SECTION 2

Behavior of Gases

Suppose you are watching a parade that you have been looking forward to for weeks. You may be fascinated by the giant balloons floating high overhead.

You may wonder how the balloons were arranged for the parade. How much helium was needed to fill all of the balloons? What role does the weather play in getting the balloons to float?

What You Will Learn

- Describe three factors that affect how gases behave.
- Predict how a change in pressure or temperature will affect the volume of a gas.

Vocabulary

temperature
volume
pressure
Boyle's Law
Charles's Law

READING STRATEGY

Reading Organizer As you read this section, make a table comparing the effects of temperature, volume, and pressure on gases.

Describing Gas Behavior

Helium is a gas. Gases behave differently from solids or liquids. Unlike the particles that make up solids and liquids, gas particles have a large amount of empty space between them. The space that gas particles occupy is the gas's volume, which can change because of temperature and pressure.

Temperature

How much helium is needed to fill a parade balloon, like the one in **Figure 1?** The answer depends on the outdoor temperature. **Temperature** is a measure of how fast the particles in an object are moving. The faster the particles are moving, the more energy they have. So, on a hot day, the particles of gas are moving faster and hitting the inside walls of the balloon harder. Thus, the gas is expanding and pushing on the walls of the balloon with greater force. If the gas expands too much, the balloon will explode. But, what will happen if the weather is cool on the day of the parade? The particles of gas in the balloon will have less energy. And, the particles of gas will not push as hard on the walls of the balloon. So, more gas must be used to fill the balloons.

temperature a measure of how hot (or cold) something is; specifically, a measure of the movement of particles.

Figure 1 *To properly inflate a helium balloon, you must consider the temperature outside of the balloon.*

Volume

Volume is the amount of space that an object takes up. But because the particles of a gas spread out, the volume of any gas depends on the container that the gas is in. For example, have you seen inflated balloons that were twisted into different shapes? Shaping the balloons was possible because particles of gas can be compressed, or squeezed together, into a smaller volume. But, if you tried to shape a balloon filled with water, the balloon would probably explode. It would explode because particles of liquids can't be compressed as much as particles of gases.

volume a measure of the size of a body or region in three-dimensional space

pressure the amount of force exerted per unit area of a surface

Pressure

The amount of force exerted on a given area of surface is called **pressure.** You can think of pressure as the number of times the particles of a gas hit the inside of their container.

The balls in **Figure 2** are the same size, which means they can hold the same volume of air, which is a gas. Notice, however, that there are more particles of gas in the basketball than in the beach ball. So, more particles hit the inside surface of the basketball than hit the inside surface of the beach ball. When more particles hit the inside surface of the basketball, the force on the inside surface of the ball increases. This increased force leads to greater pressure, which makes the basketball feel harder than the beach ball.

Reading Check **Why is the pressure greater in a basketball than in a beach ball?** (*See the Appendix for answers to Reading Checks.*)

INTERNET ACTIVITY

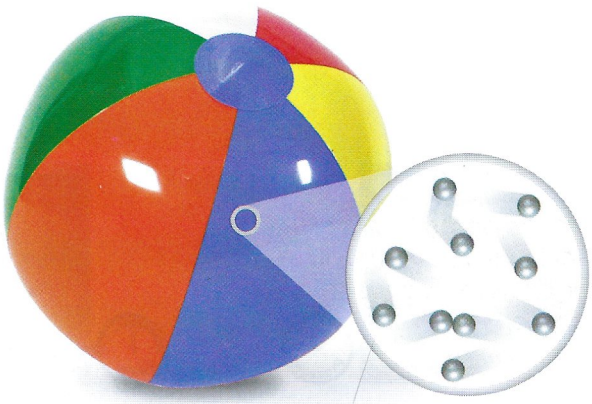
For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5STAW**.

Figure 2 **Gas and Pressure**

High pressure

The basketball has a higher pressure because there are more particles of gas in it, and they are closer together. The particles collide with the inside of the ball at a faster rate.

Low pressure



The beach ball has a lower pressure because there are fewer particles of gas, and they are farther apart. The particles in the beach ball collide with the inside of the ball at a slower rate.

Gas Behavior Laws

Scientists found that the temperature, pressure, and volume of a gas are linked. Changing one of the factors changes the other two factors. The relationships between temperature, pressure, and volume are described by gas laws.

