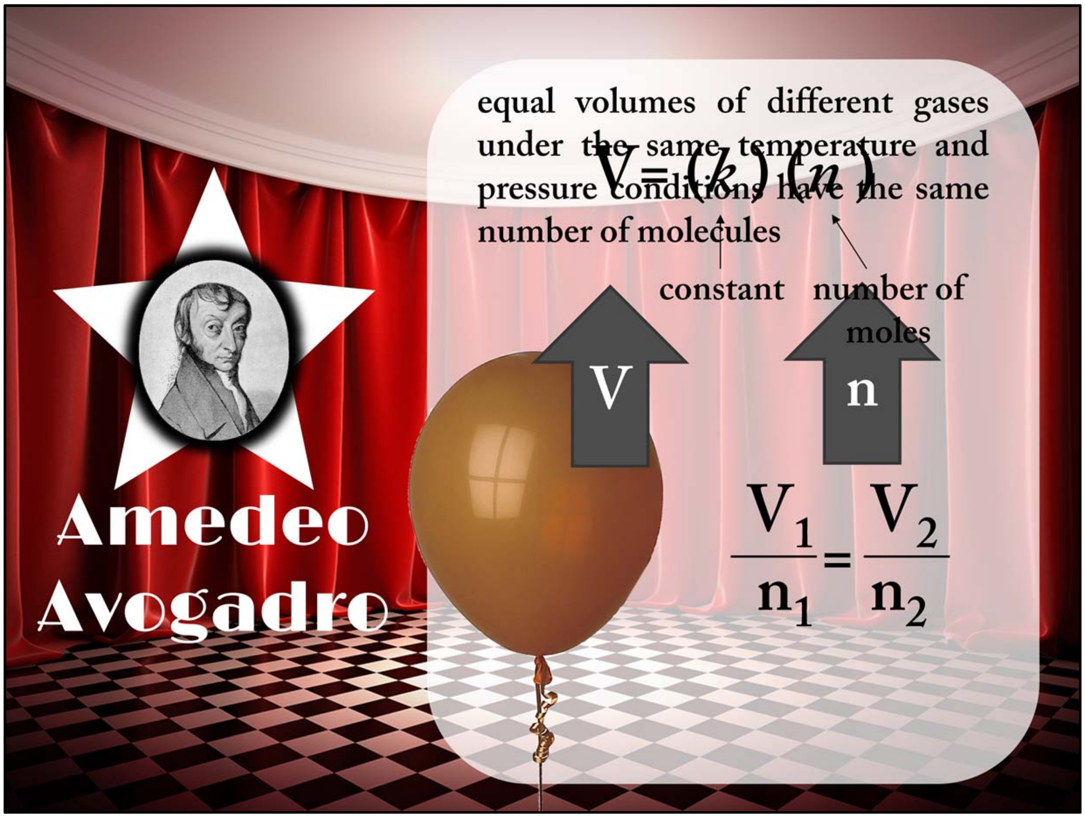
Module 9: States of Matter and Gas Laws
Topic 3 Content: Gas Laws Presentation Notes

