5.1 The Classification of Matter

Chemistry is the study of matter. **Matter** is anything that has mass and volume. **Mass** is the amount of matter that an object has. **Volume** is the amount of space that an object fills. How many different examples of matter can you count in the classroom? Did you include the air and the glass in the windows? Air and glass both have mass and volume. Matter is not limited to your immediate surroundings. It is the material that makes up the whole universe (Figure 1).

Figure 1 Matter is anything that has mass and volume, whether or not you can see it. The air and clouds (a), a paramecium (b), desks (c), and the trees, rocks, and water (d) in Cayoosh Creek, B.C. are all matter.

Is there anything that is not matter? What do you think? What about sound or light or heat? These are not matter—they are forms of energy, and although they do not take up space or have mass, they are present in your environment.

All matter can be classified according to the diagram in Figure 2:

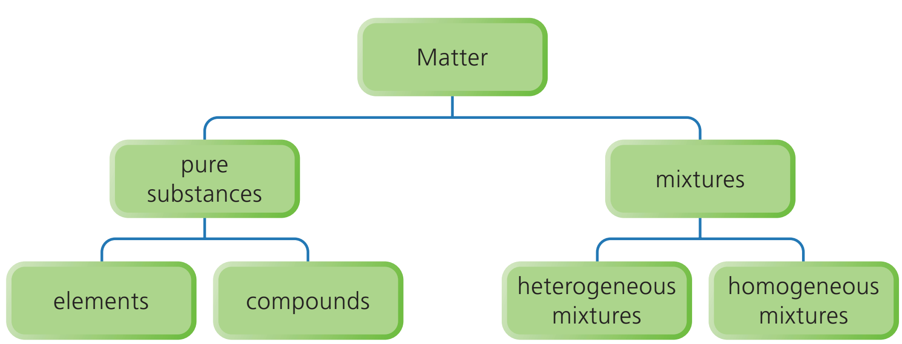


Figure 2 A tree diagram showing the classification of matter

Pure Substances

All matter can be classified as pure substances or mixtures. A **pure substance** is matter that contains only one type of particle. For example, copper wire is made from only copper particles. Water is a pure substance that contains only water particles. A **mixture** contains two or more pure substances, such as table salt dissolved in water, or iron mixed with sulfur.

Pure substances can be further classified as elements or compounds. Elements are the basic building blocks of matter. An **element** is a pure substance that cannot be changed into anything simpler. An element contains only one kind of particle. By 1000 BCE, the physical properties of some of the metal elements (such as copper, zinc, silver, and gold) were understood, but none of these were recognized yet as elements (Figure 3). Today, we know that there are at least 116 elements.

LEARNING TIP

Active readers ask questions to check their understanding of new terms. Ask yourself, "Can I tell the meaning of the words in bold on pages 153 and 154 from the sentences in which they are found?"

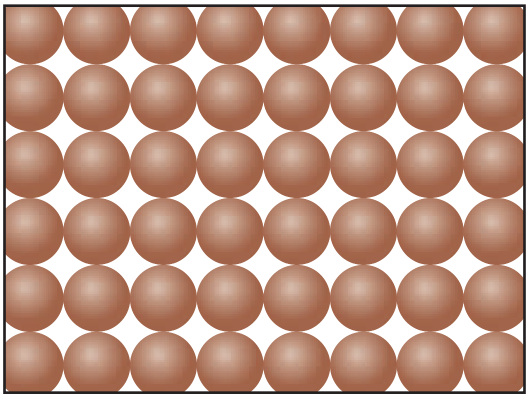


Figure 3 Copper is an element with only one kind of particle.

A **compound** is a pure substance that consists of two or more elements. The elements are in definite proportions and cannot be separated by physical means. For example, water always has two parts hydrogen to one part oxygen. Compounds have only one kind of particle, but each particle consists of two or more elements that are chemically joined (Figure 4).

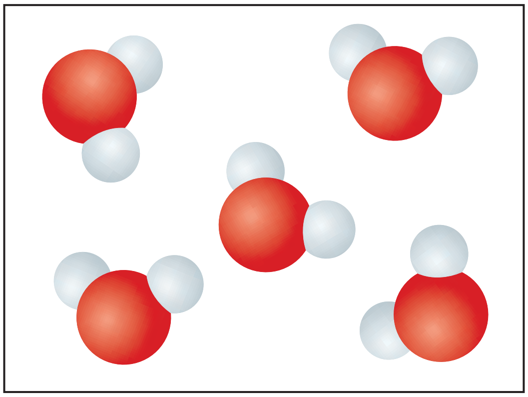


Figure 4 Water is a compound that has only one kind of particle. Compound particles are made from elements that are chemically joined.

Remember that elements and compounds are considered to be pure substances because they both contain only one kind of particle. For convenience, the term "substance" is often used by chemists to mean the proper term "pure substance."

