section 2

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.

Magnetism easily separates iron from sand.

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 (µm), 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.

INTEGRATE Environment

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.

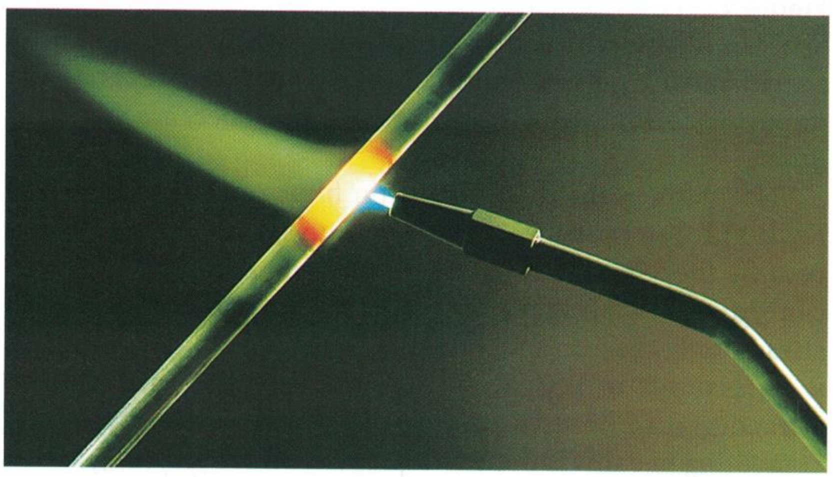


Figure 13 Heating iron raises its energy level and changes its color. These energy changes are physical changes because it is still iron.

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.

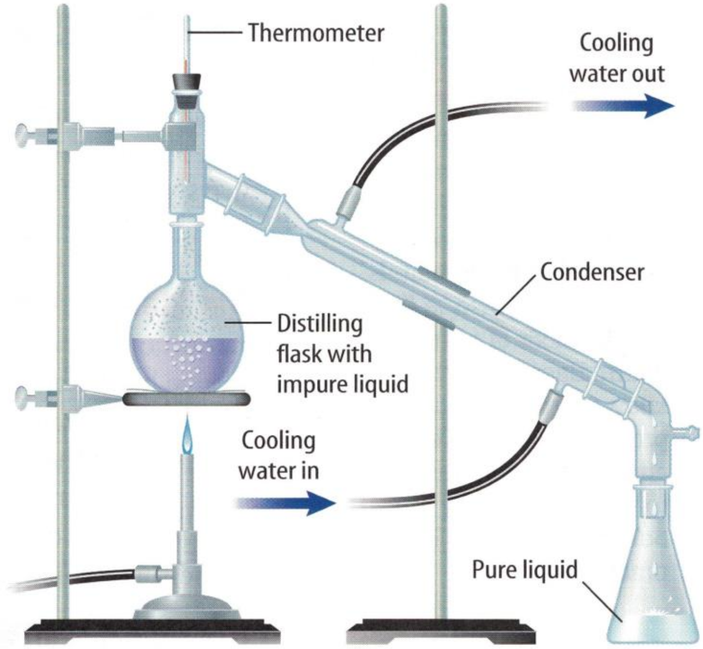


Figure 14 Distillation can easily separate liquids from solids dissolved in them. The liquid is heated until it vaporizes and moves up the column. Then, as it touches the water-cooled surface of the condenser, it becomes liquid again.

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.

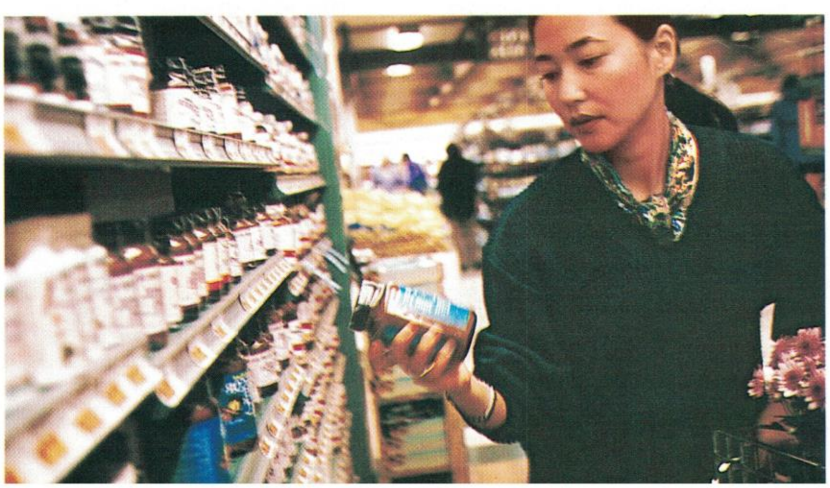


Figure 15 The brown color of these bottles tells you that these vitamins may react to light. Reaction to light is a chemical property.

INTEGRATE
History

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.**

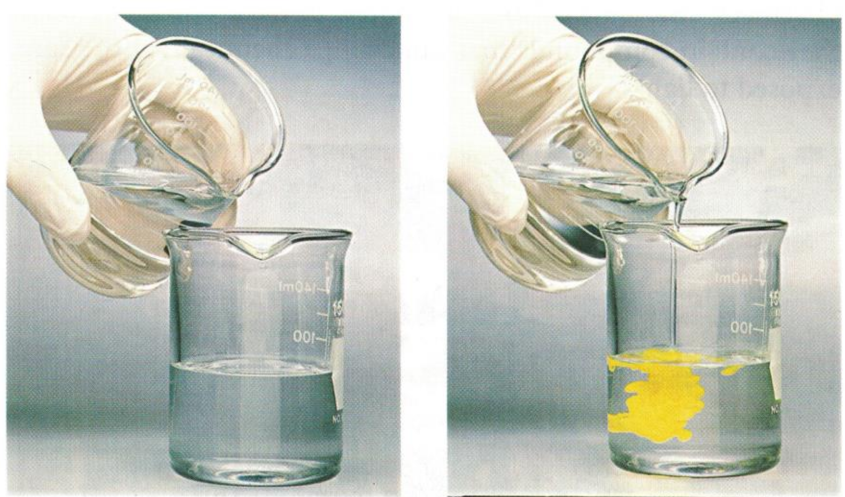


Figure 16 The solid forming from two liquids is another sign that a chemical reaction has taken place.

