Gases

What You'll Learn

- You will use gas laws to calculate how pressure, temperature, volume, and number of moles of a gas will change when one or more of these variables is altered.
- You will compare properties of real and ideal gases.
- You will apply the gas laws and Avogadro's principle to chemical equations.

Why It's Important

From barbecuing on a gas grill to taking a ride in a hot-air balloon, many activities involve gases. It is important to be able to predict what effect changes in pressure, temperature, volume, or amount, will have on the properties and behavior of a gas.

Chemistry Online

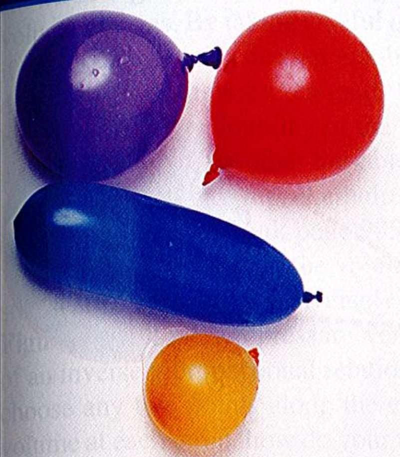
Visit the Glencoe Chemistry Web site at **chemistrymc.com** to find links about gases.

Firefighters breathe air that has been compressed into tanks that they can wear on their backs.

DISCOVERY LAB

More Than Just Hot Air

How does a temperature change affect the air in a balloon?



Safety Precautions

Always wear goggles to protect eyes from broken balloons.

Procedure

1. Inflate a round balloon and tie it closed.
2. Fill the bucket about half full of cold water and add ice.
3. Use a string to measure the circumference of the balloon.
4. Stir the water in the bucket to equalize the temperature. Submerge the balloon in the ice water for 15 minutes.
5. Remove the balloon from the water. Measure the circumference.

Materials

5-gal bucket
round balloon
ice
string

Analysis

What happens to the size of the balloon when its temperature is lowered? What might you expect to happen to its size if the temperature is raised?

Section 14.1 The Gas Laws

Objectives

- **State** Boyle's law, Charles's law, and Gay-Lussac's law.
- **Apply** the three gas laws to problems involving the pressure, temperature, and volume of a gas.

Vocabulary

Boyle's law
Charles's law
Gay-Lussac's law

The manufacturer of the air tank in the photo on the opposite page had to understand the nature of the gases the tank contains. Understanding gases did not happen accidentally. The work of many scientists over many years has contributed to our present knowledge of the nature of gases. The work of three scientists in particular was valuable enough that laws describing gas behavior were named in their honor. In this section, you'll study three important gas laws: Boyle's law, Charles's law, and Gay-Lussac's law. Each of these laws relates two of the variables that determine the behavior of gases—pressure, temperature, volume, and amount of gas present.

Kinetic Theory

You can't understand gases without understanding the movement of gas particles. Remember from your study of the kinetic-molecular theory in Chapter 13 that gas particles behave differently than those of liquids and solids. The kinetic theory provides a model that is used to explain the properties of solids, liquids, and gases in terms of particles that are always in motion and the forces that exist between them. The kinetic theory assumes the following concepts about gases are true.

- *Gas particles do not attract or repel each other.* Gases are free to move within their containers without interference from other particles.
- *Gas particles are much smaller than the distances between them.* You saw in the **DISCOVERY LAB** that gas has volume. However, the kinetic theory assumes that gas particles themselves have virtually no volume.

