The Ideal Gas Law

We have considered three laws that describe the behavior of gases:

Boyle's law:	$V = \frac{k}{P}$	(at constant T and n)
Charles's law:	$V = bT$	(at constant P and n)
Avogadro's law:	$V = an$	(at constant T and P)

The three gas laws can be combined as follows:

$$V = R\left(\frac{Tn}{P}\right)$$

where R is the combined constant called the **universal gas constant**. When the pressure is in atmospheres, the volume is in liters, and the temperature is in Kelvin,

$$R = 0.08206\ L \cdot atm/K \cdot mol$$

The previous equation is known as the **ideal gas law**, and is typically rearranged to:

$$PV = nRT$$

The ideal gas law is based on experimental observation of the properties of gases. A gas that obeys this equation is said to behave *ideally*. No gas *exactly* follows the ideal gas law. However, most gases follow the ideal gas law closely enough at pressures below 1 *atm*.

For the purposes of this class, we will **assume ideal gas behavior for all problems**.

The ideal gas law can be used to solve a variety of problems.

Example 1
A sample of hydrogen gas H_2 has a volume of 8.56 L at a temperature of 0°C and a pressure of 1.5 *atm*. Calculate the moles of H_2 molecules present in this gas sample.

Gas law problems can be solved in a variety of ways. They can be classified as Boyle's law, Charles' law, or Gay-Lussac law problems and solved, but that requires remembering the specific law and when it applies.

The main advantage of the ideal gas law is that it works for all problems involving gases.

Example 2
Suppose we have a sample of ammonia gas with a volume of 7.0 *mL* at a pressure of 1.68 *atm*. The gas is compressed to a volume of 2.7 *mL* at a constant temperature. Use the ideal gas law to calculate the final pressure.

Example 3
A sample of methane gas that has a volume of 3.8 *L* at 5℃ is heated to 86℃ at constant pressure. Calculate its new volume.

Example 4

A sample of diborane gas (B_2H_6), a substance that bursts into flame when exposed to air, has a pressure of 345 *mm Hg* at a temperature of $-15℃$ and a volume of 3.48 *L*. If conditions are changed so that the temperature is $36℃$ and the pressure is 468 *mm Hg*, what will be the volume of the sample?

Example 5

A sample containing 0.35 *mol* of argon gas at a temperature of $13℃$ and a pressure of 568 *mm Hg* is heated to $56℃$ and a pressure of 897 *mm Hg*. Calculate the change in volume that occurs.

Ideal Gas Law Worksheet

1. Complete the following table for an ideal gas.

P (atm)	V (L)	n (mol)	T
5.00		2.00	155 ℃
0.300	2.00		155 K
4.47	25.0	2.01	
	2.25	10.5	75 ℃

2. Complete the following table for an ideal gas.

P	V	n	T
$7.74 \times 10^3\ Pa$	$12.2\ mL$		25℃
	$43.0\ mL$	$0.421\ mol$	$223\ K$
$455\ torr$		$4.4 \times 10^{-2}\ mol$	331℃
$745\ mm\ Hg$	$11.2\ L$	$0.401\ mol$	

3. Suppose two 200 *L* tanks are to be filled separately with the gases helium and hydrogen. What mass of each gas is needed to produce a pressure of 2.7 *atm* in its respective tank at 24℃?

4. The average lung capacity of a human is 6 *L*. How many moles of air are in your lungs when you are in the following situations?

   a) At sea level ($T = 298\ K, P = 1\ atm$)
   b) 10 *m* below water ($T = 298\ K, P = 1.97\ atm$)
   c) At the top of Mount Everest ($T = 200\ K, P = 0.296\ atm$)

5. The steel reaction vessel of a bomb calorimeter, which has a volume of 75 *mL*, is charged with oxygen gas to a pressure of 14.5 *atm* at 22℃. Calculate the moles of oxygen in the reaction vessel.

6. A 5 *L* flask contains 0.6 *g* O_2 at a temperature of 22℃. What is the pressure (in *atm*) inside the flask?

7. A 2.5 *L* container is filled with 175 *g* argon.

   a) If the pressure is 10 *atm*, what is the temperature?
   b) If the temperature is 225 *K*, what is the pressure?

8. A person accidentally swallows a drop of liquid oxygen, $O_2(l)$, which has a density of 1.149 *g/mL*. Assuming the drop has a volume of 0.05 *mL*, what volume of gas will be produced in the person's stomach at body temperature (37℃) and a pressure of 1 *atm*?

9. A gas sample containing 1.5 *mol* at 25℃ exerts a pressure of 400 *mm Hg*. Some gas is added to the same container and the temperature is increased to 50℃. If the pressure increases to 800 *mm Hg*, how many moles of gas were added to the container? Assume the volume of the container is constant.

10. What will be the effect on the volume of an ideal gas if the pressure is doubled and the absolute temperature is halved?

11. A container is filled with an ideal gas to a pressure of 11 *atm* at 0℃.

    a) What will be the pressure in the container if it is heated to 45℃?
    b) At what temperature would the pressure be 6.5 *atm*?
    c) At what temperature would the pressure be 25 *atm*?