Colloids, and Suspensions**

| Description                  | Solutions | Colloids | Suspensions |
|------------------------------|-----------|----------|-------------|
| Settle upon standing?        | no        | no       | yes         |
| Separate using filter paper? | no        | no       | yes         |
| Particle size                | 0.1–1 nm  | 1–100 nm | >100 nm     |
| Scatter light?               | no        | yes      | yes         |

**Suspensions** Some mixtures are neither solutions nor colloids. One example is muddy pond water. If pond water stands long enough, some mud particles will fall to the bottom, and the water clears. Pond water is a **suspension**, which is a heterogeneous mixture containing a liquid in which visible particles settle. **Table 1** summarizes the properties of different types of mixtures.



River deltas are a large scale example of how a suspension settles. Rivers flow swiftly through narrow channels, picking up soil and debris along the way. As the river widens, it flows more slowly. Suspended particles settle forming deltas at the mouth, as shown in **Figure 10**.

## section 1 review

### Summary

#### Pure Substances

- An element is a substance in which all atoms have the same identity.
- A compound is a substance that has two or more elements combined in a fixed proportion.

#### Mixtures

- Heterogeneous mixtures are mixtures in which different materials can be distinguished easily.
- A homogeneous mixture contains two or more gaseous, liquid, or solid substances that are blended evenly throughout.
- Mixtures can be heterogeneous, homogeneous, colloids, or suspensions.

### Self Check

1. **Describe** How is a compound similar to a homogeneous mixture? How is it different?
2. **Distinguish** between a substance and a mixture. Give two examples of each.
3. **Describe** the differences between colloids and suspensions.
4. **Think Critically** Why do the words “Shake well before using” indicate that the fruit juice is a suspension?

### Applying Skills

5. **Compare and Contrast** In terms of suspensions and colloids, compare and contrast a glass of milk and a glass of fresh-squeezed orange juice.



# Elements, Compounds, and Mixtures

Elements, compounds, and mixtures all contain atoms. In elements, the atoms all have the same identity. In compounds, two or more elements have been combined in a fixed ratio. In mixtures, the ratio of substances can vary.

## Real-World Question

What are some differences among elements, compounds, and mixtures?

### Goals

- **Determine** whether several materials are elements, compounds, or mixtures.

### Materials

plastic freezer bag containing the following labeled items:

- |                       |                           |
|-----------------------|---------------------------|
| copper wire           | chalk (calcium carbonate) |
| small package of salt | piece of granite          |
| pencil                | sugar water in a vial     |
| aluminum foil         |                           |

### Safety Precautions



## Procedure

1. Copy the data table into your Science Journal and use it to record your observations.
2. Obtain a bag of objects. Identify each object and classify it as an element, compound, heterogeneous mixture, or homogeneous mixture. The elements appear in the periodic table. Compounds are named as examples in Section 1.

## Conclude and Apply

1. If you know the name of a substance, how can you find out whether or not it is an element?

2. **Explain** how the appearance of the items is different. Which would you classify as a compound? Why? Which would you classify as a mixture? Why?
3. **Discuss** how chalk is different from the granite in relation to compounds and mixtures.



### Classification of Objects

| Object | Identity                   | Classification |
|--------|----------------------------|----------------|
| 1      |                            |                |
| 2      | Do not write in this book. |                |
| 3      |                            |                |
| 4      |                            |                |
| 5      |                            |                |
| 6      |                            |                |
| 7      |                            |                |

### Communicating Your Data

Enter your data in the data table and compare your findings with those of your classmates. For more help, refer to the **Science Skill Handbook**.



# Properties of Matter

## Reading Guide

### What You'll Learn

- **Identify** substances using physical properties.
- **Compare and contrast** physical and chemical changes.
- **Identify** chemical changes.
- **Determine** how the law of conservation of mass applies to chemical changes.

### Why It's Important

Understanding chemical and physical properties can help you use materials properly.



### Review Vocabulary

**state of matter:** one of three physical forms of matter—solid, liquid, or gas

### New Vocabulary

- physical property
- physical change
- distillation
- chemical property
- chemical change
- law of conservation of mass



**Figure 11** Appearance is the most obvious physical property.

**Describe** the appearance of these items.

## Physical Properties

You can stretch a rubber band, but you can't stretch a piece of string very much, if at all. You can bend a piece of wire, but you can't easily bend a matchstick. In each case, the materials change shape, but the identity of the substances—rubber, string, wire, wood—does not change. The abilities to stretch and bend are physical properties. Any characteristic of a material that you can observe without changing the identity of the substances that make up the material is a **physical property**. Examples of other physical properties are color, shape, size, density, melting point, and boiling point. What physical properties can you use to describe the items in **Figure 11**?