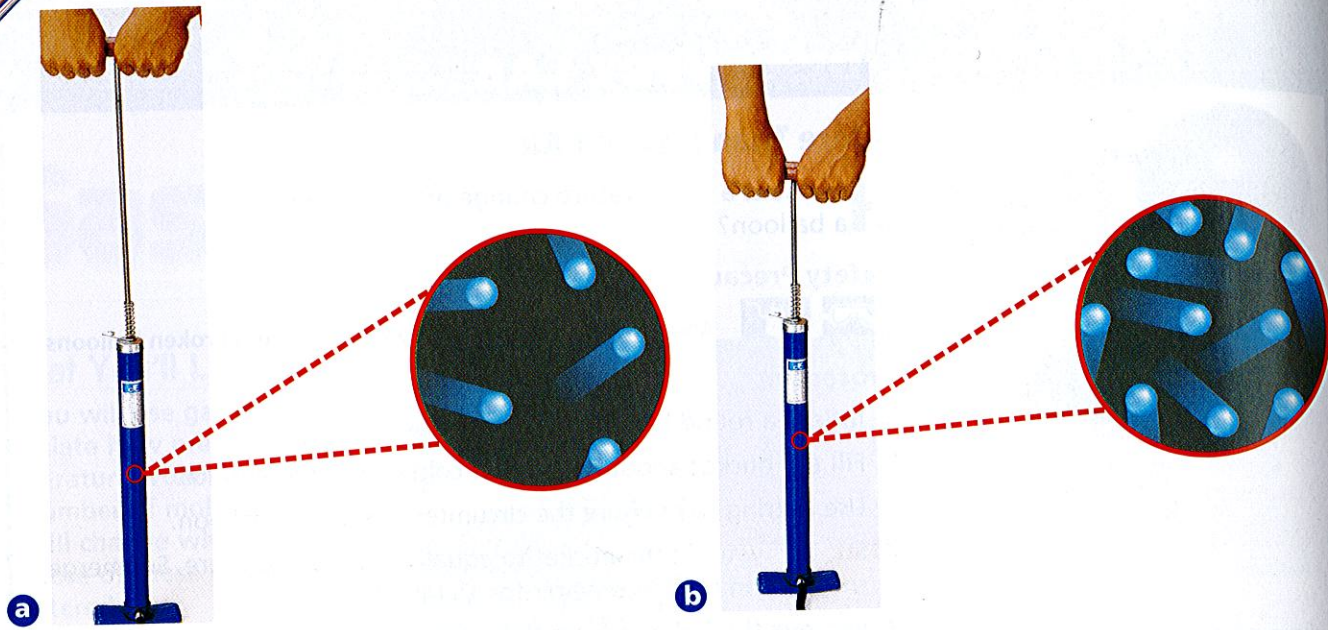


Figure 14-1

The kinetic theory relates pressure and the number of collisions per unit time for a gas.
a When the bicycle pump is pulled out as far as it will go, the pressure of the air inside the pump equals that of the atmosphere.
b If the piston is pushed down half the length of the pump, the air particles are squeezed into a space half the original size. Pressure doubles because the frequency of collisions between the gas particles and the inner wall of the pump has doubled.

Almost all the volume of a gas is empty space. Gases can be compressed by moving gas particles closer together because of this low density of particles.

- *Gas particles are in constant, random motion.* Gas particles spread out and mix with each other because of this motion. The particles move in straight lines until they collide with each other or with the walls of their container.
- *No kinetic energy is lost when gas particles collide with each other or with the walls of their container.* Such collisions are completely elastic. As long as the temperature stays the same, the total kinetic energy of the system remains constant.
- *All gases have the same average kinetic energy at a given temperature.* As temperature increases, the total energy of the gas system increases. As temperature decreases, the total energy of the gas system decreases.

The nature of gases Actual gases don't obey all the assumptions made by the kinetic theory. But for many gases, their behavior approximates the behav-

LESSON

9 Air Force

Air Pressure

Think About It

There is a layer of air surrounding Earth nearly 80 miles thick called the atmosphere. It is made up predominantly of colorless, odorless gases, which you can move through. The air molecules are tiny and they are spaced far apart, so most of the time it feels as if nothing is there. However, the weight of all that air above you exerts a great deal of pressure on you.

What evidence do we have that gases exert pressure?