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.

Applying Math Calculate

CALCULATIONS WITH THE LAW OF CONSERVATION OF MASS 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? $H_2 + Cl_2 \rightarrow 2HCl$

IDENTIFY known values and the unknown value

Identify the known values:

mass of $H_2 = 18$ g

mass of $Cl_2 = 633$ g

mass of reactants = mass of products

Identify the unknown value:

mass of HCl means ? g

SOLVE the problem

Solve for the mass of HCl. $g\ H_2 + g\ Cl_2 = g\ HCl$

Substitute the known values. $18\ g + 633\ g = 651\ g\ HCl$

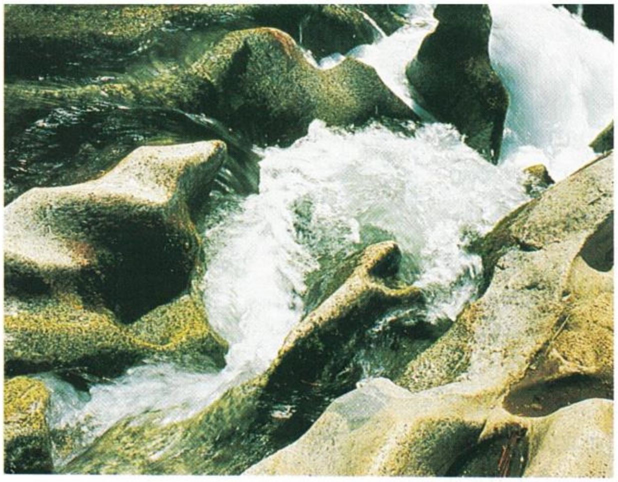
CHECK your answer

Does your answer seem reasonable? Check your answer by subtracting the mass of H_2 from the mass of HCl. Do you obtain the mass of the Cl_2? If so, the answer is correct.

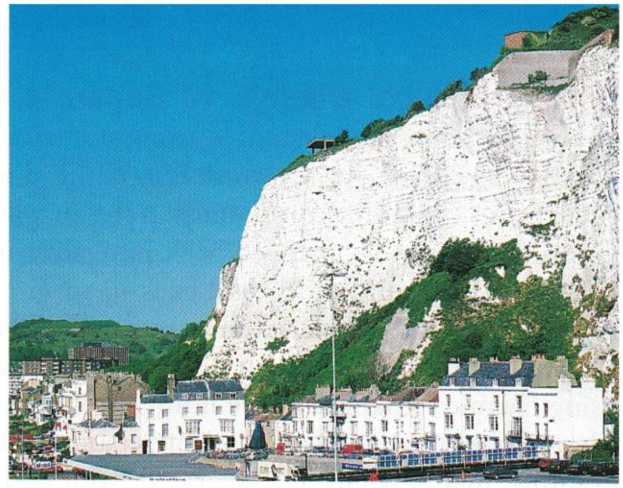
Practice Problems

1. In the following reaction, 24 g of CH_4 (methane) react completely with 96 g of O_2 to form 66 g of CO_2. How many grams of H_2O are formed? $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
2. In the following equation, 54.0 g of Al react completely with 409.2 g of $ZnCl_2$ to form 196.2 g of Zn metal. How many grams of $AlCl_3$ are formed? $2Al + 3ZnCl_2 \rightarrow 3Zn + 2AlCl_3$

For more practice problems, go to page 834, and visit 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.

Science Online

Topic: Caves
Visit 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.

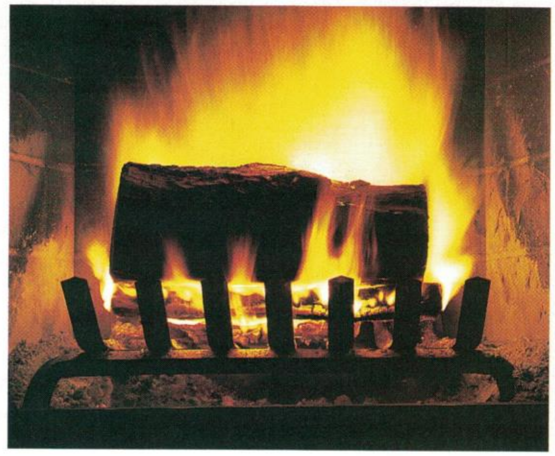


Figure 18 This reaction appears to be destroying these logs. When it is over, only ashes will remain. Yet you know that no mass is lost in a chemical reaction. **Explain** *why this is so.*

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 BiF_3 (bismuth fluoride) are formed? $2\,Bi + 3\,F_2 \longrightarrow 2\,BiF_3$

Define

Physical property -   Ex: (list 6)
Physical change - (discuss state of matter)   Ex: (list 4)
Distillation - Use the terms *boils, evaporation, condense* to describe **distillation** pg 461:   Ex: (list 2)
Chemical property - pg 461:   Ex: (list 2)
Chemical change - pg 462:   Ex: (list 5 signs) What is type of reaction is **Figure 16?** pg 462; ref Lab ______________________________