**Appearance** How would you describe a tennis ball? You could begin by describing its shape, color, and state of matter. For example, you might describe the tennis ball as a brightly colored, hollow sphere. You can measure some physical properties, too. For instance, you could measure the diameter of the ball. What physical property of the ball is measured with a balance?

To describe a soft drink in a cup, you could start by calling it a liquid with a brown color. You could measure its volume and temperature. Each of these characteristics is a physical property of that soft drink.

**Figure 12** The best way to separate substances depends on their physical properties. Size is the property used to separate poppy seeds from sunflower seeds in this example.



**Behavior** Some physical properties describe the behavior of a material or a substance. As you might know, objects that contain iron, such as a safety pin, are attracted by a magnet. Attraction to a magnet is a physical property of the substance iron. Every substance has a specific combination of physical properties that make it useful for certain tasks. Some metals, such as copper, can be drawn out into wires. Others, such as gold, can be pounded into sheets as thin as 0.1 micrometers ( $\mu\text{m}$ ), about 4-millionths of an inch. This property of gold makes it useful for decorating picture frames and other objects. Gold that has been beaten or flattened in this way is called gold leaf.

Think again about your soft drink. If you knock over the cup, the drink will spread out over the table or floor. If you knock over a jar of molasses, however, it does not flow as easily. The ability to flow is a physical property of liquids.

**Using Physical Properties to Separate** Removing the seeds from a watermelon can be easily done based on the physical properties of the seeds compared to the rest of the fruit. **Figure 12** shows a mixture of poppy seeds and sunflower seeds. You can identify the two kinds of seeds by differences in color, shape, and size. By sifting the mixture, you can separate the poppy seeds from the sunflower seeds quickly because their sizes differ.

Now look at the mixture of iron filings and sand shown in **Figure 12**. You probably won't be able to sift out the iron filings because they are similar in size to the sand particles. What you can do is pass a magnet through the mixture. The magnet attracts only the iron filings and pulls them from the sand. This is an example of how a physical property, such as magnetic attraction, can be used to separate substances in a mixture. Something like this is done to separate iron for recycling.



Magnetism easily separates iron from sand.



**Recycling and Physical Properties** Recycling conserves natural resources. In some large recycling projects, aluminum metal must be separated from scrap iron. What physical properties of the two metals could be used to separate them?



## Mini LAB

### Identifying Changes

#### Procedure



**WARNING:** Clean up any spills promptly. Potassium permanganate can stain clothing.

1. Add **water** to a **250-mL beaker** until it is half-full.
2. Add a crystal of **potassium permanganate** to the water and observe what happens.
3. Add 1 g of **sodium hydrogen sulfite** to the solution and stir it until the solution becomes colorless.

#### Analysis

1. Is dissolving a chemical or a physical change?
2. What evidence of a chemical change did you see?

## Physical Change

If you break a piece of chewing gum, you change some of its physical properties—its size and shape. However, you have not changed the identity of the materials that make up the gum.

**The Identity Remains the Same** When a substance freezes, boils, evaporates, or condenses, it undergoes physical changes. A change in size, shape, or state of matter is called a **physical change**. These changes might involve energy changes, but the kind of substance—the identity of the element or compound—does not change. Because all substances have distinct properties like densities, specific heats, and boiling and melting points, which are constant, these properties can be used to help identify them when a particular mixture contains substances which are not yet identified.



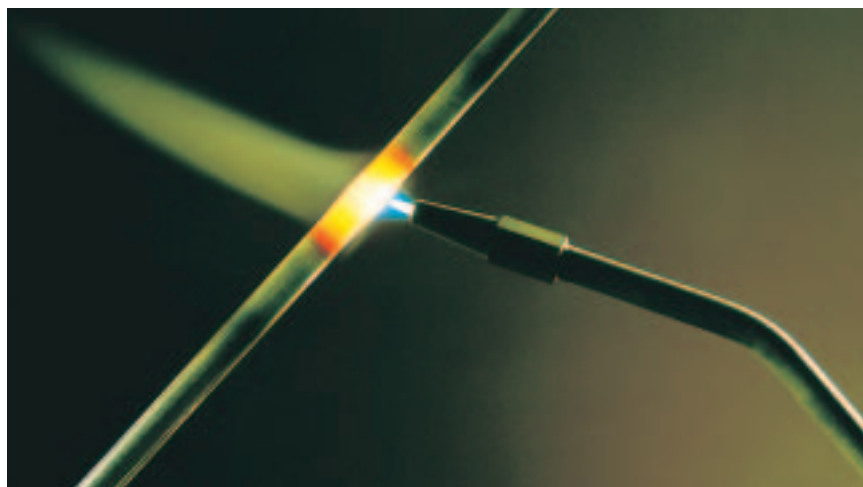
#### Reading Check

*Does a change in state mean that a new substance has formed? Explain.*

Iron is a substance that can change states if it absorbs or releases enough energy—at high temperatures, it melts. However, in both the solid and liquid state, iron has physical properties that identify it as iron. Color changes can accompany a physical change, too. For example, when iron is heated it first glows red. Then, if it is heated to a higher temperature, it turns white, as shown in **Figure 13**.

