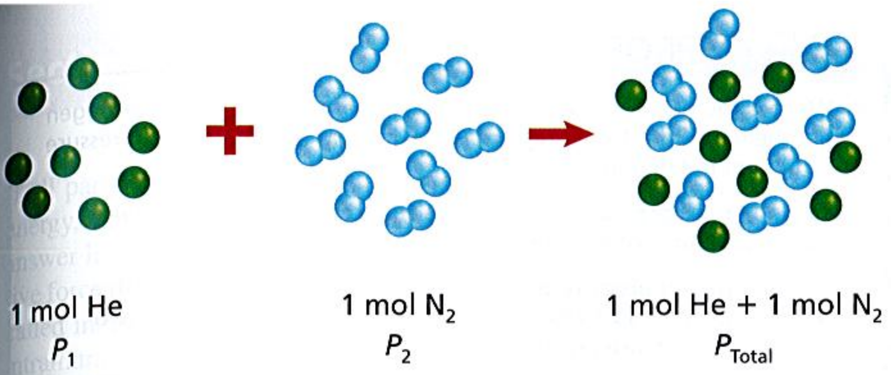


Figure 13-6

How do the partial pressures of nitrogen gas and helium gas compare when a mole of nitrogen gas and a mole of helium gas are in the same closed container? Refer to **Table C-1** in Appendix C for a key to atom color conventions.

Dalton's law of partial pressures When Dalton studied the properties of gases, he found that each gas in a mixture exerts pressure independently of the other gases present. **Dalton's law of partial pressures** states that the total pressure of a mixture of gases is equal to the sum of the pressures of all the gases in the mixture. The portion of the total pressure contributed by a single gas is called its partial pressure. The partial pressure of a gas depends on the number of moles of gas, the size of the container, and the temperature of the mixture. It does not depend on the identity of the gas. At a given temperature and pressure, the partial pressure of one mole of any gas is the same. Dalton's law of partial pressures can be summarized as

$$P_{total} = P_1 + P_2 + P_3 + \dots P_n$$

P_{total} represents the total pressure of a mixture of gases. P_1, P_2, and so on represent the partial pressures of each gas in the mixture. **Figure 13-6** shows what happens when one mole of helium and one mole of nitrogen are combined in a single closed container.

EXAMPLE PROBLEM 13-2

Finding the Partial Pressure of a Gas

A mixture of oxygen (O_2), carbon dioxide (CO_2), and nitrogen (N_2) has a total pressure of 0.97 atm. What is the partial pressure of O_2, if the partial pressure of CO_2 is 0.70 atm and the partial pressure of N_2 is 0.12 atm?

1. Analyze the Problem

You are given the total pressure of a mixture and the partial pressure of two gases in the mixture. To find the partial pressure of the third gas, use the equation that relates partial pressures to total pressure.

Known	Unknown
$P_{N_2} = 0.12$ atm	$P_{O_2} = ?$ atm
$P_{CO_2} = 0.70$ atm	
$P_{total} = 0.97$ atm	

2. Solve for the Unknown

Rearrange the equation to solve for the unknown value, P_{O_2}.

$P_{O_2} = P_{total} - P_{CO_2} - P_{N_2}$

$P_{O_2} = 0.97 \text{ atm} - 0.70 \text{ atm} - 0.12 \text{ atm}$

$P_{O_2} = 0.15$ atm

3. Evaluate the Answer

Adding the calculated value for the partial pressure of oxygen to the known partial pressures gives the total pressure 0.97 atm. The answer has two significant figures to match the data.

Practice!

For more practice with partial pressure problems, go to **Supplemental Practice Problems** in Appendix A.

PRACTICE PROBLEMS

4. What is the partial pressure of hydrogen gas in a mixture of hydrogen and helium if the total pressure is 600 mm Hg and the partial pressure of helium is 439 mm Hg?

5. Find the total pressure for a mixture that contains four gases with partial pressures of 5.00 kPa, 4.56 kPa, 3.02 kPa, and 1.20 kPa.

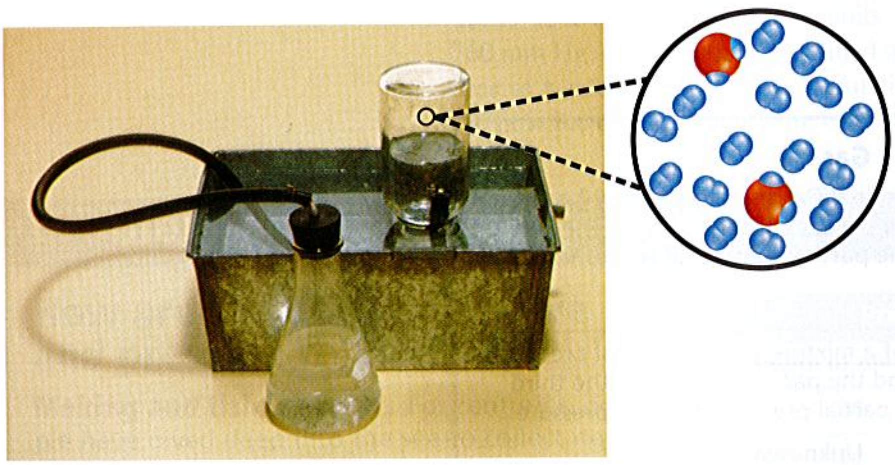
6. Find the partial pressure of carbon dioxide in a gas mixture with a total pressure of 30.4 kPa if the partial pressures of the other two gases in the mixture are 16.5 kPa and 3.7 kPa.

