▲ Gold and diamond are elements in that they each consist of only one type of atom.

3

Elements of Chemistry

THE MAIN IDEA

Elements combine to form compounds, which blend together to form mixtures.

Chapter 1 introduced 9 key terms, Chapter 2 provided 28, and in this chapter you'll find another 26. Why all these new terms? In the laboratory, chemists perform experiments, make many observations, and then draw conclusions. Over time, the result is a growing body of new knowledge that inevitably exceeds the capacity of everyday language. New terms are needed as we attempt to describe the nature of matter beyond its casual appearance.

Instead of just memorizing the formal definitions of terms, you will serve yourself better by making sure that you understand the underlying concepts. Practice articulating and paraphrasing these concepts aloud to yourself or to a friend without looking at the book. When you are able to express these concepts in your own words, you will have the insight to do well in this course and beyond.

Chemistry

HANDS ON

The Fire-Extinguishing Gas

You likely know that baking soda and vinegar combine to form a froth of bubbles. But what is the nature of the gas within these bubbles?

PROCEDURE

1. Wearing your safety goggles, add about a teaspoon of baking soda to a tall glass.
2. Place tape on the outside of the glass one-third of the way up from the bottom of the glass.
3. Slowly add about a tablespoon of white distilled vinegar to the baking soda. Allow the bubbles to subside before adding additional tablespoons of the vinegar. Do not fill the glass with vinegar beyond the taped mark.
4. Remove all flammable materials from around the glass, especially paper towels.
5. Light a wooden match and dip the flame into the mouth of the glass. At some point the flame should be extinguished. Drop the match into the glass if it does not go out.

ANALYZE AND CONCLUDE

1. At what level inside the glass is the flame extinguished? If others are doing this with you, do their matches go out at the same level? Are you able to raise and lower the flame right at the point where the flame is about to be extinguished? Your glass is not sealed on top, so why doesn't the invisible gas it contains escape?
2. Is there a limit to the number of times a flame can be extinguished by this gas? If you were to tilt the glass part way so that no liquid poured out, would anything else pour out? How might you tell?
3. Did the gas in the glass exist before you added the vinegar to the baking soda? Is this gas heavier or lighter than air? How else is this gas different from the air we breathe?

3.1 Matter Has Physical and Chemical Properties

EXPLAIN THIS

Why are physical changes typically easier to reverse than chemical changes?

LEARNING OBJECTIVE

Describe how materials can be identified by their physical and chemical properties.

Properties that describe the look or feel of a substance, such as color, hardness, density, texture, and phase, are called **physical properties.** Every substance has its own set of characteristic physical properties that we can use to identify that substance (**Figure 3.1**)

