Chapter 8

Matter and Temperature

Have you ever imagined what it would be like to live in an atom-sized world? You may have seen movies where the characters are shrunk to the size of a flea or an even tinier animal. If you were that small, what would the matter around you look like? What if you were even smaller, say the size of an atom? At that size, even the air around you could be dangerous. Everywhere you looked you would see atoms and molecules whizzing around at amazingly fast speeds and occasionally colliding with one another. Watch out! One of those particles might collide with you!

If you were the size of an atom, you would notice that the particles that make up everything are in constant motion. In liquids, the particles slide over and around one another. In solids, the particles vibrate in place. In gases, the particles move around freely. Ordinary air would look like a crazy, three-dimensional bumper-car ride where you are bombarded from all sides by giant beach balls. It will be helpful to imagine life as an atom as you study this chapter.

Key Questions

- ✔ *What is the smallest particle of sugar that is still sugar?*
- ✔ *What does temperature measure?*
- ✔ *What happens at the molecular level when water melts, freezes, and boils?*

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8.1 The Nature of Matter

From a distance, a sugar cube looks like a single piece of matter. But up close, you can see it is made up of tiny, individual crystals of sugar fused together. Can those sugar crystals be broken into even smaller particles? What is the smallest particle of sugar that is still sugar (Figure 8.1)?

Figure 8.1: *What is the smallest particle of sugar that is still sugar?*

Matter is made of tiny particles in constant motion

The idea of atoms *Matter* is a term used to describe anything that has mass and takes up space. The idea that matter is made of tiny particles goes back to 430 BCE. The Greek philosophers Democritus and Leucippus proposed that matter is made of tiny particles called *atoms*. For over 2,000 years, few people believed this theory. In 1803, John Dalton revived the idea of atoms, but he lacked proof.

Brownian motion provides evidence for particles In 1827, Robert Brown, a Scottish botanist, was looking through a microscope at tiny grains of pollen in water. He saw that the grains moved in an irregular, jerky manner. After observing the same motion in tiny dust particles, he theorized that all tiny particles move in the same way. The irregular, jerky motion was named *Brownian motion* in Brown's honor.

A human-sized comparison Imagine throwing marbles at a tire tube floating in the water. The impact of any single marble is too small to make the tire tube move. If you throw enough marbles, the tube will start moving slowly. The motion of the tire tube will appear smooth because the mass of a single marble is tiny compared to the mass of the tire tube (Figure 8.2).

Why Brownian motion is jerky, not smooth Now, imagine throwing marbles at a foam cup floating in water. The motion is jerky and the impact of individual marbles can be seen. The mass of the cup is not huge compared to the mass of a marble. A pollen grain in water moves around in a jerky manner much like the foam cup. That motion is caused by the impact of individual water molecules on the pollen grain. Like the cup, the mass of the pollen grain—while larger than a water molecule—is not so much larger that impacts are completely smoothed out.

Matter is made of atoms In 1905, Albert Einstein explained how Brownian motion is caused by collisions between visible particles like pollen grains, and smaller, invisible particles. His work provided strong evidence that matter was made of atoms.

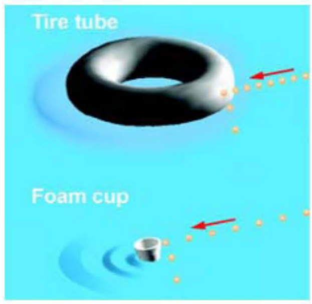
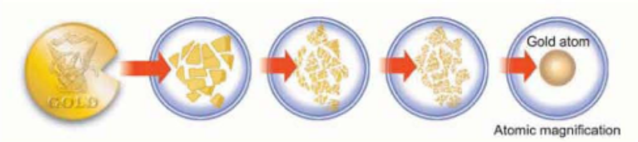


Figure 8.2: *Throwing marbles at a tire tube moves the tube smoothly. Throwing the same marbles at a foam cup moves the cup in a jerky manner, like Brownian motion.*

Atoms and elements

Elements An **element** is defined as a pure substance that cannot be broken down into simpler substances by physical or chemical means. For example, water is made from the elements hydrogen and oxygen. If you add energy, you can break water down into hydrogen and oxygen, but you cannot break the hydrogen and oxygen down into simpler substances (Figure 8.3).

Defining atoms A single **atom** is the smallest particle of an element that retains the chemical identity of the element. For example, you can keep cutting a piece of the element gold into smaller and smaller pieces until you cannot cut it any more. That smallest particle you can divide it into is one atom. A single atom of gold is the smallest piece of gold you can have. If you split the atom, it will no longer be gold.



