3.2 The Gas Laws

Reading Focus

Key Concepts

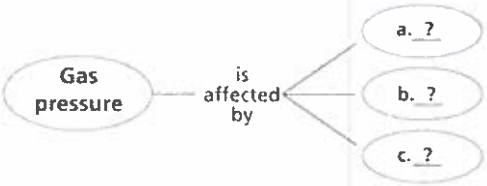
- What causes gas pressure in a closed container?
- What factors affect gas pressure?
- How are the temperature, volume, and pressure of a gas related?

Vocabulary

- pressure
- absolute zero
- Charles's law
- Boyle's law

Reading Strategy

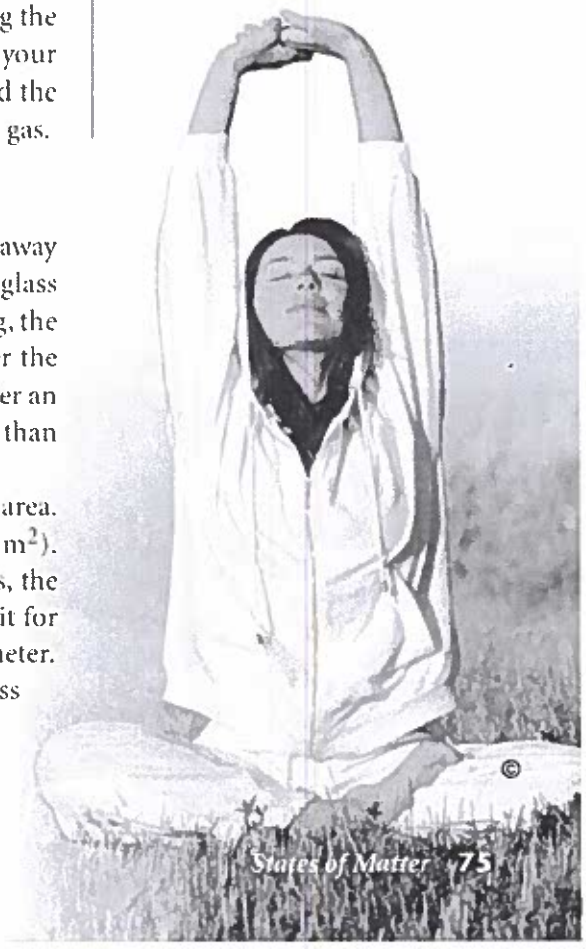
Identifying Cause and Effect Copy the diagram. As you read, identify the variables that affect gas pressure.



The woman in Figure 10 is taking a deep breath. This action helps reduce her breathing rate and increase the volume of air she inhales. When you inhale, the volume of your chest cavity increases and air moves into your lungs. When you exhale, the volume of your chest cavity decreases and air is pushed out of your lungs.

After you read this section, you will understand how changing the volume of your chest cavity causes air to move into and out of your lungs. Changes in the volume, the temperature, the pressure, and the number of particles have predictable effects on the behavior of a gas.

Figure 10 Taking a deep breath increases the volume of your chest cavity, which causes air to move into your lungs.



Pressure

At many hockey rinks, a layer of shatterproof glass keeps the puck away from the spectators. The force with which the puck hits the glass depends on the speed of the puck. The faster the puck is traveling, the greater the force is. The smaller the area of impact is, the greater the pressure produced. Pressure is the result of a force distributed over an area. If the edge of the puck hits the glass, it exerts more pressure than if the face of the puck hits the glass at the same speed.

The SI unit of pressure is derived from SI units for force and area. Force is measured in newtons (N) and area in square meters (m^2). When a force in newtons is divided by an area in square meters, the unit of pressure is newtons per square meter (N/m^2). The SI unit for pressure, the pascal (Pa), is shorthand for newtons per square meter. One pascal is a small amount of pressure. Scientists often express larger amounts of pressure in kilopascals. One kilopascal (kPa) is equal to 1000 pascals.

An object does not need to be as large as a hockey puck to exert pressure when it collides with another object. Recall that the helium atoms in a balloon are constantly moving. The pressure produced by a single helium atom colliding with a wall is extremely small. However, there are more than 10^{22} helium atoms in a small balloon. When so many particles collide with the walls of a container at the same time, they produce a measurable pressure.

Collisions between particles of a gas and the walls of the container cause the pressure in a closed container of gas. The more frequent the collisions, the greater the pressure of the gas is. The speed of the particles and their mass also affect the pressure.