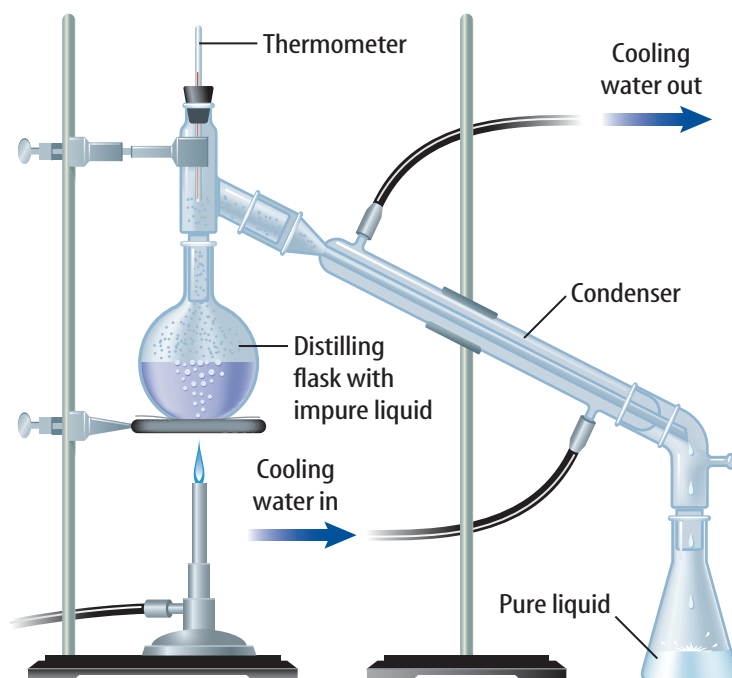
**Using Physical Change to Separate** A cool drink of water is something most people take for granted, but in some parts of the world, drinkable water is scarce. Not enough drinkable water can be obtained from wells. Many such areas that lie close to the sea obtain drinking water by using physical properties of water to separate it from the salt. One of these methods, which uses the property of boiling point, is a type of distillation.

**Figure 13** Heating iron raises its energy level and changes its color. These energy changes are physical changes because it is still iron.



**Distillation** The process for separating substances in a mixture by evaporating a liquid and recondensing its vapor is **distillation**. It usually is done in the laboratory using an apparatus similar to that shown in **Figure 14**. As you can see, the liquid vaporizes and condenses, leaving the solid material behind.

Two liquids having different boiling points can be separated in a similar way. The mixture is heated slowly until it begins to boil. Vapors of the liquid with the lowest boiling point form first and are condensed and collected. Then, the temperature is increased until the second liquid boils, condenses, and is collected. Distillation is used often in industry. For instance, natural oils such as mint are distilled.



**Figure 14** Distillation can easily separate liquids from solids dissolved in them. The liquid is heated until it vaporizes and moves up the column. Then, as it touches the water-cooled surface of the condenser, it becomes liquid again.

## Chemical Properties and Changes

You probably have seen warnings on cans of paint thinners and lighter fluids for charcoal grills that say these liquids are flammable (FLA muh buhl). The tendency of a substance to burn, or its flammability, is an example of a chemical property because burning produces new substances during a chemical change. A **chemical property** is a characteristic of a substance that indicates whether it can undergo a certain chemical change. Many substances used around the home, such as lighter fluids, are flammable. Knowing which ones are flammable helps you to use them safely.

A less dramatic chemical change can affect some medicines. Look at **Figure 15**. You probably have seen bottles like this in a pharmacy. Many medicines are stored in dark bottles because they contain compounds that can change chemically if they are exposed to light.



**Figure 15** The brown color of these bottles tells you that these vitamins may react to light. Reaction to light is a chemical property.





**Alchemy** In the Middle Ages, alchemy was an early form of chemistry devoted to the study of changing baser metals into gold and also to finding the elixir of perpetual youth. Based on what we know now about the properties of metals and biology, it is easy to understand why this field of study is no longer practiced.

## Detecting Chemical Change

If you leave a pan of chili cooking unattended on the stove for too long, your nose soon tells you that something is wrong. Instead of a spicy aroma, you detect an unpleasant smell that alerts you that something is burning. This burnt odor is a clue telling you that a new substance has formed.

**The Identity Changes** The smell of rotten eggs and the formation of rust on bikes or car fenders are signs that a chemical change has taken place. A change of one substance to another is a **chemical change**. The foaming of an antacid tablet in a glass of water and the smell in the air after a thunderstorm are other signs of new substances being produced. In some chemical changes, a rapid release of energy—detected as heat, light, and sound—is a clue that changes are occurring.