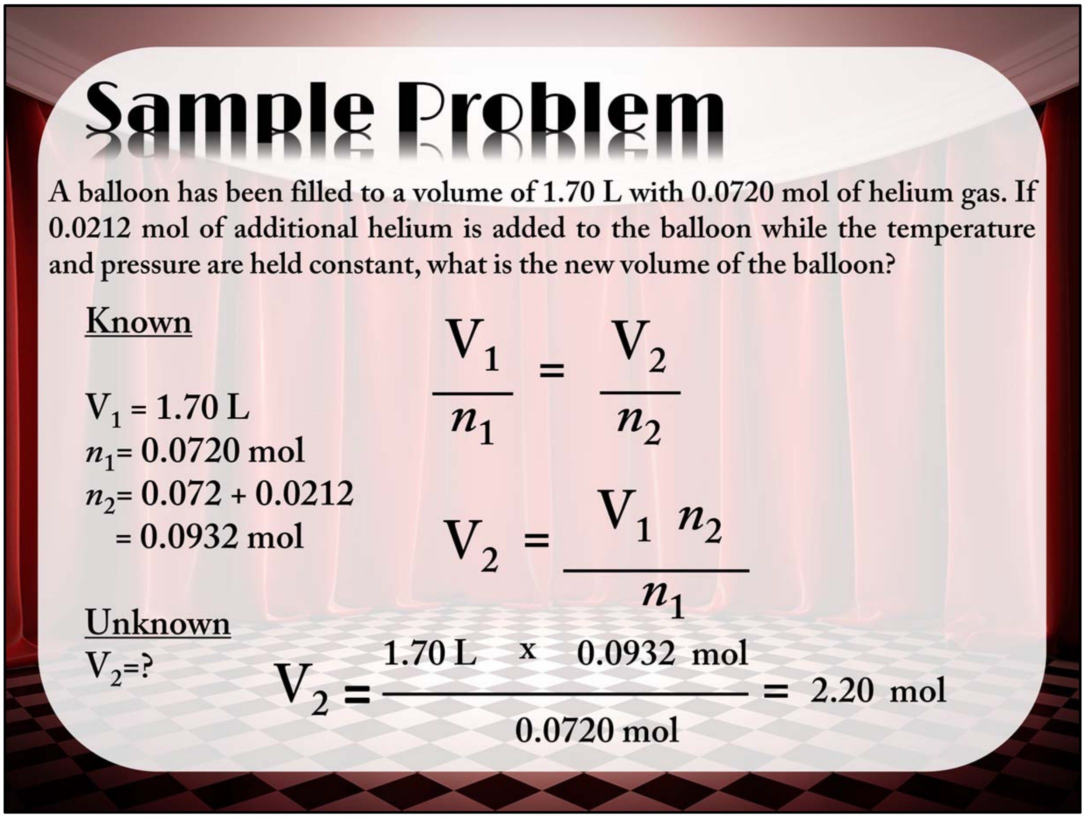
Gas Laws Hall of Fame



Avogadro's Law states that equal volumes of different gases under the same temperature and pressure conditions have the same number of molecules. This is a direct relationship in which volume increases with an increase in the number of particles. The mathematical expression of Avogadro's law is: **V= (*k*)(*n*)**.

In this equation, *n* is the number of moles of gas and *k* is a constant. Another mathematical expression is needed when two different substances are compared under a different set of conditions. In this case, the law is expressed as: $V_1/n_1=V_2/n_2$.

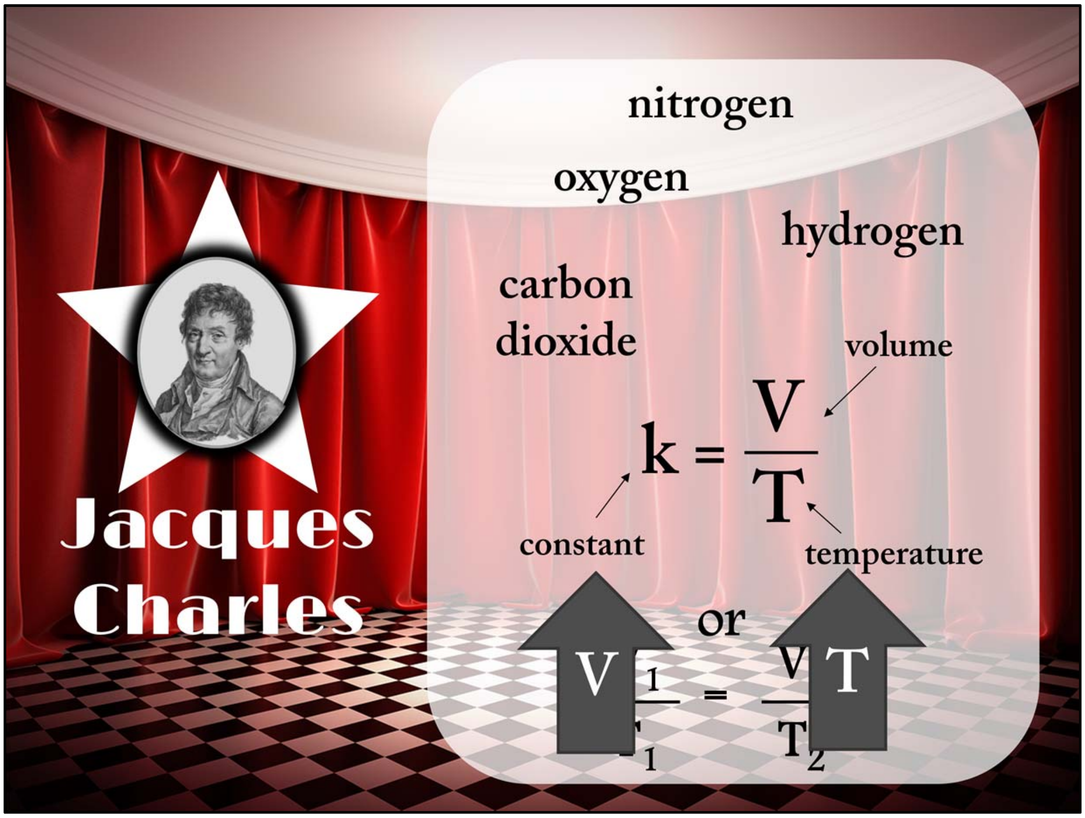
You may have witnessed this law when you have inflated a balloon. The volume of the balloon increases as you add moles of gas. In this example, the container that holds the gas is been flexible. If the container is rigid, the pressure of the contained gas increases.