Mixtures

Mixtures are formed when two or more pure substances are put together but their particles are not chemically joined. Also, the pure substances may be present in any proportions. Different fertilizers, for example, may just be mixtures of the same pure substances in different proportions (Figure 5).

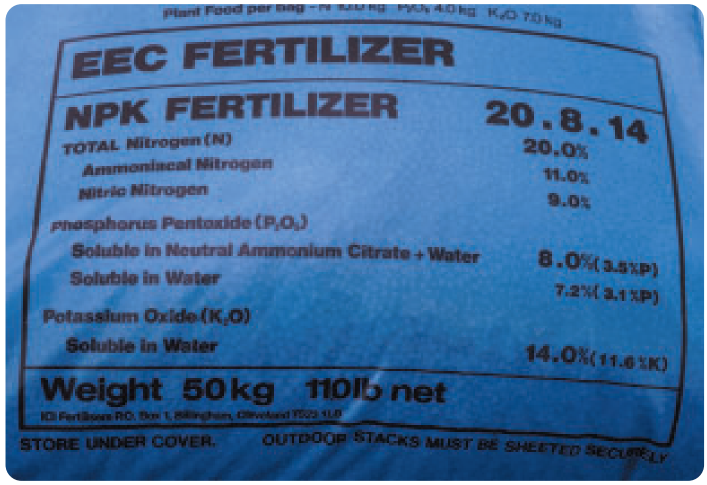


Figure 5 The numbers on a bag of fertilizer show the percentage by weight of each substance in the bag. This bag is 20 % nitrogen, 8 % phosphate (phosphorous pentoxide), and 14 % potash (potassium oxide). Other bags of fertilizer can have the same substances but in different percentages, such as 12-6-6, 24-5-11, or 30-10-10. The remaining percentage is filler.

LEARNING TIP

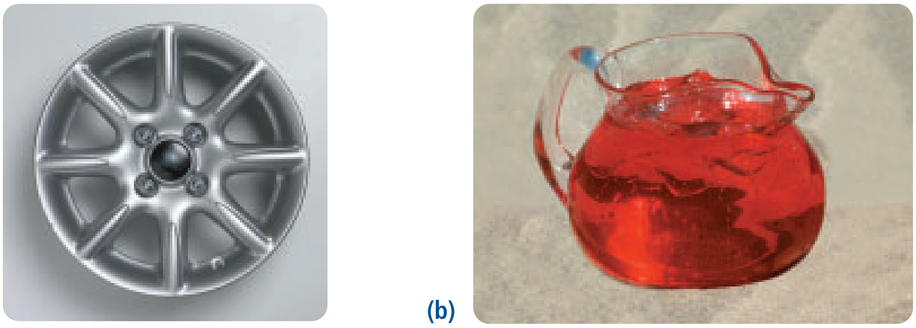
The prefix *hetero* indicates "difference." The prefix *homo* indicates "sameness." How will this help you understand the differences between heterogeneous and homogeneous mixtures?

A **heterogeneous mixture** is a mixture that is not uniform in its composition. The particles of the substances exist in large, visible clumps. This means that the components of heterogeneous mixtures can be visibly distinguished (Figure 6). For example, oil and water is a heterogeneous mixture, as is sulfur and iron.

(a) **(b)**

Figure 6 In a heterogeneous mixture, you can see the different substances that make up the mixture. In (a), you can see rocks of different sizes embedded in the cement. In (b), you can see the different layers of the salad dressing. One layer is oil and the other is vinegar based.

A **homogeneous mixture** is made of substances that are evenly and microscopically mixed together. The particles of the pure substances in a homogeneous mixture are separate but indistinguishable from each other. Solutions are examples of homogeneous mixtures of liquids and/or gases. For example, soda pop is a solution of sugar, corn syrup, and carbon dioxide gas in water. The air you breathe is a solution of oxygen, nitrogen, and small amounts of other gases. Alloys are homogeneous mixtures of solids. Alloys of metals are often stronger or harder than either of the component metals (Figure 7).



(a) (b)

Figure 7 You cannot see the different substances that make up a homogenous mixture. For example, you cannot see the different metals that make up the car wheel in (a) or the substances that make up the drink in (b).

Did You KNOW?

Mixtures in Electronics

The circuits in a music player or cell phone are highly dependent on mixtures of pure substances. Many electronic circuits consist of 99.999 % pure silicon, which does not conduct electricity. The electrical properties of the circuits are made possible by adding tiny amounts of impurities which make controlled conduction possible.

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TRY THIS: *Comparing Mixtures and Compounds*

Skills Focus: conducting, observing, recording, analyzing, inferring

Materials: letter-size blank sheet of paper, thin cardboard slightly bigger than paper, spoon or spatula, powdered sulfur, coarse powdered iron, 2 medium test tubes, 2 stoppers, 1 test tube rack, magnet, safety goggles, apron, 5 mol/L dilute hydrochloric acid, sample of heated sulfur and iron

Use caution when working with hydrochloric acid. Even dilute acid is corrosive. Wash all surfaces that come in contact with this substance.