How small are atoms? A single atom has a diameter of about 10^{-10} meters. This means that you can fit 10,000,000,000 (10^{10}) atoms side-by-side in a one-meter length. You may think a sheet of aluminum foil is thin, but it is actually more than 200,000 atoms thick!

Atoms of an element are similar to each other Each element has a unique type of atom. Sodium atoms are different from carbon atoms, carbon atoms are different from aluminum atoms, etc. But all atoms of a given element are similar to each other. If you could examine a million atoms of carbon, you would find them all to be similar. You will learn much more about atoms in Chapter 9.

VOCABULARY

element - a pure substance that cannot be broken down into simpler substances by physical or chemical means.

atom - the smallest particle of an element that retains the chemical identity of the element.

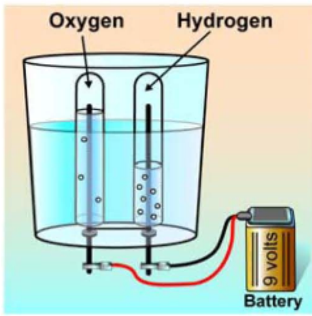
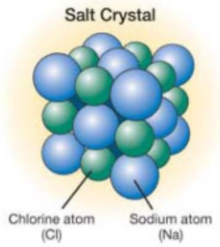


Figure 8.3: *You can break water down into oxygen and hydrogen by adding energy.*

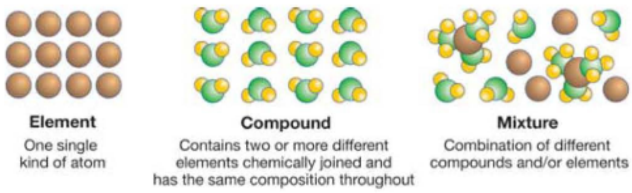
Compounds contain two or more elements

Compounds Sometimes elements are found in their pure form, but more often they are combined with other elements. Most substances contain several elements combined together. A **compound** is a substance that contains two or more different elements chemically joined and that has the same composition throughout. For example, water is a compound that is made from the elements hydrogen and oxygen. Figure 8.4 shows some familiar compounds.

Molecules If you could magnify a sample of pure water so you could see its atoms, you would notice that the hydrogen and oxygen atoms are joined together in groups of two hydrogen atoms to one oxygen atom. These groups are called molecules. A **molecule** is a group of two or more atoms joined together by *chemical bonds*. A compound is made up of only one type of molecule. Some compounds, like table salt (sodium chloride), are made of equal combinations of different atoms instead of individual molecules.



Mixtures Most of the things you see and use in everyday life are mixtures. A **mixture** contains more than one kind of atom, molecule, or compound. Hot cocoa and soil are examples of mixtures.



VOCABULARY

compound - a substance that contains two or more different elements chemically joined and that has the same composition throughout.

mixture - matter that contains a combination of different elements and/or compounds and can be separated by physical means.

molecule - a group of two or more atoms joined together by chemical bonds.

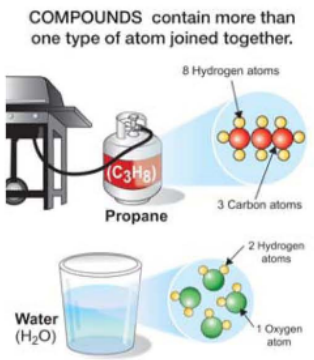


Figure 8.4: *Examples of compounds.*

Classifying matter

Pure substances Matter can be divided into two categories: pure substances and mixtures. A **pure substance** cannot be separated into different kinds of matter by physical means such as sorting, filtering, heating, or cooling. Elements and compounds are pure substances. Examples include water, table salt, gold, and oxygen.

Mixtures contain more than one kind of matter A mixture contains a combination of different elements and/or compounds. All mixtures share one common property: They can be separated into different types of matter by physical means such as sorting, filtering, heating, or cooling. For example, cola is a mixture that can be separated into carbonated water, corn syrup, caramel color, phosphoric acid, natural flavors, and caffeine.

A homogeneous mixture is the same throughout

A **homogeneous mixture** is the same throughout. In other words, all samples of a homogeneous mixture are the same. For example, an unopened can of cola is a homogeneous mixture. The cola in the top of the unopened can is the same as the cola at the bottom. Once you open the can, however, carbon dioxide will escape from the cola making the first sip a little different from your last sip. Brass is another example of a homogeneous mixture. It is made of 70 percent copper and 30 percent zinc. If you cut a brass candlestick into ten pieces, each piece would contain the same percentage of copper and zinc.