Take a look at this sample problem using Avogadro's Law.

A balloon has been filled to a volume of 1.70 L with 0.0720 mol of helium gas. If 0.0212 mol of additional helium is added to the balloon while the temperature and pressure are held constant, what is the new volume of the balloon?

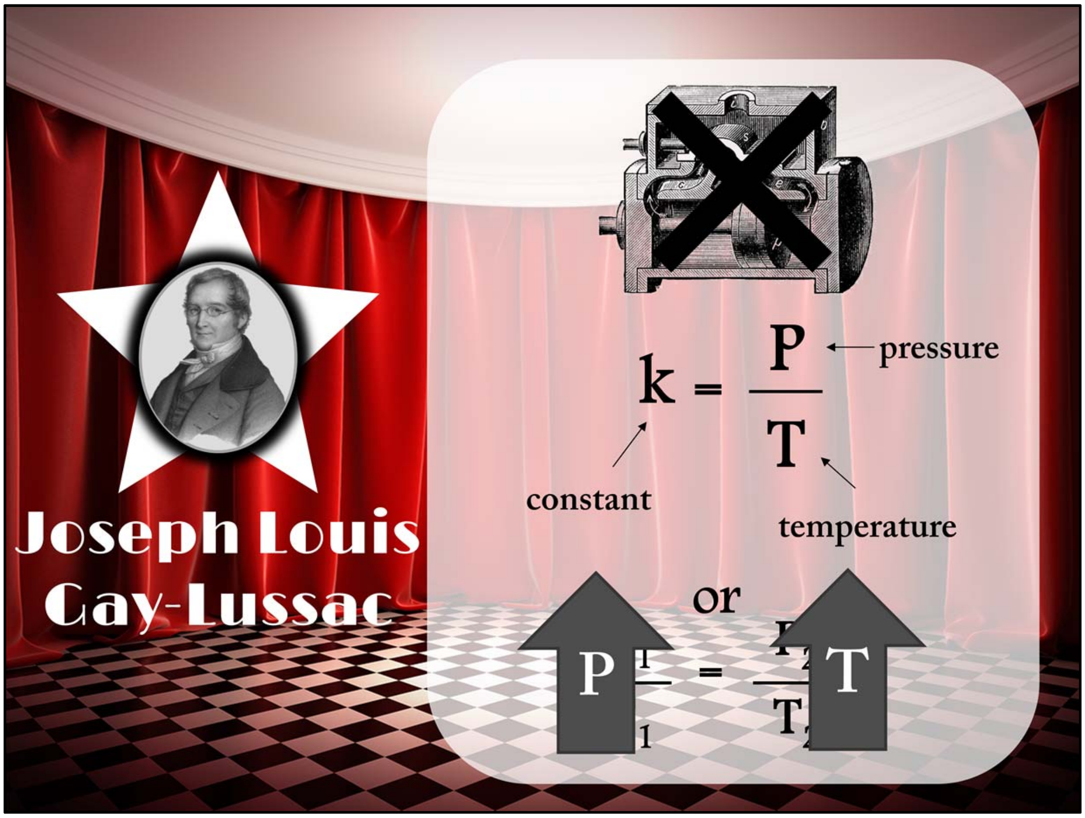
The first thing you will want to do is to list the known and unknown quantities, and then plan out how to solve the problem mathematically. The known variables in this experiment are V_1, n_1, and $n_{2.}$ To calculate n_2, add the initial amount of helium gas, or 0.0720 mol to the additional amount of helium gas added to the balloon, or 0.0212 mol. When added together, these two quantities produce a final amount of 0.0932 mol. The unknown variable is V_2. You need to rearrange the equation to solve for the final volume. The new equation reads: final volume, or V_2, equals initial volume, or V_1, times final amount, or n_2, divided by initial amount or n_1. Next, plug in your known values and solve the problem. In this example, the final volume, or V_2, equals 1.70 L times 0.0932 mol divided by 0.0720 mol. The final volume of the balloon is 2.20 moles.