### Reading Check *What is a chemical change?*

Clues such as heat, cooling, or the formation of bubbles or solids in a liquid are helpful indicators that a reaction is taking place. However, the only sure proof is that a new substance is produced. Consider the following example. The heat, light, and sound produced when hydrogen gas combines with oxygen in a rocket engine are clear evidence that a chemical reaction has taken place. But no clues announce the reaction that takes place when iron combines with oxygen to form rust because the reaction takes place so slowly. The only clue that iron has changed into a new substance is the presence of rust. Burning and rusting are chemical changes because new substances form. You sometimes can follow the progress of a chemical reaction visually. For example, you can see lead nitrate forming in **Figure 16**.

**Figure 16** The solid forming from two liquids is another sign that a chemical reaction has taken place.



**Using Chemical Change to Separate** One case where you might separate substances using a chemical change is in cleaning tarnished silver. Tarnish is a chemical reaction between silver metal and sulfur compounds in the air which results in silver sulfide. It can be changed back into silver using a chemical reaction. This chemical reversal back to silver takes place when the tarnished item is placed in a warm water bath with baking soda and aluminum foil. You don't usually separate substances using chemical changes in the home. In industry and chemical laboratories, however, this kind of separation is common. For example, many metals are separated from their ores and then purified using chemical changes.

## LAW OF CONSERVATION OF MASS

**Calculating Total Mass of Product** When a chemical reaction takes place, the total mass of reactants equals the total mass of products. If 18 g of hydrogen react completely with 633 g of chlorine, how many grams of HCl are formed? The equation for this reaction is:  $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$

- 1 This is what you know:**  
mass of  $\text{H}_2$  = 18 g  
mass of  $\text{Cl}_2$  = 633 g
- 2 This is what you need to find:** mass of HCl
- 3 Use this formula:**  
total mass of reactants = total mass of products  
mass of  $\text{H}_2$  + mass of  $\text{Cl}_2$  = mass of HCl
- 4 Substitute:**  
 $18 \text{ g} + 633 \text{ g} = 651 \text{ g}$
- 5 Determine the units:**  
units of  $\text{H}_2$  + units of  $\text{Cl}_2$  = g + g = g

**Answer:** The mass of the product, HCl, is 651g.

### Practice Problems

- 1.** In the following reaction, 24 g of  $\text{CH}_4$  (methane) react completely with 96 g of  $\text{O}_2$  to form 66 g of  $\text{CO}_2$ . How many grams of  $\text{H}_2\text{O}$  are formed?  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
- 2. Challenge** In the following equation, 54.0 g of Al react completely with 409.2 g of  $\text{ZnCl}_2$  to form 196.2 g of Zn metal. How many grams of  $\text{AlCl}_3$  are formed?  
 $2\text{Al} + 3\text{ZnCl}_2 \rightarrow 3\text{Zn} + 2\text{AlCl}_3$



For more practice problems,  
go to page 834, and visit  
[gpscience.com/extra\\_problems](http://gpscience.com/extra_problems).





Flowing water shaped and smoothed these rocks in a physical process.



Both chemical and physical changes shaped the famous White Cliffs of Dover lining the English Channel.

**Figure 17** Weathering can involve physical or chemical change.

## Weathering—Chemical or Physical Change?

The forces of nature continuously shape Earth's surface. Rocks split, deep canyons are carved out, sand dunes shift, and curious limestone formations decorate caves. Do you think these changes, often referred to as weathering, are physical or chemical? The answer is both. Geologists, who use the same criteria that you have learned in this chapter, say that some weathering changes are physical and some are chemical.

**Physical** Large rocks can split when water seeps into small cracks, freezes, and expands. However, the smaller pieces of newly exposed rock still have the same properties as the original sample. This is a physical change. Streams can cut through softer rock, forming canyons, and can smooth and sculpt harder rock, as shown at left in **Figure 17**. In each case, the stream carries rock particles far downstream before depositing them. Because the particles are unchanged, the change is a physical one.

**Chemical** In other cases, the change is chemical. For example, solid calcium carbonate, a compound found in limestone, does not dissolve easily in water. However, when the water is even slightly acidic, as it is when it contains some dissolved carbon dioxide, calcium carbonate reacts. It changes into a new substance, calcium hydrogen carbonate, which does dissolve in water. This change in limestone is a chemical change because the identity of the calcium carbonate changes. The White Cliffs of Dover, shown at right in **Figure 17**, are made of limestone and undergo such chemical changes, as well as physical changes. A similar chemical change produces caves and the icicle-shaped rock formations that often are found in them.



### Topic: Caves

Visit [gpscience.com](http://gpscience.com) for Web links to information about cave formations.

**Activity** Describe the formation of stalactites and stalagmites. Explain the differences between the two and whether they are the result of a physical and/or chemical process.

