8.8: The Combined Gas Law

Learning Objectives

- Use the combined gas law to determine the relationships between pressure, volume, and temperature of a gas.

One thing we notice about all gas laws, collectively, is that volume and pressure are always in the numerator, and temperature is always in the denominator. This suggests that we can propose a gas law that combines pressure, volume, and temperature. This gas law is known as the **combined gas law**, and its mathematical form is:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \; at \; constant \; n$$

This allows us to follow changes in all three major properties of a gas. Again, the usual warnings apply about how to solve for an unknown algebraically (isolate it on one side of the equation in the numerator), units (they must be the same for the two similar variables of each type), and units of temperature must be in kelvins.

Notice that each of the previous gas laws introduced, can be derived from the combined gas law:

At constant T, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ *gives* Boyle's Law: $P_1V_1 = P_2V_2$

At constant P, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ *gives* Charles's Law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

At constant V, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ *gives* Gay-Lussac's Law: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

In other words, if you know the equation for the combined gas law, you can calculate relationships between pressure, volume, or temperature of a fixed amount of gas.

Example 8.8.2

A sample of gas at an initial volume of 8.33 L, an initial pressure of 1.82 atm, and an initial temperature of 286 K simultaneously changes its temperature to 355 K and its volume to 5.72 L. What is the final pressure of the gas?

Solution

We can use the combined gas law directly; all the units are consistent with each other, and the temperatures are given in Kelvin. Substituting,

$$\frac{(1.82\,atm)(8.33\,L)}{286\,K} = \frac{P_2(5.72\,L)}{355\,K}$$

We rearrange this to isolate the P_2 variable all by itself. When we do so, certain units cancel:

$$\frac{(1.82\,atm)(8.33\;\cancel{L})(355\;\cancel{K})}{(286\;\cancel{K})(5.72\;\cancel{L})} = P_2$$

Multiplying and dividing all the numbers, we get

$$P_2 = 3.29\,atm$$

Ultimately, the pressure increased, which would have been difficult to predict because two properties of the gas were changing.

Exercise 8.8.2

If P_1 = 662 torr, V_1 = 46.7 mL, T_1 = 266 K, P_2 = 409 torr, and T_2 = 371 K, what is V_2?

Answer

105 mL

Summary

- There are gas laws that relate any two physical properties of a gas.
- The combined gas law relates pressure, volume, and temperature of a gas.

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