Jacques Charles studied the relationship between temperature and volume. He had found that oxygen, nitrogen, hydrogen, carbon dioxide, and air expand to the same extent over the same eighty degree interval. Charles did not publish his work, but was referenced by Joseph Louis Gay-Lussac in the early 1800s.

The mathematical expression for Charles's law is: k=V/T.

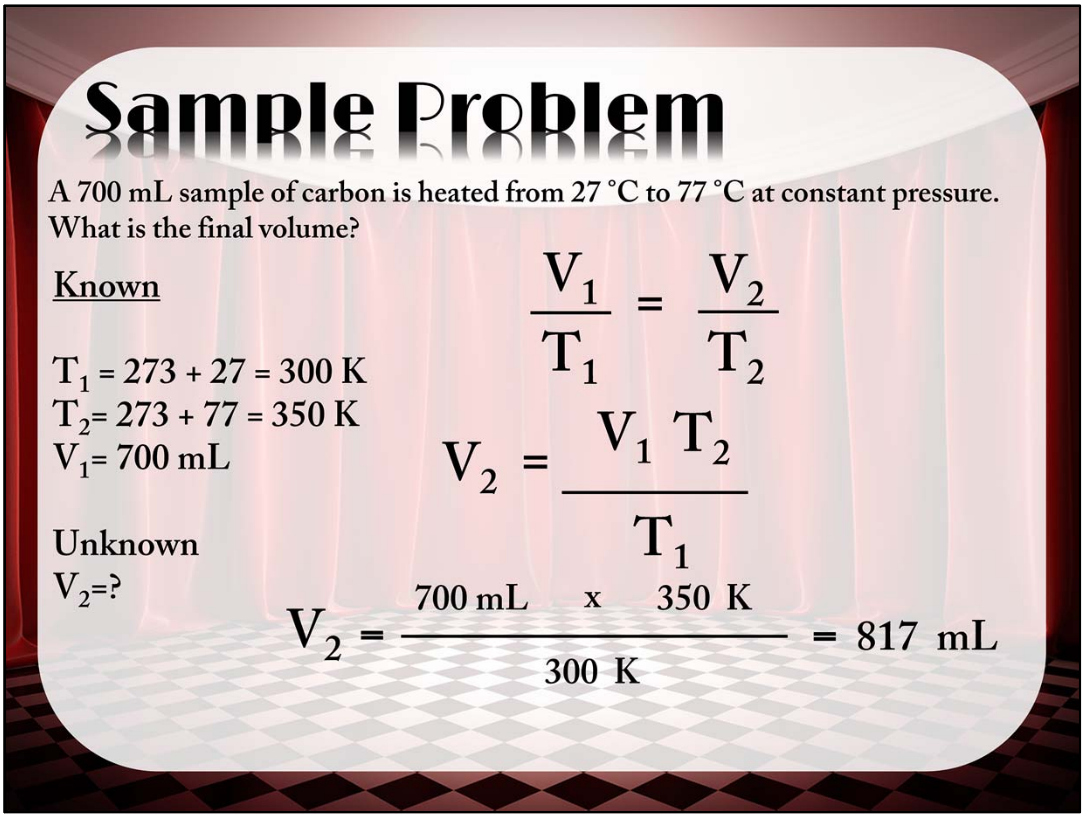
In this equation V, is the volume of the gas, T is temperature, and *k* is a constant. This law gives the relationship between volume and temperature, if pressure and amount are held constant. This is a direct relationship, as volume increases with an increase in temperature. Another mathematical expression is needed when two different substances are compared under a different set of conditions. In this case, the law is expressed as: $V_1/T_1=V_2/T_2$.