Two samples of a heterogeneous mixture could be different A **heterogeneous mixture** is one in which different samples are not necessarily made up of exactly the same proportions of matter. One common heterogeneous mixture is chicken noodle soup (Figure 8.5). One spoonful might contain broth, noodles, and chicken, while another contains only broth. Can you think of a way to separate this mixture?

VOCABULARY

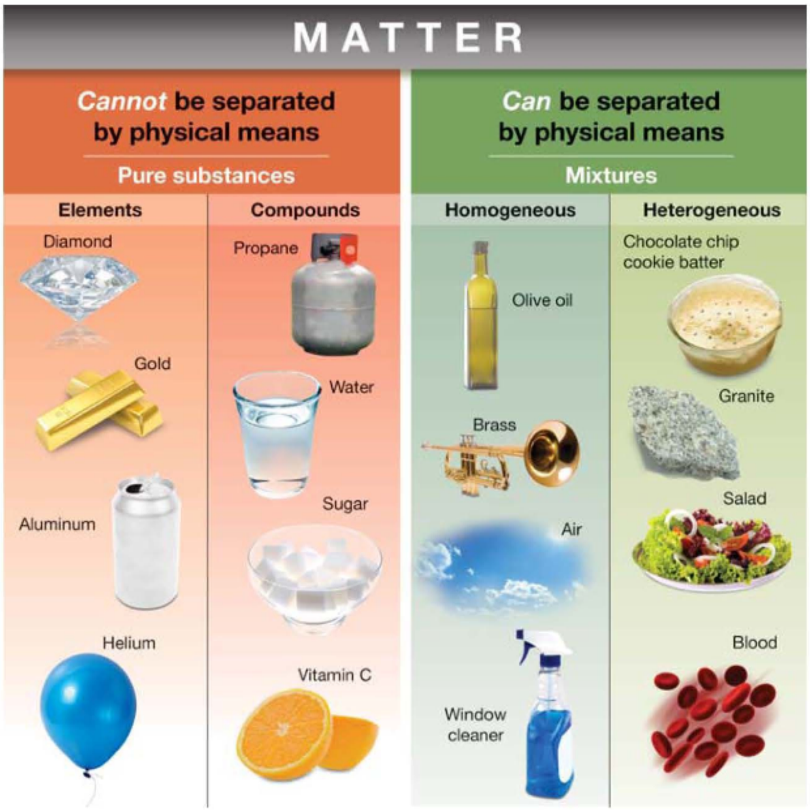
pure substance - matter that cannot be separated into other types of matter by physical means. Includes all elements and compounds.

homogeneous mixture - a mixture that is the same throughout. All samples of a homogeneous mixture are the same.

heterogeneous mixture - a mixture in which different samples are not necessarily made up of the same proportions of matter.

Figure 8.5: *Chicken soup is a heterogeneous mixture.*

Summary



JOURNAL

Keep track of at least 20 types of matter you use in one day. List each item and classify it according to the diagram at the left. You may need to do some research for some of your items. Make a poster showing how the matter you used is classified. Use pictures from the Internet or magazines.

STUDY SKILLS

A graphic organizer is a chart that shows how ideas and topics are related. Draw a graphic organizer that depicts the diagram to the left.

Section 8.1 Review

1. Explain why Brownian motion provides evidence for the existence of atoms and molecules.
2. Describe the difference between elements, compounds, and mixtures.
3. Which would be easier to separate, a mixture or a compound? Explain your answer.
4. Give an example of an element, a compound, and a mixture. Use examples that are not mentioned in the reading.
5. Identify each of the following as element, compound, homogeneous mixture, or heterogeneous mixture. Explain your reasoning for each.
   a. milk
   b. iron nail
   c. glass
   d. sugar
   e. bottled spring water
   f. distilled water
   g. air
   h. metal bicycle frame
   i. propane
   j. baking soda
6. Most things you use every day are:
   a. compounds
   b. elements
   c. mixtures
7. Your teacher has mixed salt, pepper, and water. Describe a procedure that you could use to separate this mixture. Be sure to list all of the materials you would need, your set up, and your expected results.

BIOGRAPHY

Edouard Benedictus

In 1903, a French chemist named Edouard Benedictus dropped a glass flask in the lab. The flask was full of cracks, but surprisingly, the pieces did not scatter across the floor. The shape of the flask remained intact. The flask had been used to store a compound called *cellulose nitrate*. Although the chemical had evaporated, it left a plastic film on the inside of the glass. Initially, Benedictus tried to sell his shatter-resistant glass to automobile manufacturers but they weren't interested. During World War I, he sold it for use in gas mask lenses. Soon after the war, the auto industry began using his glass.