1.2: States of Matter

Learning Objectives

- Describe the different physical states of matter; solid, liquid, and gas.
- Understand how external conditions can affect the states of matter.

Water can take many forms. At low temperatures (below $0^{o}C$), it is a solid. When at "normal" temperatures (between $0^{o}C$ and $100^{o}C$), it is a liquid. While at temperatures above $100^{o}C$, water is a gas (steam). The state the water is in depends upon the temperature. Each state (solid, liquid, and gas) has its own unique set of physical properties.

Figure 1.2.1: Matter is usually classified into three classical states. From left to right: quartz (solid), water (liquid), nitrogen dioxide (gas).

Matter typically exists in one of three states: **solid**, **liquid**, or **gas** and these different states of matter have different properties (Table 1.2.1):

- A **gas** is a state of matter in which atoms or molecules have enough energy to move freely. The molecules come into contact with one another only when they randomly collide. Forces between atoms or molecules are not strong enough to hold them together.
- A **liquid** is a state of matter in which atoms or molecules are constantly in contact but have enough energy to keep changing positions relative to one another. Forces between atoms or molecules are strong enough to keep the molecules relatively close together but not strong enough to prevent them from moving past one another.
- A **solid** is a state of matter in which atoms or molecules do not have enough energy to move. They are constantly in contact and in fixed positions relative to one another. Forces between atoms or molecules are strong enough to keep the molecules together and to prevent them from moving past one another.

The state a given substance exhibits is a physical property. Some substances exist as gases at room temperature (oxygen and carbon dioxide), while others, like water and mercury metal, exist as liquids. Most metals exist as solids at room temperature. All substances can exist in any of these three states. Figure 1.2.2 shows the differences among solids, liquids, and gases at the molecular level. A solid has definite volume and shape, a liquid has a definite volume but no definite shape, and a gas has neither a definite volume nor shape (Table 1.2.1).

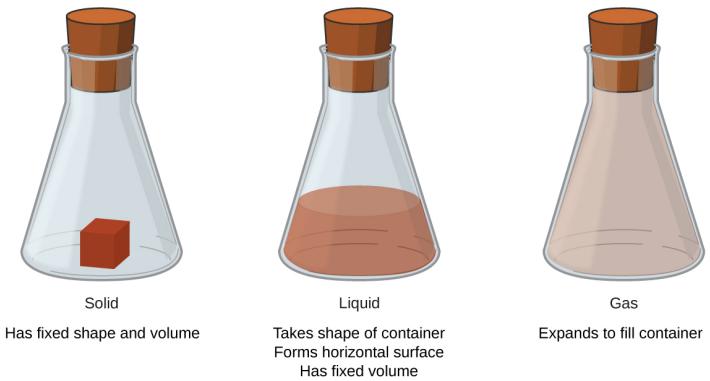

Figure 1.2.2: The three most common states or phases of matter are solid, liquid, and gas. (CC BY-4.0; OpenStax)

A beaker labeled solid contains a cube of red matter and says has fixed shape and volume. A beaker labeled liquid contains a brownish-red colored liquid. This beaker says takes shape of container, forms horizontal surfaces, has fixed volume. The beaker labeled gas is filled with a light brown gas. This beaker says expands to fill container.

These three descriptions each imply that the matter has certain physical properties when in these states. A solid has a definite shape and a definite volume. Liquids ordinarily have a definite volume but not a definite shape; they take the shape of their containers. Gases have neither a definite shape nor a definite volume, and they expand to fill their containers. We encounter matter in each phase every day; in fact, we regularly encounter water in all three phases: ice (solid), water (liquid), and steam (gas).

Table 1.2.1: Characteristics of each Phase of Matter

	Gas	Liquid	Solid
Shape	no definite shape (takes the shape of its container)	no definite shape (takes the shape of its container)	definite shape (rigid)
Volume	particles move in random motion with little or no attraction to each other	has definite volume	definite volume
Mobility	particles move in random motion with little or no attraction to each other	particles are free to move over each other, but are still attracted to each other	particles vibrate around fixed axes
Compressibility	highly compressible	weakly compressible	weakly compressible

Adding energy to matter gives its atoms or molecules the ability to resist some of the forces holding them together. For example, heating ice to its **melting point** gives its molecules enough energy to move. The ice melts and becomes liquid water. Similarly, heating liquid water to its **boiling point** gives its molecules enough energy to pull apart from one another so they no longer have contact. The liquid water vaporizes and becomes water vapor.

State of Matter Depends on the External Conditions

The temperature of the melting and boiling points depend on the identity of the substance and the atmospheric pressure. Each substance has its own boiling and melting points that depend on the properties of the substance. As an example, the values for water are given in Table 1.2.2. Note how the boiling point of water varies greatly with pressure.

Table 1.2.1: Boiling point of water as a function of pressure

Altitude (ft)	Pressure (atm)	Boiling Point (^{o}C)
-500	1.05	100.5
0	1.00	100
4000	0.892	96
7000	0.797	93

✔ Example 1.2.1

Isopropyl alcohol is a colorless, flammable chemical compound with a strong odor. Its melting point is –89°C and it boiling point is 82.5°C. Is isopropyl alcohol a solid, liquid or gas at room temperature (25°C)?

Solution

Room temperature (25°C) is above the melting point of isopropyl alcohol (–89°C), but lower than its boiling point (82.5°C), therefore, it is a **liquid** at room temperature.

? Exercise 1.2.1

Freon-12 is used as a refrigerant and aerosol spray propellant. Its melting point is –157.7°C and it boiling point is –29.8 °C. Is Freon-12 a solid, liquid or gas at room temperature (25°C).

Answer

> Freon-12 is a **gas** at room temperature

Key Takeaways

- Matter exists in different physical states.
- Changes in conditions such as temperature and pressure can allow matter to change state.

Contributors and Attributions

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