SCIENCE 1103
GASES AND MOLES

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IV. COMBINED GAS LAW

Nature operates with perfect precision and order because it was created by a perfect God. The gas laws we have been studying are examples of this order. Under real conditions one variable of a gas seldom affects just one other variable. Usually two or three of the four variables change simultaneously. Therefore, we need an easy way to handle the simultaneous change in several gaseous con-ditions. Boyle's and Charles' Laws are combined in one single **Combined Gas Law**.

SECTION OBJECTIVES

Read these objectives. When you have completed this section, you should be able:

7. To use the Combined Gas Law to solve problems.
   - 7.1 To identify the data-variable pairs.
   - 7.2 To use the mathematical formula for the Combined Gas Law to solve for the unknown condition.

VOCABULARY

Study this term to enhance your learning success in this section.

Combined Gas Law

DEVELOPMENT

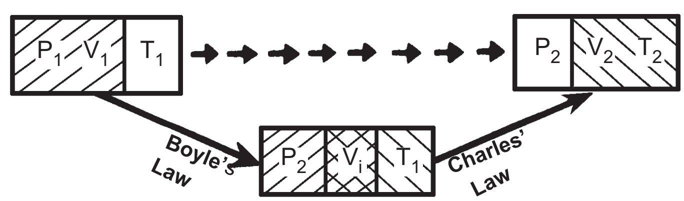
In our study of gases in the LightUnit we have studied two separate relationships: Boyle's Law and Charles' Law. Both of these laws were studied under laboratory conditions where only two variables were considered at one time. In practice, however, more often pressure, volume, and temperature all vary at the same time. A combination of Boyle's Law and Charles' Law into one mathematical relationship would be helpful. We could use the laboratory to find this relationship in the same way that we have found Boyle's Law and Charles' Law. This method, however, is not very convenient with the laboratory facilities normally available to us. Therefore, another way is used.

One way to find this relationship is by thinking through and analyzing what happens to a gas when one *set* of conditions changes to another. What we really want to do is to change conditions $P_1\ V_1\ T_1$ to $P_2\ V_2\ T_2$.

Condition 1		**Condition 2**
$P_1\ V_1\ T_1$	$\longrightarrow$	$P_2\ V_2\ T_2$

When we look at both Boyle's Law (P • V = k) and Charles' Law (V/T = k'); we see that both involve the variable of volume. If $P_1 \rightarrow P_2$ the volume changes and if $T_1 \rightarrow T_2$ the volume changes. Therefore, if we combine Boyle's Law and Charles' Law into one law, we can do it on the basis of volume change. This procedure can best be done if we use some intermediate volume, V_i, found by Boyle's Law, and then change V_i to V_2 with Charles' Law.

We use V_i because it represents V_2 in Boyle's Law and represents V_1 in Charles' Law. Therefore, it is called an intermediate.



(V_i = intermediate volume)

The first step (Boyle's Law) might be represented mathematically:

$$P_1V_1 = k = P_2V_2.$$

But using V_i for V_2 gives

$$P_1V_1 = P_2V_i.$$

When solved for V_i algebraically we get

$$V_i = \frac{P_1V_1}{P_2}$$

(temperature is held constant)

The second step (Charles' Law) might be repre-sented mathematically: $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

Using V_i for V_1 gives $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

Solving for V_i gives $V_i = \dfrac{T_1V_2}{T_2}$

(pressure is held constant)

Do this activity.

4.1 Since we solved for V_i in both cases, we may put them in an equation together. Write it here:

From that equation, use algebra to arrive at this equation:

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

APPLICATION

The **Combined Gas Law** is the result of mathematically combining Boyle's Law and Charles' Law. Very few times in the real world do you find a system where only two variables change at one time. In most gaseous systems pressure, volume, and temperature change at the same time. Therefore, we must be able to solve problems using the Combined Gas Law. The equation states $P_1V_1/T_1 = P_2V_2,/T_2$, where P_1, V_1, and T_1 represent the *original* set of conditions and P_2, V_2, and T_2 represent the *final* set of conditions.

One set of conditions has been defined as *standard*. This set of conditions is called *S*tandard *T*emperature and *P*ressure (STP). STP is defined as a pressure of 760 mm Hg (1 atm) and a temperature of 273°K (0°C). These STP values will be important in the last section of this LightUnit.

Let's try some Combined Gas Law problems. Remember to change Celsius to Kelvin.

4.2 On a cold winter day when the outside temperature was -30°C, a balloon was filled with 10.0 liters of helium at 27°C and 740 mm of Hg. When it was released it rose into the air. After 20 minutes, the gas reached the outside air temperature. At that point the air pressure was 525 mm Hg. What was the new volume of the gas? (Neglect any force necessary to stretch the balloon.)

a. P_1 = ________________

b. V_1 = ________________

c. T_1 = ________________

d. P_2 = ________________

e. T_2 = ________________

f. Calculate the new volume, V_2. Show your work.

4.3 A diesel engine's piston compresses 16 volume units of fuel-air mixture into 1 volume unit. The pressure changes from 1 atmosphere to 48 atmospheres. If the initial temperature of the gas was 305°K, what was the final temperature?

Show your work.

4.4 A 25-liter sample of steam at 100°C and 1 atm is cooled to 25°C and expanded until the pressure is 20 mm Hg. If no water condenses, calculate the final volume of the water vapor.

4.5 A compressor takes 0.5 m^3 of a gas at 33°C and 760 mm Hg and compresses it to 0.1 m^3, cooling it to -50°C at the same time. What is the pressure of the gas at these new conditions?

4.6 Hydrogen chloride gas is shipped in a container under 5,000 mm Hg pressure that occupies 20 liters at 30°C. How many liters of gas would be produced at STP?

4.7 On exploding, a gram of gunpowder produced 300 cc of gases when measured at STP. What volume would these gases occupy at the temperature produced by the explosion (2,200°C) if the pressure was 2 atmospheres?

4.8 An aerosol can with a capacity of 0.360 L was filled at the factory with gas at a temperature of 25°C to a pressure of 2.3 atm. The can sat in sunlight which raised the temperature to 50°C and the can bulged to 0.370 L. What was the new pressure? (Since many aerosol cans warn against setting in direct sunlight or temperatures above 49°C, this was a close disaster!)

4.9 OPTIONAL: Bromine vapor occupied 2.5 liters when measured at 57°C and 7.80 mm. What theoretical volume would the vapor occupy if it were measured at 17°C and 750 mm?