Joseph Louis Gay-Lussac credited Jacques Charles with noticing the same relationship. The only fundamental difference between Charles's Law and the Gay-Lussac Law was that the relationship was observed under a different set of conditions. In Charles's Law, the container holding the gas contained a moveable piston. In Gay-Lussac's observations, the container holding the gas was rigid.

The mathematical expression of the Gay-Lussac Law is: k=P/T.

In this equation, P is the pressure of the gas, T is temperature, and *k* is a constant. This law gives the relationship between pressure and temperature, if volume and amount are held constant. This is a direct relationship, as pressure increases with an increase in temperature. Another mathematical expression is needed when two different substances are compared under a different set of conditions. In this case, the law is expressed as: $P_1/T_1=P_2/T_2$.



Take a look at this sample problem using Charles's Law.

A 700 mL sample of carbon is heated from 27 °C to 77 °C at constant pressure. What is the final volume?

The first thing you will want to do is to list the known and unknown quantities, and then plan out how to solve the problem mathematically. You will notice that the temperatures in the problem are listed in Celsius. These temperatures need to be converted to Kelvin. Failure to convert these temperatures will result in an incorrect result. The conversions are shown here. Next, use Charles's Law to find the final volume. You will need to rearrange the equation to solve for the final volume, or V_2. The new equation reads: final volume, or V_2, equals initial volume, or V_1, times final temperature, or T_2 divided by initial temperature, or T_1. Next, plug your known values into the equation and solve the problem. In this example, final volume, or V_2, equals 700 mL times 350 K divided by 300K. The final volume of the carbon is 817 mL.

