9.4: The Mole-Volume Relationship - Avogadro's Law

A plot of the effect of temperature on the volume of a gas at constant pressure shows that the volume of a gas is directly proportional to the number of moles of that gas. This is stated as **Avogadro's law.**

Avogadro's law

The volume (V) of an ideal gas varies *directly* with the number of moles of the gas (n) when the pressure (P) and the number of temperature (T) are constant.

We can express this mathematically as:

$$V \propto n \;\; at \;\; constant \; P \; and \; T$$

$$V = constant \times (n) \;\; or \;\; \frac{V}{n} = constant$$

As before, we can use Avogadro's law to predict what will happen to the volume of a sample of gas as we change the number of moles. Because V/n is a constant for any given sample of gas (at constant P and T), we can again imagine two states; an initial state with a certain number of moles and volume (V_1/n_1), and a final state with values for a different number of moles and volume (V_2/n_2). Because V/n is always a constant, we can equate the two states and write:

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Example 9.4.1

We have a container with a piston that we can use to adjust the pressure on the gas inside, and we can control the temperature. You are told that, initially, the container contains 0.20 moles of hydrogen gas and 0.10 mole of oxygen in a volume is 2.40 L. The two gases are allowed to react (a spark ignites the mixture) and the piston is then adjusted so that the pressure is identical to the pressure in the initial state and the container is cooled to the initial temperature; what is the final volume of the product of the reaction?

Solution

First, we need to look at the reaction involved. Hydrogen and oxygen react to form water. Two moles of hydrogen react with one mole of oxygen to give two moles of water, as shown below:

$$2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(g)$$

Initially we have three moles of gas and, after reaction, we have two moles. We can now substitute into Avogadro's law:

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

$$\frac{2.40\ L}{3\ moles} = \frac{V_2}{2\ moles}$$

$$V_2 = \left(\frac{(2.40\ L)(2\ moles)}{3\ moles}\right) = 1.60\ L$$

Thus we have described the dependence of the volume of a gas on the pressure (Boyle's law), the temperature (Charles's law) and the number of moles of the gas (Avogadro's law). In the following section, we will combine these to generate the Ideal Gas Law, in which all three variables (pressure, temperature and number of moles) can vary independently.