Avogadro's Law

Recall an important point of Dalton's atomic theory: atoms are indivisible. Dalton also thought that the particles of gaseous elements exist in the form of isolated single atoms. He believed that one atom of one element always combines with one atom of another element to form a single particle of the product. However, some of the volume relationships observed by Gay-Lussac could not be accounted for by Dalton's theory. For example, in reactions such as the formation of water vapor, mentioned on the preceding page, it would seem that the oxygen atoms involved would have to divide into two parts.

In 1811, Avogadro found a way to explain Gay-Lussac's simple ratios of combining volumes without violating Dalton's idea of indivisible atoms. He did this by rejecting Dalton's idea that reactant elements are always in monatomic form when they combine to form products. He reasoned that these molecules could contain more than one atom. Avogadro also put forth an idea known today as **Avogadro's law.** The law states that *equal volumes of gases at the same temperature and pressure contain equal numbers of molecules.* **Figure 11** illustrates Avogadro's law. It follows that at the same temperature and pressure, the volume of any given gas varies directly with the number of molecules. Avogadro's law also indicates that gas volume is directly proportional to the amount of gas, at a given temperature and pressure. Note the equation for this relationship.

$$V = kn$$

Here, n is the amount of gas, in moles, and k is a constant.

Avogadro's reasoning applies to the combining volumes for the reaction of hydrogen and oxygen to form water vapor. Dalton had guessed that the formula of water was HO, because this formula seemed to be the most likely formula for such a common compound. But Avogadro's reasoning established that water must contain twice as many H atoms as O atoms, consistent with the formula H_2O. As shown below, the coefficients in a chemical reaction involving gases indicate the relative numbers of molecules, the relative numbers of moles, and the relative volumes.

$$\begin{array}{llcl} 2H_2(g) & + \quad O_2(g) & \longrightarrow & 2H_2O(g) \\ \text{2 molecules} & \text{1 molecule} & & \text{2 molecules} \\ \text{2 mol} & \text{1 mol} & & \text{2 mol} \\ \text{2 volumes} & \text{1 volume} & & \text{2 volumes} \end{array}$$

The simplest hypothetical formula for oxygen indicated two oxygen atoms, which turns out to be correct. The simplest possible molecule of water indicated two hydrogen atoms and one oxygen atom per molecule, which is also correct. Experiments eventually showed that all elements that are gases near room temperature, except the noble gases, normally exist as diatomic molecules.

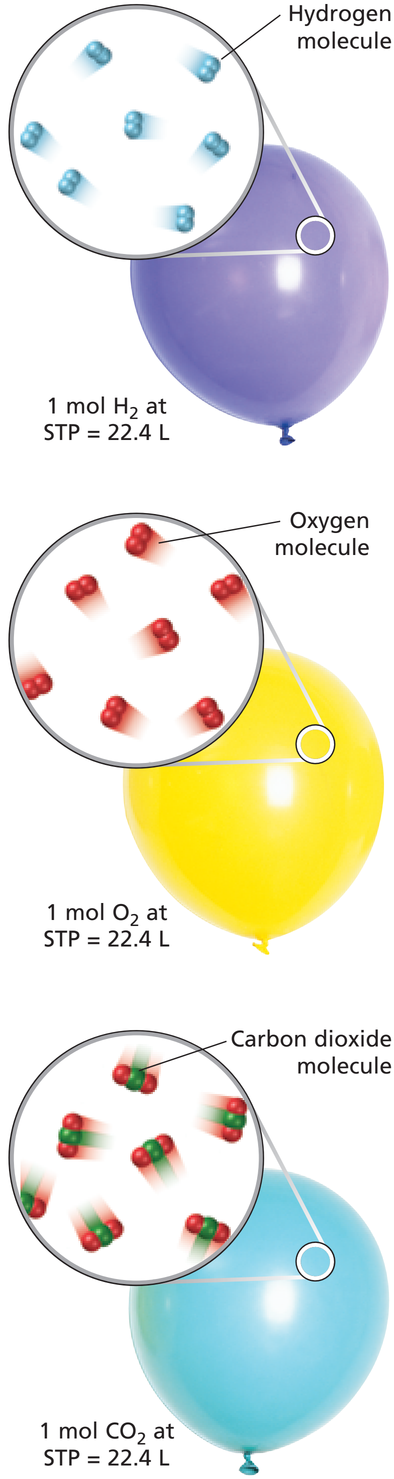

FIGURE 11 At the same temperature and pressure, balloons of equal volume have equal numbers of molecules, regardless of which gas they contain.