## The Conservation of Mass

Wood is combustible, or burnable. As you just learned, this is a chemical property. Suppose you burn a large log in the fireplace, as shown in **Figure 18**, until nothing is left but a small pile of ashes. Smoke, heat, and light are given off and the changes in the appearance of the log confirm that a chemical change took place. At first, you might think that matter was lost during this change because the pile of ashes looks much smaller than the log did. In fact, the mass of the ashes is less than that of the log. However, suppose that you could collect all the oxygen in the air that was combined with the log during the burning and all the smoke and gases that escaped from the burning log and measure their masses, too. Then you would find that no mass was lost after all.

Not only is no mass lost during burning, mass is not gained or lost during any chemical change. In other words, matter is neither created nor destroyed during a chemical change. According to the **law of conservation of mass**, the mass of all substances that are present before a chemical change equals the mass of all the substances that remain after the change.



**Figure 18** This reaction appears to be destroying these logs. When it is over, only ashes will remain. Yet you know that no mass is lost in a chemical reaction.

**Explain** why this is so.

### Reading Check

*Explain what is meant by the law of conservation of mass.*

## section 2 review

### Summary

#### Physical Properties

- You can observe physical properties without changing the identity of a substance.

#### Physical Change

- Change in the size, shape, or state of matter is a physical change.

#### Chemical Properties and Changes

- A chemical property is a characteristic of a substance that indicates whether it can undergo a certain chemical change.
- A change of one substance to another is a chemical change.
- Many metals are separated from their ores and purified using chemical changes.

### Self Check

1. **Explain** why evaporation of water is a physical change and not a chemical change.
2. **List** four physical properties you could use to describe a liquid.
3. **Describe** why flammability is a chemical property rather than a physical property.
4. **Explain** how the law of conservation of mass applies to chemical changes.
5. **Think Critically** How might you demonstrate this law of conservation of mass for melting ice and distillation of water?

### Applying Math

6. **Calculate** In the following equation, 417.96 g of Bi (bismuth) react completely with 200 g of F (fluorine). How many grams of  $\text{BiF}_3$  (bismuth fluoride) are formed?  $2 \text{ Bi} + 3 \text{ F}_2 \rightarrow 2 \text{ BiF}_3$



## Checking Out Chemical Changes

### Goals

- **Observe** the results of adding dilute hydrochloric acid to baking soda.
- **Infer** that the production of new substances indicates that a chemical change has occurred.
- **Design** an experiment that allows you to compare the activity of baking soda with that of a product formed when baking soda reacts.

### Possible Materials

baking soda  
small evaporating dish  
magnifying lens  
1M hydrochloric acid (HCl)  
10-mL graduated cylinder  
electric hot plate

### Safety Precautions



### Real-World Question

Mixing materials together does not always produce a chemical change. You must find evidence of a new substance with new properties being produced before you can conclude that a chemical change has taken place. Try this lab and use your observation skills to deduce what kind of change has occurred. What evidence indicates a chemical change?

### Form a Hypothesis

Think about what happens when small pieces of limestone are mixed with sand. What happens when limestone is mixed with an acid? Based on these thoughts, form a hypothesis about how to determine when mixing substances together produces a chemical change.

### Test Your Hypothesis

#### Make a Plan

1. As a group, agree upon a hypothesis and decide how to test it. Write the hypothesis statement.
2. To test your hypothesis, devise a plan to compare two different mixtures. The first mixture consists of 3 mL of hydrochloric acid and 0.5 g of baking soda. The second mixture is 3 mL of hydrochloric acid and the solid product of the first mixture. Describe exactly what you will do at each step.



Limestone



Sand

## Using Scientific Methods

3. Make a list of the materials needed to complete your experiment.
4. **Design** a table for data and observations in your Science Journal so that it is ready to use as your group observes what happens.

### Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Read over your entire experiment to make sure that all steps are in logical order.
3. **Identify** any constants and the variables of the experiment.
4. Should you run any test more than once? How will observations be summarized?
5. Assemble your materials and carry out the experiment according to your plan. Be sure to record your results as you work.



### Analyze Your Data

1. **Observe** what happened to the baking soda. Did anything happen to the product formed from the first mixture? Explain why this occurred.
2. **Describe** What different properties of any new substances did you observe after adding hydrochloric acid to the baking soda?

### Conclude and Apply

1. Did the results support your hypothesis? Explain.
2. If you had used vinegar, which contains acetic acid, as the acid, do you think a new substance would have formed? How could you test this?

### Communicating Your Data

**Write** a description of your observations in your Science Journal. **Compare** your results with those of other groups. **Discuss** your conclusions.