1. Draw four large circles, one in each quarter of a piece of blank paper, and label them A, B, C, and D. Place the paper on the cardboard. Measure approximately 2 mL of sulfur onto circle A, and measure another 2 mL into a test tube. Measure approximately 2 mL of coarse powdered iron onto circle B, and 2 mL into the test tube with the sulfur. Put a stopper in the test tube and shake well.
2. Pour half of the mixture from the test tube onto circle C. Lift the cardboard a little and place the end of the magnet under the sulfur, and then under the iron (Figure 8). Move the magnet under each circle. What happens?
3. Place the magnet under the mixture and move it. What happens?
4. Put on your safety goggles and apron. Carefully add two or three drops of hydrochloric acid to the mixture left in the test tube. What do you observe?

Figure 8

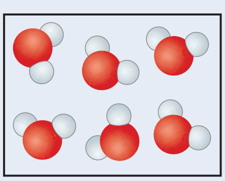
5. Your teacher will give you a sample of a mixture of iron and sulfur that has been heated and then ground into a fine powder. Put part of this sample on circle D and the rest into a second test tube.
6. Place the magnet under the sample in circle D and move it. What happens?
7. Carefully add two or three drops of hydrochloric acid to the sample in the second test tube. What do you observe?
8. Clean up your work area as instructed by your teacher. Wash your hands and all glassware carefully.

A. Which substance—the substance in circle C or the substance in circle D—is a mixture? Which one is a compound? How do you know?

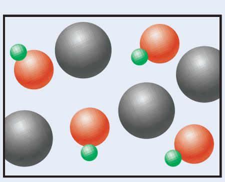
5.1 CHECK YOUR Understanding

1. What are the characteristics of matter?
2. What are the two classifications of pure substances? How are they similar? How are they different?
3. Give two examples of each of the following:
   (a) an element
   (b) a compound
   (c) a homogeneous mixture
   (d) a heterogeneous mixture
4. Use the terms "element," "compound," "homogenous mixture," or "heterogenous mixture" to classify the following substances:
   (a) iron
   (b) the air you breathe
   (c) soda pop
   (d) distilled water
5. If all the particles in a material are made up of several smaller particles, and every larger particle is identical, is the material a pure substance or not? Explain your reasoning.
6. In the Middle Ages, most scientists believed that the world was made from four simple elements and that almost everything was a mixture. Which type of pure substance had they not yet discovered?
7. What does each of the following diagrams represent: an element, mixture, or compound? Explain your choice.

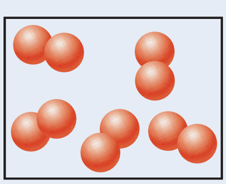
(a)



(b)

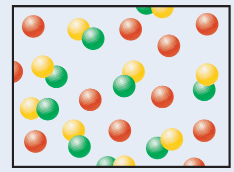


(c)

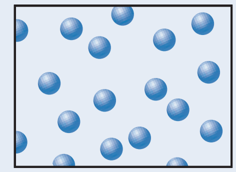


8. Which of the following diagrams might represent a mixture? Why?

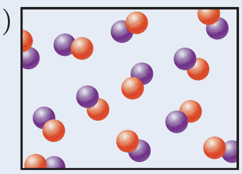
(a)



(c)

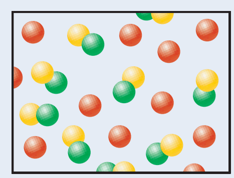


(b)

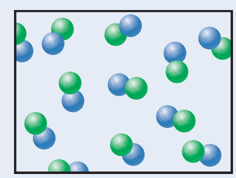


9. Which of the following diagrams might represent an element? Why?

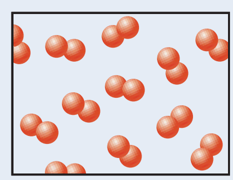
(a)



(c)



(b)



10. Identify each of the following as an element, mixture, or compound.
    (a) salt
    (b) silver
    (c) seawater
    (d) hydrogen
    (e) gasoline
    (f) water
11. Is blood a mixture? Explain your reasoning.
12. An unknown, clear liquid is given to you in a beaker. You transfer some of the liquid from the beaker to a clean, empty test tube, and begin to heat it. Soon, you observe a vapour leaving the top of the test tube. With further analysis you discover that the vapour is water vapour. Eventually, all that's left are a few crystals stuck to the sides of the test tube. Was the original liquid an element, a compound, or a mixture? Explain your reasoning.
13. A shiny magnesium ribbon is burned in air, to form a greyish powder called magnesium oxide. Is this oxide an element, a compound, or a mixture? Explain your thinking.