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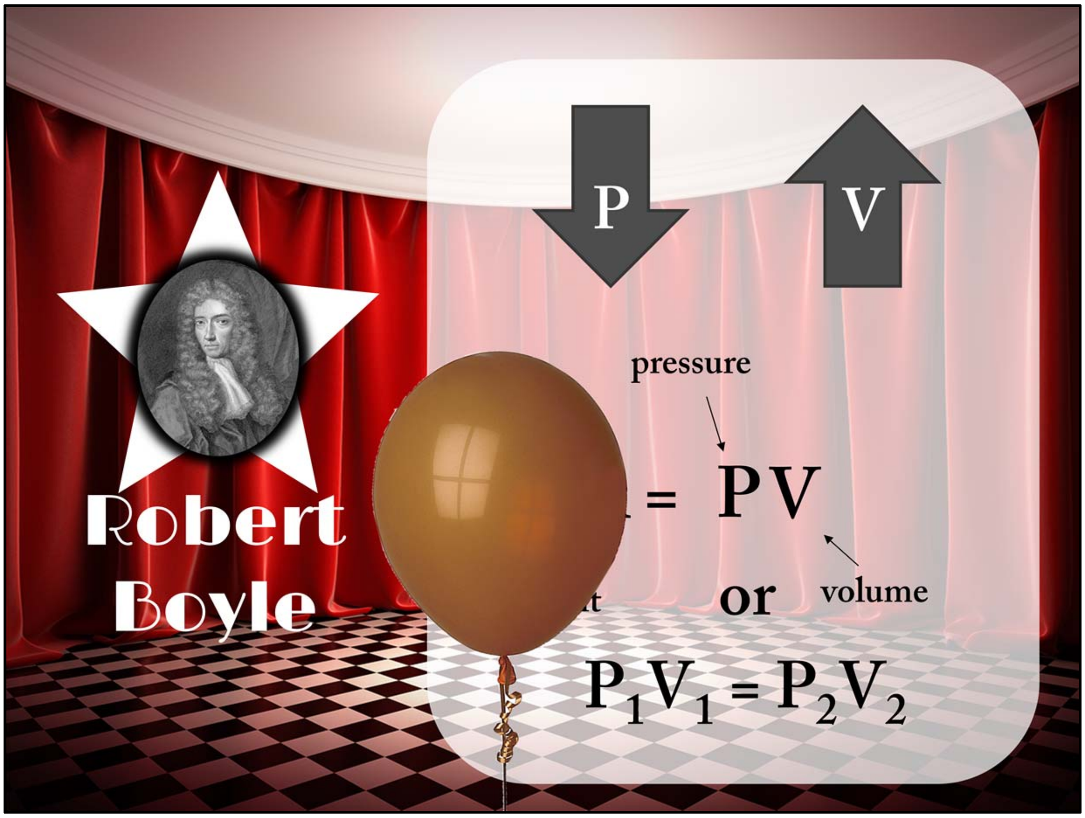
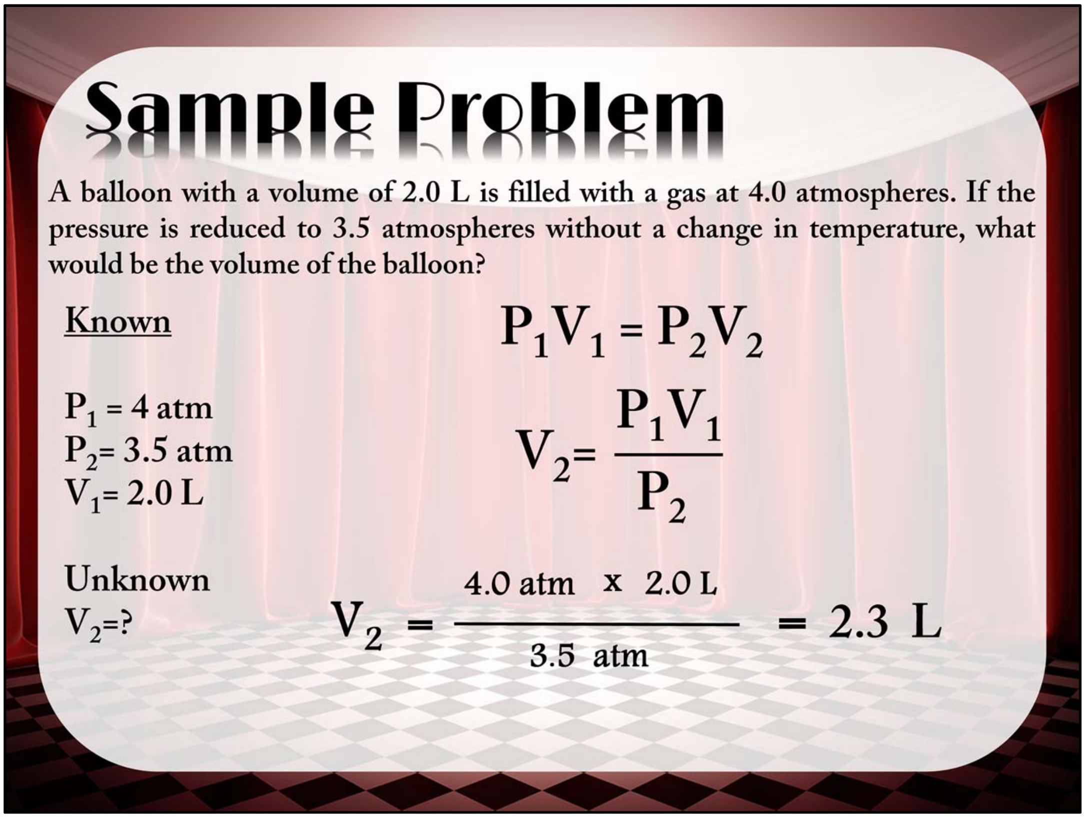


Irish chemist Robert Boyle is credited with a law that describes the relationship between pressure and volume. This relationship occurs when temperature and amount are held constant. Imagine the volume is increased, and this means that gas molecules have more space and they will impact the container walls less often. This results in less gas pressure. If the volume is decreased, the gas molecules have a shorter distance to go, thus striking the walls more often per unit time, so the pressure would increase. This is an inverse mathematical relationship. As one quantity goes up in value, the other goes down. Volume increases with a decrease in pressure.

One very simple way to observe Boyle's Law is to squeeze a balloon. As the balloon becomes smaller the resistance to squeezing is greater. This means that the pressure inside of the balloon is greater. A larger balloon is easily squeezed. This means that the molecules of gas inside the larger balloon have more room and are under less pressure. The mathematical expression of Boyle's Law is: $k=(P)(V)$.