To answer this question, you will explore

1. Evidence of Air Pressure
2. Explanation for Air Pressure
3. The Atmosphere

Exploring the Topic

1 Evidence of Air Pressure

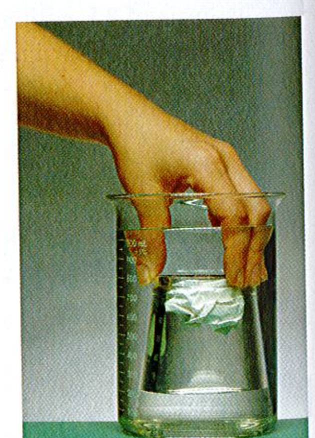
When you fill the tires on your car with air, the rubber is stretched quite tightly. The pressure exerted by the air in the tires is large enough to push the entire car up off the ground. Indeed, the air pressure is holding up more than 2000 pounds. How can air be so powerful?

The ability of automobile tires to remain inflated while holding up so much weight provides evidence that air is pushing on the inside of the tire in all directions. This "pushing" property of a gas is called **pressure.** Pressure is defined as a force over a specific surface area. A gas exerts pressure on all surfaces it comes in contact with.

There are many ways to demonstrate that gases exert pressure on the things around them. Here are two examples.

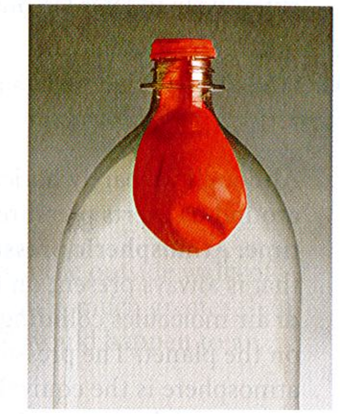
Submerged Paper

When a plastic cup is turned upside-down and submerged in water, the paper inside the cup stays dry. There is air trapped in the cup that pushes out in all directions. The air pushes on the water with enough pressure to keep the water out of the cup.



Balloon in a Bottle

Suppose you try to blow up a balloon inside a bottle. Even with a great deal of effort, the balloon will inflate only a tiny bit. The balloon does not inflate because there is air inside the bottle. Even though it looks like "nothing is there," the bottle is full of air, and when you try to inflate the balloon, you are pushing on this air, which takes a lot of work!

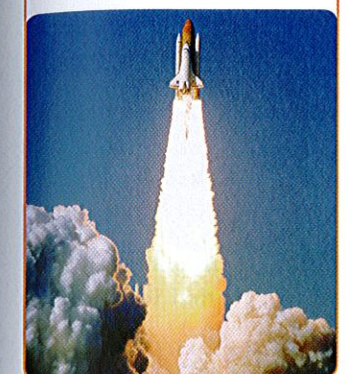


ASTRONOMY CONNECTION

Atmospheric pressure varies from planet to planet. On Venus, for instance, the atmosphere is much denser than on Earth. The atmospheric pressure is 90 atm at the surface of Venus. This would crush a human being. On Mars, however, the atmospheric pressure at the surface is just 0.007 atm. On either Venus or Mars, you would need a very good pressure suit to keep your body at the pressure it is used to.

PHYSICS CONNECTION

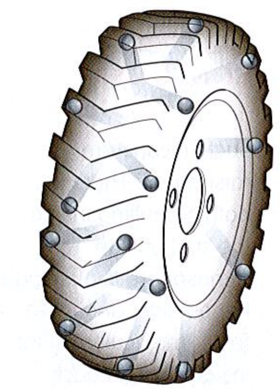
A gas can even push against another gas. In fact, gas with a high pressure pushes the space shuttle into the air.



2 Explanation for Air Pressure

Collisions of gas molecules with surrounding objects are what we experience as air pressure. There are huge numbers of molecules in an automobile tire, many more than are shown in the illustration. The tiny push from each one adds up to a lot, enough to hold a car up.

The pressure of the air inside your tires is expressed in pounds per square inch, or lb/in^2. This unit is sometimes written as *psi*, for pounds per square inch. That is, each square inch of surface area on the tire experiences a certain number of pounds of force from the air inside. A tire on a racing bicycle might be inflated to a pressure of 100 lb/in^2.



A tire filled with air is firm because the air molecules are colliding with the inside walls of the tire, thereby pushing the walls out.