Reading Checkpoint *How does the frequency of collisions affect the pressure of a gas?*

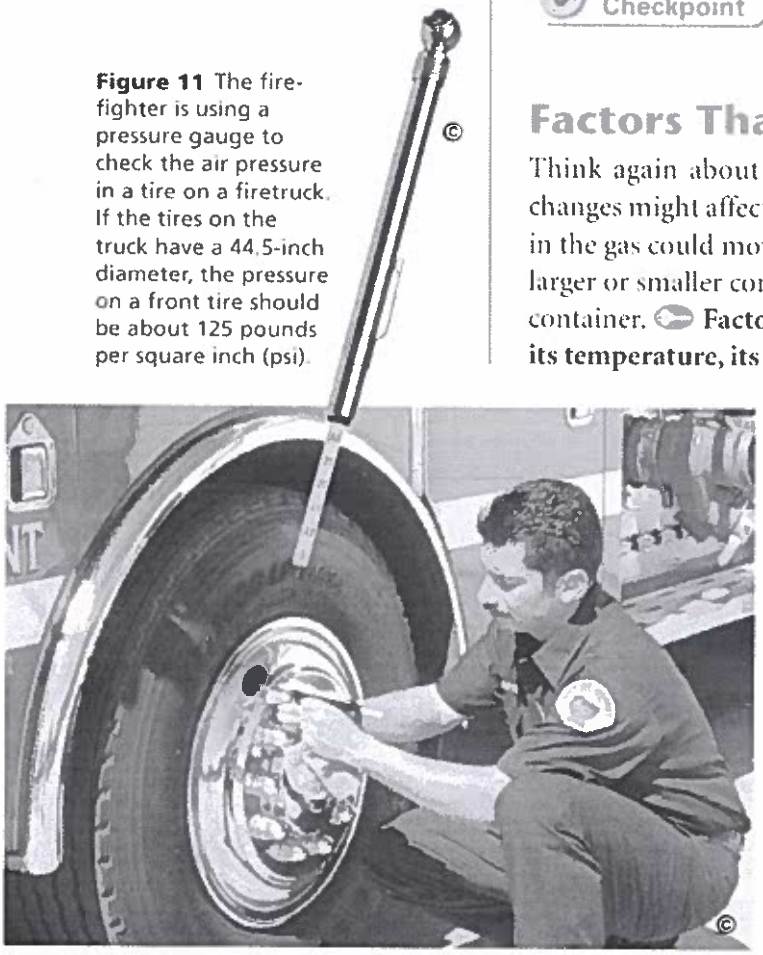


Figure 11 The firefighter is using a pressure gauge to check the air pressure in a tire on a firetruck. If the tires on the truck have a 44.5-inch diameter, the pressure on a front tire should be about 125 pounds per square inch (psi).

Factors That Affect Gas Pressure

Think again about the collisions that produce gas pressure. What changes might affect the pressure of a gas in a container? The particles in the gas could move faster or slower. The gas could be moved into a larger or smaller container. You could add gas or remove gas from the container. **Factors that affect the pressure of an enclosed gas are its temperature, its volume, and the number of its particles.**

Temperature Suppose you are about to go on a long drive. The driver suspects that the air pressure in the automobile tires might be low. You check the pressure in each tire, using a pressure gauge like the one in Figure 11. You find that the measurements are well within the automobile manufacturer's guidelines. If you checked the tire pressures again after a few hours on the highway, would you be surprised to find that the pressure in the tires had increased?

The constant motion of tires on the highway causes the tires and the air in the tires to warm up. As the temperature rises, the average kinetic energy of the particles in the air increases. With increased kinetic energy, the particles move faster and collide more often with the inner walls of the tires. The faster-moving particles also hit the walls with greater force. The increase in the number of collisions along with the increase in the force of the collisions causes an increase in the pressure of the air in the tires. **Raising the temperature of a gas will increase its pressure if the volume of the gas and the number of particles are constant.**

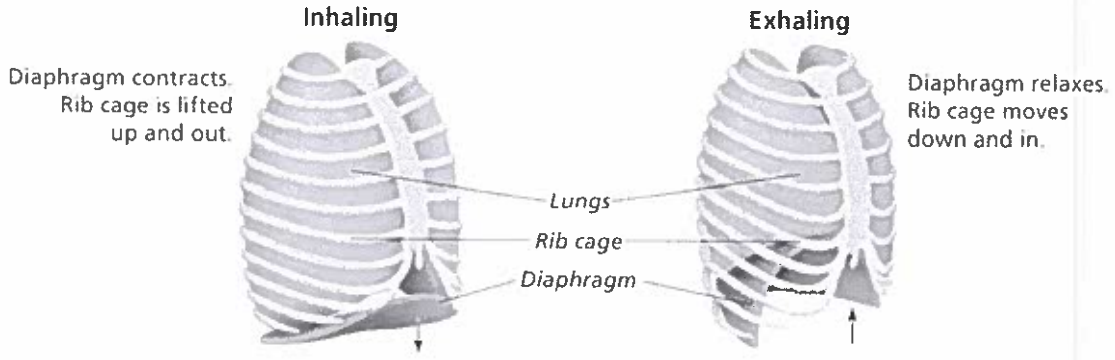


Figure 12 Movement of a muscle called the diaphragm changes the volume of your chest cavity. The volume increases when you inhale and decreases when you exhale.
Interpreting Diagrams ***How does the movement of your rib cage affect the volume of your chest cavity?***

Volume Imagine that you have a plastic bottle that appears empty. If you twist the cap onto the bottle and then squeeze the bottle, what will happen? At first, the plastic will give a little, reducing the volume of the bottle. But soon you will feel pressure from inside the bottle resisting your efforts to further reduce the volume. The pressure you feel is a result of the increased pressure of the air trapped inside the bottle. As the volume is decreased, particles of trapped air collide more often with the walls of the bottle. **Reducing the volume of a gas increases its pressure if the temperature of the gas and the number of particles are constant.**

Figure 12 shows how the relationship between volume and pressure explains what happens when you breathe. As you inhale, a muscle called the diaphragm (DY uh fram) contracts. The contraction causes your chest cavity to expand. This temporary increase in volume allows the particles in air to spread out, which lowers the pressure inside the chest cavity. Because the pressure of the air outside your body is now greater than the pressure inside your chest, air rushes into your lungs.