Boyle's Law

Imagine that a diver 10 m below the surface of a lake blows a bubble of air. When the bubble reaches the surface, the bubble's volume has doubled. The difference in pressure between the surface and 10 m below the surface caused this change.

The relationship between the volume and pressure of a gas was first described by Robert Boyle, a 17th-century Irish chemist. The relationship is now known as Boyle's law. **Boyle's law** states that for a fixed amount of gas at a constant temperature, the volume of the gas is inversely related to the pressure. So, as the pressure of a gas increases, the volume decreases by the same amount, as shown in **Figure 3.**

Boyle's law the law that states that the volume of a gas is inversely proportional to the pressure of a gas when temperature is constant

Charles's law the law that states that the volume of a gas is directly proportional to the temperature of a gas when pressure is constant

Charles's Law

If you blow air into a balloon and leave it in the hot sun, the balloon might pop. **Charles's law** states that for a fixed amount of gas at a constant pressure, the volume of the gas changes in the same way that the temperature of the gas changes. So, if the temperature increases, the volume of gas also increases by the same amount. Charles's law is shown by the model in **Figure 4.**

Reading Check State Charles's law in your own words.

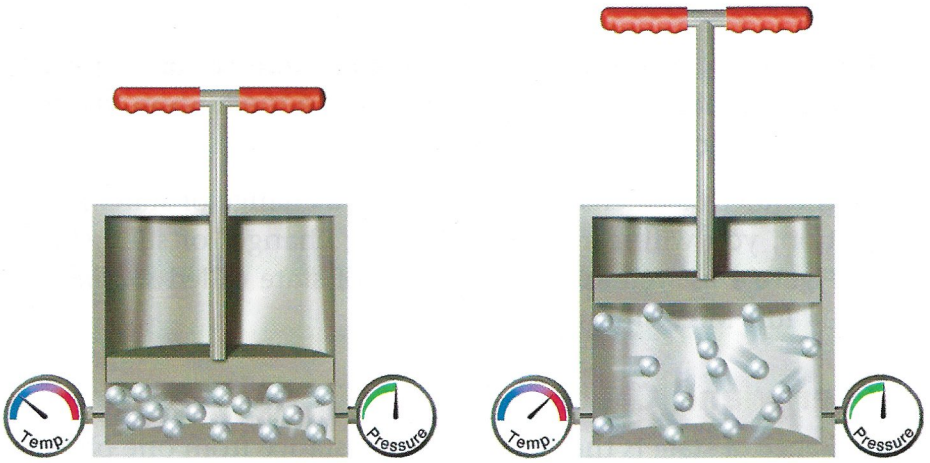
Figure 3 Boyle's Law

Lifting the piston lets the particles of gas spread far apart. The volume of the gas increases as the pressure decreases.

Releasing the piston allows the particles of gas to return to their original volume and pressure.

Pushing the piston forces the gas particles close together. The volume of the gas decreases as the pressure increases.

Figure 4 Charles's Law



Decreasing the temperature of the gas causes the particles to move more slowly. The gas particles hit the piston less often and with less force. So, the volume of the gas decreases.

Increasing the temperature of the gas causes the particles to move more quickly. The gas particles hit the piston more often and with greater force. So, the volume of the gas increases.

SECTION Review

Summary

- Temperature measures how fast the particles in an object are moving.
- Gas pressure increases as the number of collisions of gas particles increases.
- Boyle's law states that if the temperature doesn't change, the volume of a gas increases as the pressure decreases.
- Charles's law states that if the pressure doesn't change, the volume of a gas increases as the temperature increases.

Using Key Terms

1. Use each of the following terms in the same sentence: *temperature, pressure, volume,* and *Charles's law.*

Understanding Key Ideas

2. Boyle's law describes the relationship between
   - **a.** volume and pressure.
   - **b.** temperature and pressure.
   - **c.** temperature and volume.
   - **d.** All of the above
3. What are the effects of a warm temperature on gas particles?

Math Skills

4. You have 3 L of gas at a certain temperature and pressure. What would the volume of the gas be if the temperature doubled and the pressure stayed the same?

Critical Thinking

5. **Applying Concepts** What happens to the volume of a balloon that is taken outside on a cold winter day? Explain.
6. **Making Inferences** When scientists record a gas's volume, they also record its temperature and pressure. Why?
7. **Analyzing Ideas** What happens to the pressure of a gas if the volume of gas is tripled at a constant temperature?

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