# 9.7: The Combined Gas Law

## Learning Objectives

- Learn and apply the Combined Gas Law.

One thing that may be noticed about all the gas laws is that, collectively, volume and pressure are always in the numerator, and temperature is always in the denominator. This suggests that a gas law that combines pressure, volume, and temperature for a given amount of gas may be proposed. This gas law is known as the **Combined Gas Law**, and its mathematical form is:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \tag{9.7.1}$$

This allows changes in all three major properties of a gas to be followed. Again, the usual warnings apply when algebraically solving for an unknown variable (it must be isolated on one side of the equation in the numerator), units ($P_1$ and $P_2$ must each the same units, as must $V_1$ and $V_2$), and units of temperature must be in kelvins.

## ✅ Example 9.7.1:

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

**Solution**

| Steps for Problem Solving | |
|---|---|
| Identify the "given" information and what the problem is asking you to "find." | Given: $V_1$ = 8.33 L, $P_1$ = 1.82 atm, $T_1$ = 286 K, $V_2$ = 5.72 L, $T_2$ = 355 K<br>Find: $P_2$ = ? atm |
| List other known quantities. | none |
| Plan the problem. | Rearrange the equation to solve for $P_2$.<br>$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$<br>$\frac{P_1V_1}{T_1} \times \frac{T_2}{V_2} = \frac{P_2\cancel{V_2}}{\cancel{T_2}} \times \frac{\cancel{T_2}}{\cancel{V_2}} \Rightarrow \boxed{P_2 = \frac{P_1V_1T_2}{T_1V_2}}$ |
| Calculate and cancel units. | Substitute the known quantities into the equation and solve.<br>$P_2 = \frac{(1.82\text{ atm})(8.33\ \cancel{\text{L}})(355\ \cancel{\text{K}})}{(286\ \cancel{\text{K}})(5.72\ \cancel{\text{L}})} = 3.29\text{ atm}$ |
| Think about your result. | The pressure increased, which is a little more difficult to predict because two properties of the gas were changing. |

## ✏️ Exercise 9.7.1

A weather balloon was filled with helium to a volume of 256 L at 760 mm Hg and 0°C. The weather balloon rose to an altitude where the volume of the balloon expanded slightly to 272 L and the pressure inside the balloon decreased to 684 mm Hg. If no gas was added to or removed from the balloon, what was the new temperature of the helium inside the balloon, in °C?

**Answer**

–12°C

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \xrightarrow{\text{cross multiply}} P_1V_1T_2 = P_2V_2T_1 \xrightarrow{\text{solve for } T_2} T_2 = \frac{P_2V_2T_1}{P_1V_1} = \frac{(684 \cancel{\text{ mm Hg}})(272 \cancel{\text{ L}})(273.15 \text{ K})}{(760 \cancel{\text{ mm Hg}})(256 \cancel{\text{ L}})} = 261 \text{ K} = -12^\circ\text{C}$$

As with other gas laws, when calculating the value of a variable in the denominator, you may either cross-multiply all the terms (as shown above) or to first take the reciprocal to get the variable in the numerator. As always, the variable for which you are solving for must be in the numerator and all by itself on one side of the equation.

As with other gas laws, if you need to determine the value of a variable in the denominator of the combined gas law, you can either cross-multiply all the terms or just take the reciprocal of the combined gas law. Remember, the variable you are solving for must be in the numerator and all by itself on one side of the equation.

## Summary

- The Combined Gas Law relates pressure, volume, and temperature of a gas.