When you exhale, your diaphragm relaxes and the volume of your chest cavity decreases. The particles in the air are squeezed into a smaller volume and the pressure inside your lungs increases. Because the pressure of the air inside your chest is now greater than the pressure of the air outside your body, air is forced out of your lungs.

Number of Particles You can probably predict what will happen to the pressure when you add more gas to a container. Think about a tire. Once the tire is inflated, its volume is fairly constant. So adding more air will increase the pressure inside the tire. The more particles there are in the same volume, the greater the number of collisions and the greater the pressure. At some point the rubber from which the tire is made will not be strong enough to withstand the increased pressure and the tire will burst. **Increasing the number of particles will increase the pressure of a gas if the temperature and the volume are constant.**

It is harder for scientists to do a controlled experiment when they are studying events that occur in natural settings. Scientists need laws like the combined gas law to deal with situations in which multiple variables are changing. Balloons like the one in Figure 14 are used by scientists to gather data about Earth's atmosphere. The balloon is filled with hydrogen or helium. It carries a package of weather instruments up into the atmosphere. The instruments measure temperature, pressure, and water content at different levels in the atmosphere.

What will happen to the volume of the weather balloon as it rises through the atmosphere? Both pressure and temperature decrease as the altitude increases in Earth's atmosphere. A decrease in external pressure should cause the balloon to expand to a larger volume. A decrease in temperature should cause the balloon to contract to a smaller volume. Whether the balloon actually expands or contracts depends on the size of the changes in pressure and temperature.

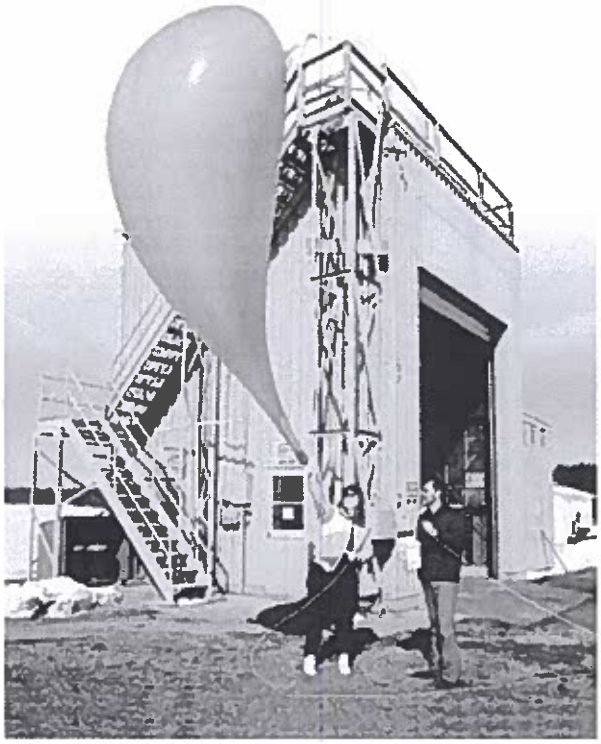


Figure 14 These scientists are releasing a weather balloon into the atmosphere. The balloon is designed to burst when it reaches an altitude of about 27,400 meters.
Drawing Conclusions ***What happens to the pressure inside a weather balloon as it rises?***

Section 3.2 Assessment

Reviewing Concepts

HINT 1. How is the gas pressure produced in a closed container of gas?

HINT 2. What three factors affect gas pressure?

HINT 3. How does increasing the temperature affect the pressure of a contained gas?

HINT 4. What happens to the pressure of a gas if its volume is reduced?

HINT 5. How does increasing the number of particles of a contained gas affect its pressure?

Critical Thinking

HINT 6. **Predicting** What happens to the pressure in a tire if air is slowly leaking out of the tire? Explain your answer.

HINT 7. **Comparing and Contrasting** What do Boyle's law and Charles's law have in common? How are they different?

HINT 8. **Applying Concepts** Some liquid products are sold in aerosol cans. Gas is stored in a can under pressure and is used to propel the liquid out of the can. Explain why an aerosol can should never be thrown into a fireplace or incinerator.

Math Practice

9. Two liters of hydrogen gas are stored at a pressure of 100 kPa. If the temperature does not change, what will the volume of the gas be when the pressure is decreased to 25 kPa?

10. You know that a gas in a sealed container has a pressure of 111 kPa at 23°C. What will the pressure be if the temperature rises to 475°C?