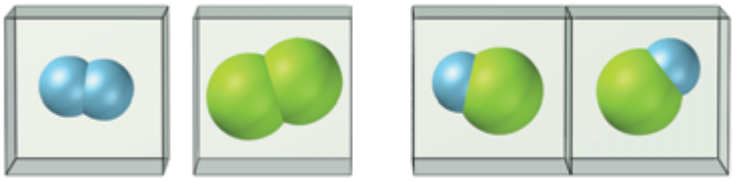

FIGURE 12 Hydrogen molecules combine with chlorine molecules in a 1:1 volume ratio to produce 2 volumes of hydrogen chloride. Avogadro's law thus demonstrates that hydrogen and chlorine gases are diatomic.

Consider the reaction of hydrogen and chlorine to produce hydrogen chloride, illustrated in **Figure 12.** According to Avogadro's law, equal volumes of hydrogen and chlorine contain the same number of molecules. Avogadro's idea of diatomic gases applies to this reaction also. He concluded that the hydrogen and chlorine components must each consist of two or more atoms joined together. The simplest assumption was that hydrogen and chlorine molecules are composed of two atoms each. That assumption leads to the following balanced equation for the reaction of hydrogen with chlorine.

$$\underset{\text{1 volume}\\\text{1 molecule}}{H_2(g)} + \underset{\text{1 volume}\\\text{1 molecule}}{Cl_2(g)} \longrightarrow \underset{\text{2 volumes}\\\text{2 molecules}}{2HCl(g)}$$

The simplest hypothetical formula for hydrogen chloride, HCl, indicates that the molecule contains one hydrogen atom and one chlorine atom. Given the ratios of the combined volumes, the simplest formulas for hydrogen and chlorine must be H_2 and Cl_2, respectively.

Chemistry in Action

Automobile Air Bags

Since the late 1980s, air bags have been offered as a safety feature in cars to minimize injuries in the event of a high-speed collision. Modern automobile air bags use a series of very rapid chemical reactions to inflate the bag. When a collision is detected by sensors, an igniter triggers decomposition of solid sodium azide, Na_3N, to form N_2 gas. The hazardous sodium metal that also forms reacts with KNO_3 to form Na_2O, also producing additional N_2. Finally, the highly reactive Na_2O is removed by reaction with SiO_2 to form harmless silicate glass. This entire sequence of reactions occurs to inflate the air bag with nitrogen gas in as few as 40 milliseconds (0.04 s) after a collision is detected by sensors.

Molar Volume of a Gas

Recall that one mole of a molecular substance contains a number of molecules equal to Avogadro's constant (6.022×10^{23}). One mole of oxygen, O_2, contains 6.022×10^{23} diatomic oxygen molecules and has a mass of 31.9988 g. One mole of helium, a monatomic gas, contains the same number of helium atoms and has a mass of 4.002 602 g.

According to Avogadro's law, one mole of any gas will occupy the same volume as one mole of any other gas at the same temperature and pressure, despite mass differences. *The volume occupied by one mole of a gas at STP is known as the* **standard molar volume of a gas.** *It has been found to be 22.414 10 L.* For calculations in this book, we use 22.4 L as the standard molar volume.

Knowing the volume of a gas, you can use 1 mol/22.4 L as a conversion factor to find the number of moles, and therefore the mass, of a given volume of a given gas at STP. You can also use the molar volume of a gas to find the volume, at STP, of a known number of moles or a known mass of a gas.