Example

Air Pressure in Car Tires

Suppose a car weighs 2000 pounds. Each of the four tires touches the road over an area that is about a 4-by-4-inch square. What air pressure do you need in each tire to hold up the car?

Solution

Each of the four tires needs to push up ¼ of the 2000 pounds, or 500 pounds. A 4-by-4-inch square has an area of 16 in^2, so each tire is in contact with a 16 in^2 area of the ground. Pressure is force per unit area.

$$\text{Pressure} = \text{force/area}$$
$$= 500 \text{ lb}/16 \text{ in}^2$$
$$= 31 \text{ lb/in}^2$$

The pressure in each tire needs to be at least 31 lb/in^2.

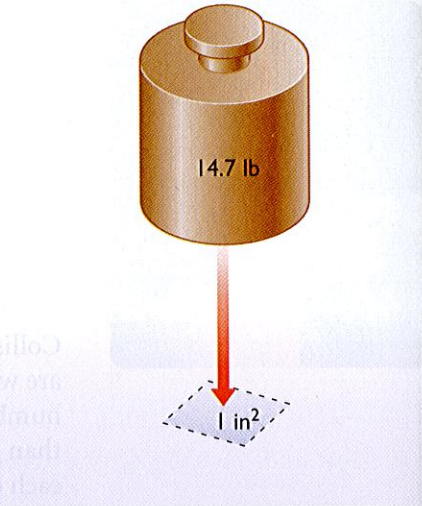
3 The Atmosphere

Earth's atmosphere is a mixture of gases, mostly nitrogen, with some oxygen, carbon dioxide, water vapor, and argon. This mixture of gases is what we call air.

The density of the Earth's atmosphere changes as you travel up in altitude—the air becomes thinner at higher elevations. This concept will be covered more extensively in later lessons.

BIG IDEA The atmosphere is a mixture of gases, including gaseous water.

Although we barely notice it, the air around us exerts pressure on us all the time. **Atmospheric pressure** is air pressure that is always present on Earth as a result of air molecules colliding with objects on the planet. The pressure due to the atmosphere is the equivalent of a 14.7-pound weight pushing on every square inch of surface. We say that the pressure due to the atmosphere is 14.7 pounds per square inch, or 14.7 lb/in^2. This pressure is measured at sea level.



Scientists also use a unit called an **atmosphere,** or **atm,** to measure air pressure.

CONSUMER CONNECTION

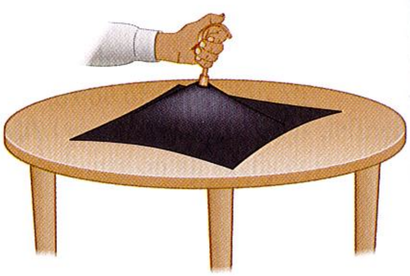
Suction cups are misnamed. There is nothing pulling inside the suction cup. The atmosphere is pushing on the outside, and there are fewer molecules on the inside to push back.

Atmospheric Pressure

At sea level and 25 °C, there is 1 atm of pressure.

$$1 \text{ atm} = 14.7 \text{ lb/in}^2$$

The pressure of the atmosphere played a role in all of the demonstrations you completed in class. The air pressure mat is particularly good at demonstrating how much pressure the air around us exerts on objects. If the mat has a surface area of 100 square inches and standard air pressure from the atmosphere is 14.7 lb/in^2, the total pressure on the mat from the air is 1,470 pounds! No wonder no one can lift it.



Lesson Summary

What evidence do we have that gases exert pressure?

The Earth is surrounded by an atmosphere of gases. We call this mixture of gases air. Although we cannot see it, the air around us exerts pressure. Gas molecules are constantly moving and colliding with anything they come in contact with. Air pressure is defined as the force over a surface area. This force is caused by the collisions of the gas molecules. Gas pressure is measured in pounds per square inch, lb/in^2, or in atmospheres, atm. At sea level and 25 °C, the atmospheric pressure is 14.7 lb/in^2, or 1 atm.

Key Terms

pressure
atmospheric pressure
atmosphere (atm)