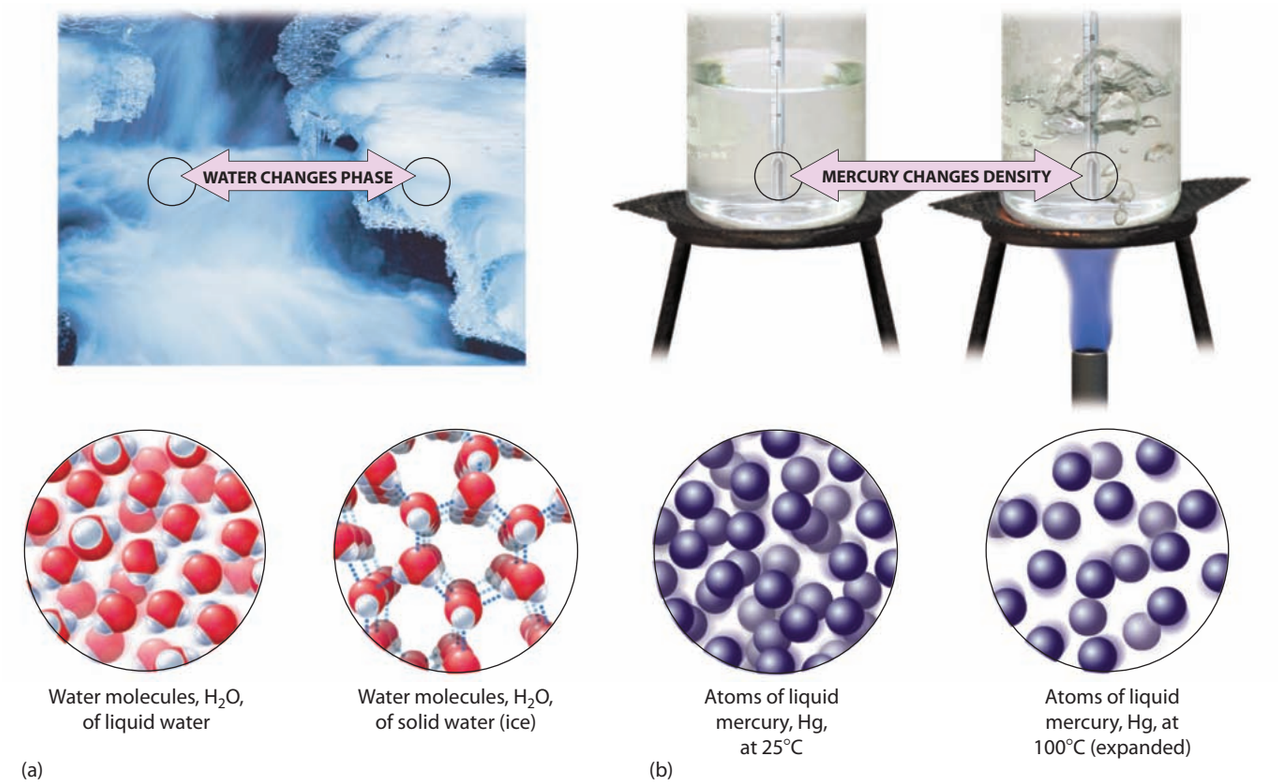
The physical properties of a substance can change when conditions change, but that does not mean a different substance is created. Cooling liquid water to below 0°C causes the water to change to ice, but the substance is still water, no matter what the phase. The only difference is how the H_2O molecules are arranged and how rapidly they are moving. In the liquid phase, the water molecules tumble around one another, whereas in the ice phase, they vibrate about fixed positions. Water freezing is an example of what chemists call a physical change. During a **physical change,** a substance changes its phase or some other physical property but not its chemical identity. As shown in **Figure 3.2**, water in either the liquid or solid phase is still made of water

▼ **Figure 3.1**
Gold, diamond, and water can be identified by their physical properties.

Gold
Opacity: opaque
Color: yellowish
Phase at 25°C: solid
Density: 19.3 g/mL

Diamond
Opacity: transparent
Color: colorless
Phase at 25°C: solid
Density: 3.5 g/mL

Water
Opacity: transparent
Color: colorless
Phase at 25°C: liquid
Density: 1.0 g/mL



▲ **Figure 3.2**
Two physical changes. (a) Liquid water and ice might appear to be different substances, but at the submicroscopic level, it is evident that both consist of water molecules. (b) At 25°C, the atoms in a sample of mercury are a certain distance apart, yielding a density of 13.5 grams per milliliter. At 100°C, the atoms are farther apart, meaning that each milliliter now contains fewer atoms than at 25°C, and the density is now 13.4 grams per milliliter. The physical property we call density has changed with temperature, but the identity of the substance remains unchanged: mercury is mercury.

molecules. Likewise, the density of elemental mercury, Hg, decreases with increasing temperature because its atoms become spaced farther apart—but the mercury is still made of mercury atoms.

Chemical properties are those that characterize the ability of a substance to react with other substances or to transform from one substance to another. **Figure 3.3** shows three examples. One chemical property of methane, the main component of natural gas, is that it reacts with oxygen to produce carbon dioxide and water, along with appreciable heat energy. Similarly, it is

▶ **Figure 3.3**
The chemical properties of substances determine the ways in which they can change into new substances. Natural gas and baking soda, for example, can both undergo chemical reactions in which they are transformed into carbon dioxide and water. Similarly, copper can be transformed into patina.

Methane
Reacts with oxygen to form carbon dioxide and water, giving off lots of heat during the reaction.

Baking soda
Reacts with vinegar to form carbon dioxide and water, absorbing heat during the reaction.

Copper
Reacts with carbon dioxide and water to form the greenish-blue substance called patina.