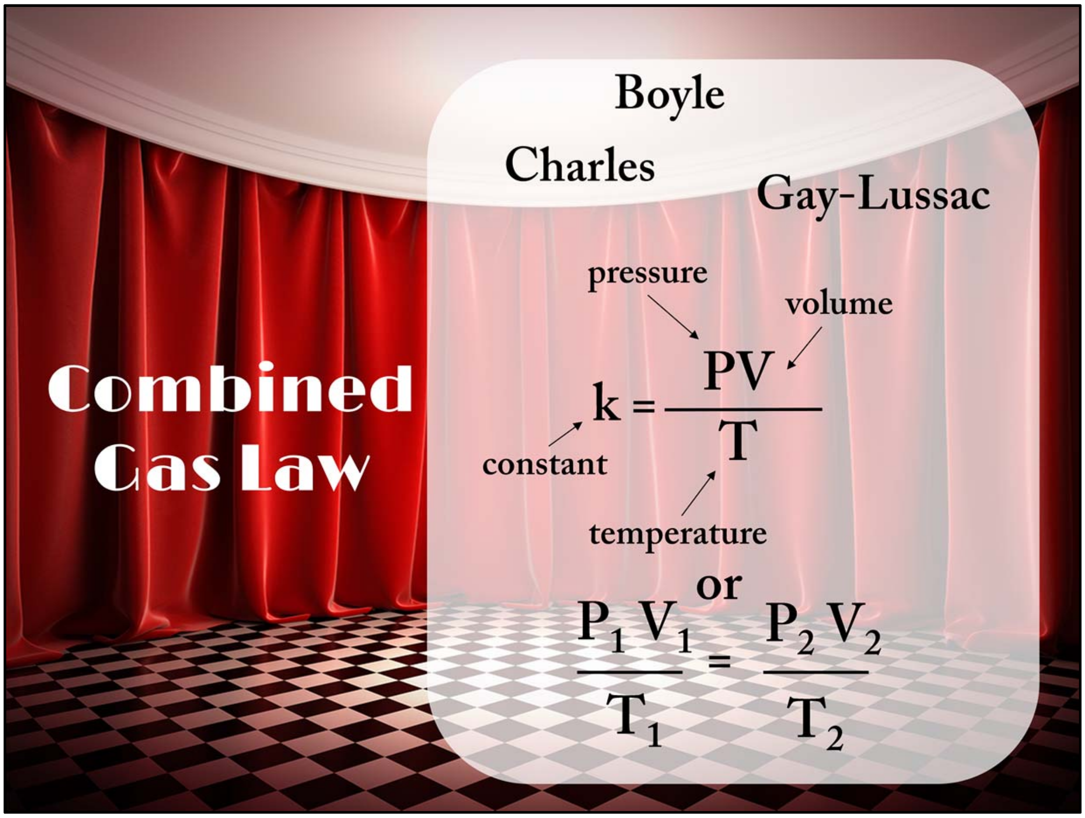
In this equation, V is the volume of the gas, P is pressure and k is a constant. This law gives the relationship between pressure and volume, if temperature and amount are held constant. Another mathematical expression is needed when two different substances are compared under a different set of conditions. In this case, the law is expressed as: $P_1V_1 = P_2V_2$.



Take a look at this sample problem using Boyle's Law.

