9.5 Relationships: Pressure, Volume, and Temperature

When you push a plunger in a sealed container, it compresses the air in the cylinder into a smaller volume. When a gas is under pressure in a closed system, its volume is decreased significantly (Figure 1). When liquids are under pressure, their volumes decrease as well; however, the decrease in volume is so small that it is barely noticeable. This is because particles of a liquid are much closer together than particles of a gas.

LINKING TO LITERACY

Reading Diagrams

Use the following strategies to gain the best understanding of a diagram.

- Read the caption. It will give details about the diagram.
- Scan the diagram. Make sure you notice all details.
- Follow the arrows that point to parts of the illustration.
- Make connections between the words in the caption and the information in the diagram.

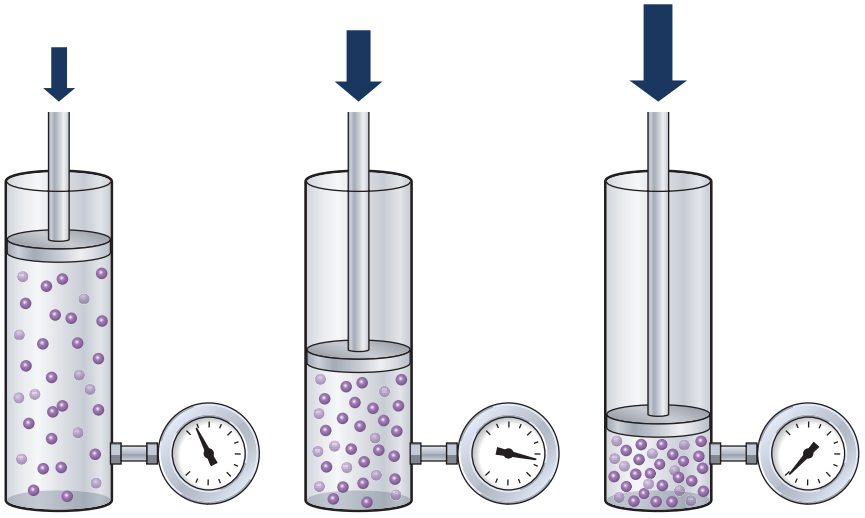

Figure 1 Increasing the pressure on a gas in a closed system reduces its volume significantly.

We use this property of fluids when we compress gases into scuba tanks and other rigid containers (Figure 2). All of these containers have a large amount of gas compressed into a small volume. As more gas particles are forced into the rigid container, the number of collisions between particles and the sides of the container increases. This increases the pressure that the gas particles exert on the interior walls of the container. The container is made of strong material (usually metal), so it does not burst. Why are most containers that hold gases under pressure curved?

If you have ever used a hand pump to fill a bicycle tire, you may have noticed that the barrel of the pump warms up. Some warming is due to friction between the piston and the cylinder walls. Rapidly pushing in the plunger of the pump also forces the air into a smaller volume. This compression causes more collisions among the particles of air and between the particles and the cylinder walls. This increase in collisions not only causes the pressure to increase, it also causes the temperature to rise. Conversely, increasing the volume causes the temperature to drop.

Figure 2 Pressure has been used to force a large amount of gas into a small volume in these welders' tanks.

For more information on the uses and process of compressing gases,
Go to Nelson Science

TRY THIS: Observing the Effects of Temperature Change on a Fluid

SKILLS MENU: questioning, hypothesizing, performing, observing, analyzing, communicating

SKILLS HANDBOOK 2.B.1., 2.B.3.

In this activity, you will change the temperature of the air in a bottle and observe the effects on the volume of air in the bottle.

Equipment and Materials: plastic pop or water bottle; balloon; 2 containers; hot water; ice water

1. Read over the entire activity. In your notebook, write a testable question you will attempt to answer. Once you have written the question, write a hypothesis based on your question. Your hypothesis should include a prediction and the reasons for your prediction.
2. Stretch the opening of a deflated balloon over the mouth of an empty pop or water bottle.
3. Immerse the upright bottle up to its neck in a container of hot water. Record what happens.
4. Remove the bottle and immerse it up to its neck in a container of ice water. Record your observations.

A. What happened to the volume of air as you heated and then cooled the bottle?

B. Did your observations support your hypothesis? Explain.

C. If your observations did not support your hypothesis, try to explain your observations using the particle theory.

D. Answer your testable question.

As temperature increases, the particles of a fluid move faster and farther apart. This causes the fluid to expand. As the temperature of a fluid drops, its volume decreases (contracts). This is generally true for all forms of matter. (As you saw in Chapter 8, water between 0 °C and 4 °C is a special case that does not follow this pattern.) Thermometers use this principle of thermal expansion during heating and thermal contraction during cooling to give us accurate temperature readings (Figure 3).

Figure 3 The principle of expansion and contraction of fluids has been used in thermometers for centuries.

Figure 4 shows a familiar warning sign. Why is heating aerosol containers so dangerous? As the temperature inside the pressurized can increases, so does the speed of the particles. As the particles move faster, they hit the inside walls of the can with increased force, causing the pressure on the walls to build up. Eventually, the pressure could become so great that the walls of the container explode.

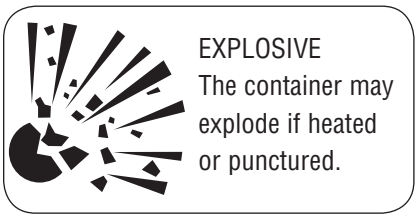

Figure 4 Aerosol cans and other containers of compressed gas are extremely dangerous when heated, due to the danger of explosion.

In the opposite way, decreasing the temperature causes particles to slow down and move closer together. There will be fewer collisions with the sides of the container, and the pressure inside the container will drop.

Unit Task Will you need to consider relationships between temperature, pressure, and volume when designing your toy? Why or why not?

CHECK YOUR LEARNING

1. What happens to the volume of a gas in a cylinder when you try to compress it? Use a diagram in your explanation.
2. How is the property of compressibility of gases used in everyday life? Give an example.
3. Explain why the barrel of a bicycle pump heats up when you use it to pump a tire.
4. Why is heating an aerosol can so dangerous?