## Intriguing Elements

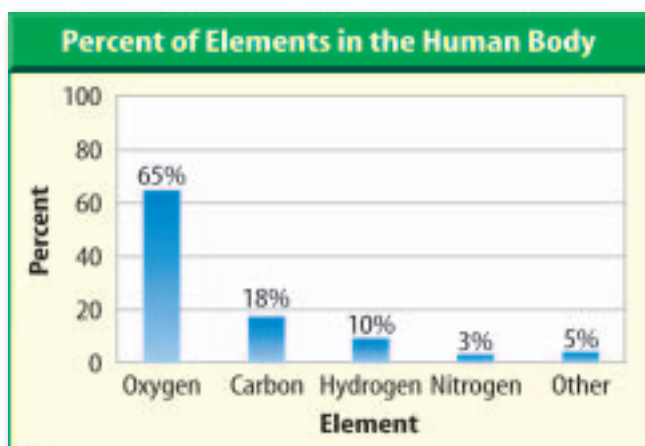
### Did you know...

... **Silver-white cobalt**, which usually is combined with other elements in nature, is used to create rich paint pigments. It can be used to form powerful magnets, treat cancer patients, build jet engines, and prevent disease in sheep.



### ... Gold is the most ductile

(stretchable) of all the elements. Just 29 g of gold—about ten wedding bands—can be pulled into a wire 100 km long. That's long enough to stretch from Toledo, Ohio, to Detroit, Michigan, and beyond.



### ... Zinc makes chewing gum taste better.

Up to 0.3 mg of zinc acetate can be added per 1,000 mg of chewing gum to provide a tart, zingy flavor.



### Applying Math

1. Zinc acetate is approximately 35% zinc. How many grams of chewing gum would be needed to provide a total of 10.0 mg of zinc?
2. If you wanted to produce a gold wire as mentioned in our example, how many grams would be needed to make a wire one kilometer in length?
3. Table sugar has the chemical formula  $C_{12}H_{22}O_{11}$ . If you were going to build a scale model of sucrose (table sugar) and you had 36 carbon model atoms, how many of each of the others (hydrogen and oxygen) would you need to build an accurate, complete sucrose model?

## Reviewing Main Ideas

**Section 1 Composition of Matter**

1. Elements and compounds are substances. A mixture is composed of two or more substances.
2. You can distinguish between the different materials in a heterogeneous mixture using either your unaided eye or a microscope.
3. Colloids and suspensions are two types of heterogeneous mixtures. The particles in a suspension will settle eventually. Particles of a colloid will not. Milk is an example of a colloid.
4. In a homogeneous mixture, the particles are distributed evenly and are not visible, even when using a microscope. Homogeneous mixtures can be composed of solids, liquids, or gases.
5. A solution is another name for a homogeneous mixture that remains constantly and uniformly mixed.



This is a clear indication that this is a suspension.

**Section 2 Properties of Matter**

1. Physical properties are characteristics of materials that you can observe without changing the identity of the substance.
2. Chemical properties indicate what chemical changes substances can undergo. Many medicines are stored in dark bottles because they react with light.
3. In physical changes, the identities of substances remain unchanged.
4. In chemical changes, the identities of substances change—new substances are formed. There is a visible chemical change that takes place when rust is cleaned with bleach.



5. The law of conservation of mass states that during any chemical change, matter is neither created nor destroyed.

**FOLDABLES**

Use the Foldable that you made at the beginning of the chapter to help you review the classifications of matter.



**Using Vocabulary**

|                             |                                   |
|-----------------------------|-----------------------------------|
| chemical change p.462       | law of conservation of mass p.465 |
| chemical property p.461     | physical change p.460             |
| colloid p.454               | physical property p.458           |
| compound p.452              | solution p.454                    |
| distillation p.461          | substance p.450                   |
| element p.450               | suspension p.456                  |
| heterogeneous mixture p.453 | Tyndall effect p.455              |
| homogeneous mixture p.454   |                                   |

*Complete each sentence with the correct vocabulary word or words.*

- Substances formed from atoms of two or more elements are called \_\_\_\_\_.
- A(n) \_\_\_\_\_ is a heterogeneous mixture in which visible particles settle.
- Freezing, boiling, and evaporation are all examples of \_\_\_\_\_.
- According to the \_\_\_\_\_, matter is neither created nor destroyed during a chemical change.
- A mixture in which different materials are easily identified is \_\_\_\_\_.
- Compounds are made from the atoms of two or more \_\_\_\_\_.
- Distillation is a process that can separate two liquids using \_\_\_\_\_.
- Which of the following is NOT an element?  
A) water C) oxygen  
B) carbon D) hydrogen
- Which of the following is an example of a chemical change?  
A) boiling C) evaporation  
B) burning D) melting
- What type of substance is gelatin?  
A) colloid C) substance  
B) compound D) suspension
- A visible sunbeam is an example of which of the following?  
A) an element C) a compound  
B) a solution D) the Tyndall effect
- You start to eat some potato chips from an open bag you found in your locker and notice that they taste unpleasant. What do you think might cause this unpleasant taste?  
A) combustion C) physical change  
B) melting D) chemical change
- How would you classify the color of a rose?  
A) chemical change C) chemical property  
B) physical change D) physical property
- How would you describe the process of evaporating water from seawater?  
A) chemical change C) chemical property  
B) physical change D) physical property
- Which of these warnings refers to a chemical property of the material?  
A) Fragile C) Handle with Care  
B) Flammable D) Shake Well