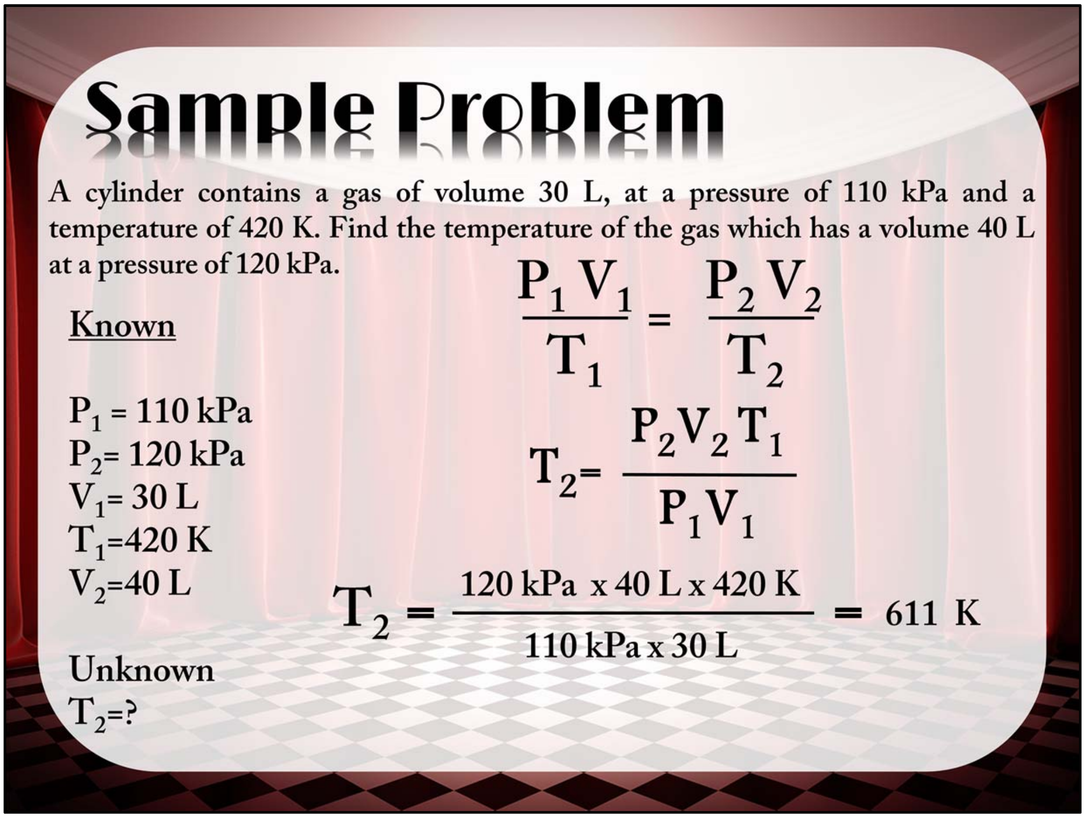
A balloon with a volume of 2.0 L is filled with a gas at 4.0 atmospheres. If the pressure is reduced to 3.5 atmospheres without a change in temperature, what would be the volume of the balloon?

The first thing you will want to do is to list the known and unknown quantities, and then plan out how to solve the problem mathematically. The known variables in this experiment are initial volume, or $V_{1,}$ initial pressure, or P_1, and final pressure, or P_2. The unknown variable is final volume, or $V_{2.}$ You will need to rearrange the equation to solve for the final volume, or V_2. The new equation reads: final volume, or V_2, equals initial pressure, or P_1, times initial volume, or V_1, divided by final pressure, or P_2. Next, plug in your known values into the equation and solve the problem. In this example, final volume, or V_2, equals 4.0 atm times 2.0 L divided by 3.5 atm. The final volume, or V_2, of the balloon is 2.3 L.



The Combined Gas Law combines the Charles, Boyle, and Gay-Lussac Laws. Why is a combined gas law needed? Sometimes, the variables P, V, and T change. The Combined Gas Law addresses the relationship between these three variables. The only constant is the amount of gas. The mathematical expression of the Combined Gas Law is: k =PV/T.

In this equation V is the volume of the gas, P is pressure, T is temperature, and k is a constant. Another mathematical expression is needed when all three of the different substances are compared under a different set of conditions. In this case, the law is expressed as: $P_1V_1/T_1 = P_2V_2/T_2$.



Take a look at this sample problem using the Combined Gas Law.

A cylinder contains a gas of volume 30 L, at a pressure of 110 kPa and a temperature of 420 K. Find the temperature of the gas which has a volume 40 L at a pressure of 120 kPa.

The first thing you will want to do is to list the known and unknown quantities, and then plan out how to solve the problem mathematically. The known variables in this experiment are V_1, V_2, P_1, P_2, and T_1. The unknown variable is T_2. Before you solve this problem, you will need to rearrange the equation to solve for final temperature. The new equation reads: final temperature, or T_2 equals final pressure, or P_2 times final volume, or V_2 times initial temperature, or T_1 divided by final pressure, or P_2 times initial volume, or V_1. Next, plug in your known values into the equation and solve the problem. In this example, final temperature, or T_2 equals 120 kPa times 40 L times 420 K divided by 110 kPa times 30 L. The final temperature of the balloon is 611 K.