Dalton's law of partial pressures can be used to determine the amount of gas produced by a reaction. The gas produced is bubbled into an inverted container of water, as shown in **Figure 13-7.** As the gas collects, it displaces the water. The gas collected in the container will be a mixture of hydrogen and water vapor. Therefore, the total pressure inside the container will be the sum of the partial pressures of hydrogen and water vapor.

The partial pressures of gases at the same temperature are related to their concentration. The partial pressure of water vapor has a fixed value at a given temperature. You can look up the value in a reference table. At 20°C, the partial pressure of water vapor is 2.3 kPa. You can calculate the partial pressure of hydrogen by subtracting the partial pressure of water vapor from the total pressure. If the total pressure of the hydrogen and water mixture is 95.0 kPa, what is the partial pressure of hydrogen at 20°C?

Figure 13-7

In the flask, sulfuric acid (H_2SO_4) reacts with zinc to produce hydrogen gas. The hydrogen is collected at 20°C.



As you will learn in Chapter 14, knowing the pressure, volume, and temperature of a gas allows you to calculate the number of moles of the gas. Temperature and volume can be measured during an experiment. Once the temperature is known, the partial pressure of water vapor is used to calculate the pressure of the gas. The known values for volume, temperature, and pressure are then used to find the number of moles.

Section 13.1 Assessment

7. What assumption of the kinetic-molecular theory explains why a gas can expand to fill a container?

8. How does the mass of a gas particle affect its rate of effusion?

9. Suppose two gases in a container have a total pressure of 1.20 atm. What is the pressure of gas B if the partial pressure of gas A is 0.75 atm?

10. Explain how changes in atmospheric pressure affect the height of the column of mercury in a barometer.

11. **Recognizing Cause and Effect** Explain why a tire or balloon expands when air is added.

12. **Thinking Critically** Explain why the container of water must be inverted when a gas is collected by displacement of water.

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where X_A is called the mole fraction of A. The ***mole fraction*** is *a dimensionless quantity that expresses the ratio of the number of moles of one component to the number of moles of all components present.* In general, the mole fraction of component i in a mixture is given by

First Equation (Description above and below)

$$X_i = \frac{n_i}{n_T} \tag{5.13}$$

where n_i and n_T are the number of moles of component i and the total number of moles present, respectively. The mole fraction is always smaller than 1.

If a system contains more than two gases, then the partial pressure of the ith component is related to the total pressure by

Second Equation (Description below)

$$P_i = X_i P_T \tag{5.14}$$

How are partial pressures determined? A manometer can measure only the total pressure of a gaseous mixture. To obtain the partial pressures, we need to know the mole fractions of the components, which would involve elaborate chemical analyses. The most direct method of measuring partial pressures is using a mass spectrometer. The relative intensities of the peaks in a mass spectrum are directly proportional to the amounts, and hence to the mole fractions, of the gases present.

EXAMPLE 5.7

A mixture of gases contains 4.46 moles of neon (Ne), 0.74 mole of argon (Ar), and 2.15 moles of xenon (Xe). Calculate the partial pressures of the gases if the total pressure is 2.00 atm at a certain temperature.

(Continued)

Strategy What is the relationship between the partial pressure of a gas and the total gas pressure? How do we calculate the mole fraction of a gas?

Solution According to Equation (5.14), the partial pressure of Ne (P_{Ne}) is equal to the product of its mole fraction (X_{Ne}) and the total pressure (P_T)

need to find

$$P_{Ne} = X_{Ne} P_T$$

want to calculate given

Using Equation (5.13), we calculate the mole fraction of Ne as follows:

$$X_{Ne} = \frac{n_{Ne}}{n_{Ne} + n_{Ar} + n_{Xe}} = \frac{4.46 \text{ mol}}{4.46 \text{ mol} + 0.74 \text{ mol} + 2.15 \text{ mol}} = 0.607$$

Therefore

$$\begin{aligned} P_{Ne} &= X_{Ne} P_T \\ &= 0.607 \times 2.00 \text{ atm} \\ &= 1.21 \text{ atm} \end{aligned}$$

Similarly,

$$\begin{aligned} P_{Ar} &= X_{Ar} P_T \\ &= 0.10 \times 2.00 \text{ atm} \\ &= 0.20 \text{ atm} \end{aligned}$$

and

$$\begin{aligned} P_{Xe} &= X_{Xe} P_T \\ &= 0.293 \times 2.00 \text{ atm} \\ &= 0.586 \text{ atm} \end{aligned}$$

Check Make sure that the sum of the partial pressures is equal to the given total pressure; that is, (1.21 + 0.20 + 0.586) atm = 2.00 atm.

Similar problems: 5.57, 5.58.

Practice Exercise A sample of natural gas contains 8.24 moles of methane (CH_4), 0.421 mole of ethane (C_2H_6), and 0.116 mole of propane (C_3H_8). If the total pressure of the gases is 1.37 atm, what are the partial pressures of the gases?

Animation:
Collecting a Gas over Water
Online Learning Center, Animations