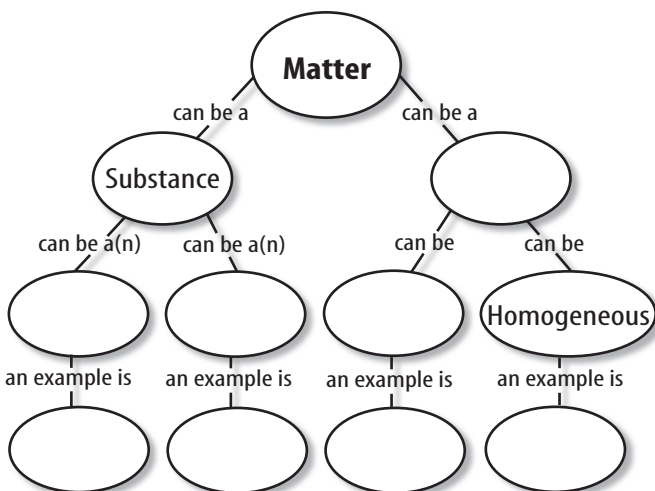
**Checking Concepts**

*Choose the word or phrase that best answers the question.*

- Bending a copper wire is an example of what type of property?  
A) chemical C) conservation  
B) physical D) element
- Which of the following is a substance?  
A) colloid C) mixture  
B) element D) solution
- Which of these properties can be used to help identify an unknown substance?  
A) specific heat C) temperature  
B) combustion D) Tyndall effect

## Interpreting Graphics

19. Copy and complete the concept map below about matter.



Use the table below to answer question 20.

| Common Colloids   |         |
|-------------------|---------|
| Colloid           | Example |
| Solid in a liquid | Gelatin |
| Solid in a gas    |         |
| Gas in a solid    |         |
| Solid in a liquid |         |
| Liquid in a gas   |         |

20. Different colloids can involve different states. For example, gelatin is formed from solid particles in a liquid. Complete this table using these colloids: *smoke*, *marshmallow*, *fog*, and *paint*.

## Thinking Critically

21. **Describe** the contents of a carton of milk using at least four physical properties.
22. **Explain** Carbon and the gases hydrogen and oxygen combine to form sugar. How do you know sugar is a compound?
23. **Explain** The word *colloid* means “gluelike.” Why was this term chosen to name certain mixtures?
24. **Use** a nail rusting in air to explain the law of conservation of mass.
25. **Explain** Mai says that ocean water is a solution. Tom says that it’s a suspension. Can they both be correct? Explain.
26. **Use Variables, Constants, and Controls** Marcos took a 100-cm<sup>3</sup> sample of a suspension, shook it well, and poured equal amounts into four different test tubes. He placed one test tube in a rack, one in hot water, one in warm water, and the fourth in ice water. He then observed the time it took for each suspension to settle. What was the variable in the experiment? What was one constant?
27. **Concept Map** Make a network tree to show types of liquid mixtures. Include these terms: *homogeneous mixtures*, *heterogeneous mixtures*, *solutions*, *colloids*, and *suspensions*.

## Applying Math

28. **Interpret Data** Hannah started with a 25-mL sample of pond water. Without shaking the sample, she poured 5 mL through a piece of filter paper. She repeated this with four more pieces of filter paper. She dried each piece of filter paper and measured the mass of the sediment. Why did the last sample have a higher mass than did the first sample?
29. **Use Numbers** In the following equation, 243.5 g of Sb (antimony) react completely with 1000 g of I<sub>2</sub> (iodine) to form 1004.9 g of SbI<sub>3</sub> (antimony triiodide). How many grams of I<sub>2</sub> were consumed in the reaction?  $2 \text{ Sb} + 3 \text{ I}_2 \rightarrow 2 \text{ SbI}_3$

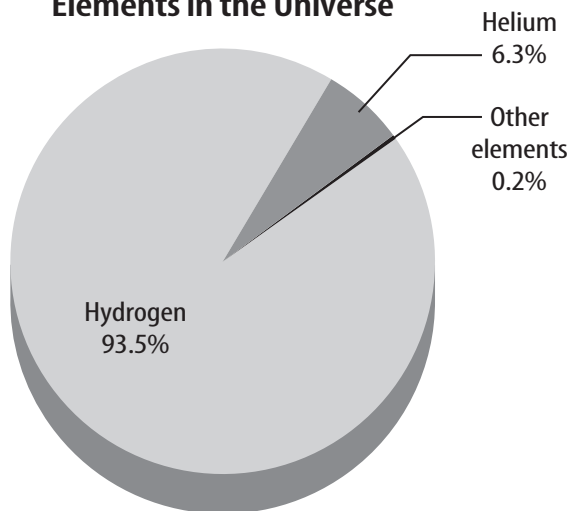
## Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- Which statement about elements is FALSE?
  - All atoms in an element are alike.
  - There are about 1,000 elements found in nature.
  - Some elements have been made in laboratories.
  - Zinc, copper, and iron are elements.
- $\text{CaCO}_3$  is an example of which type of material?
  - element
  - mixture
  - compound
  - colloid

Use the graph below to answer questions 3 and 4.

Elements in the Universe



- What percentage do the elements hydrogen and helium account for in the universe?
  - 100%
  - 99.9%
  - 98%
  - 99.8%

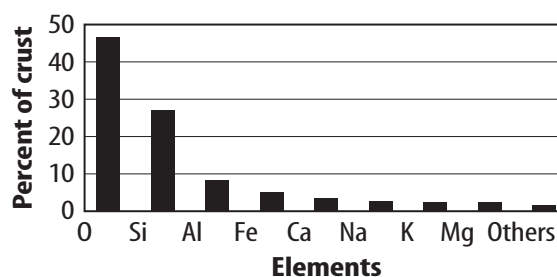
## Test-Taking Tip

**Directions and Instructions** Listen carefully to the instructions from the teacher and read the directions and each question carefully.

- The most plentiful element in the universe readily burns in air. What is this chemical property called?
  - flammability
  - ductility
  - density
  - boiling point

Use the graph below to answer questions 5 and 6.

Elements in Earth's Crust



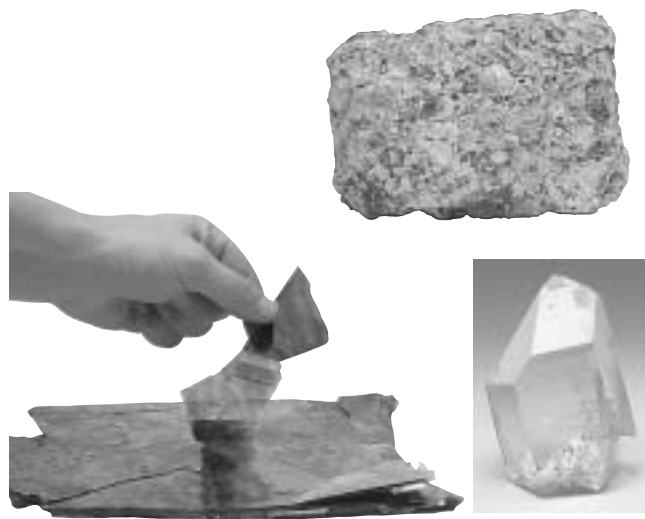
- Which element makes up 8 percent of Earth's crust?
  - iron
  - aluminum
  - silicon
  - oxygen
- Which element has the physical property of magnetism?
  - sodium
  - iron
  - oxygen
  - calcium
- Which statement best describes the law of conservation of mass?
  - The mass of the products is always greater than the mass of the materials which react in a chemical change.
  - The mass of the products is always less than the mass of the materials which react in a chemical change.
  - A certain mass of material must be present for a reaction to occur.
  - Matter is neither lost nor gained during a chemical change.



## Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the illustrations below to answer questions 8 and 9.



8. What physical properties could be used to identify these minerals?
9. Describe some ways these minerals, or rocks which contain these minerals, are weathered in nature.
10. Why are some medicines stored in dark bottles?
11. Describe the properties of tungsten which make it a useful material. How do you use this element daily?
12. What physical and chemical properties of gold make it useful as a coating for space vehicles?
13. Compare and contrast the properties of heterogeneous and homogeneous mixtures. What is another name for a homogeneous mixture?
14. You are given a mixture of iron filings, sand, and salt. Describe how to separate this mixture.

## Part 3 Open Ended

Record your answers on a sheet of paper.

Use the illustration below to answer questions 15 and 16.



15. What indicates that more than just a physical change is taking place as the wood burns?
16. Design an experiment which shows that this type of chemical change is governed by the law of conservation of mass.
17. Illustrate and describe the process of distillation of sea water using a multi-step process. On what physical property is this process based?
18. Explain the statement "Everything on Earth is made from 90 elements." Does this surprise you? Why or why not?
19. What type of mixture is a salad dressing made with oil, vinegar, and herbs? How do you know?
20. Choose an object in the room and describe its physical properties as completely as possible. Use available tools to describe measurable properties of the object.
21. Describe how a compound is a combination of elements in a fixed proportion. Give two examples.