TOPIC: 3.4 IDEAL GAS LAW

ENDURING UNDERSTANDING:	
SAP-7	Gas properties are explained macroscopically - using the relationships among pressure, volume, temperature, moles, gas constant - and molecularly by the motion of the gas.
LEARNING OBJECTIVE:	
SAP-7.A	Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law.
ESSENTIAL KNOWLEDGE:	
SAP-7.A.1	The macroscopic properties of ideal gases are related through the ideal gas law
SAP-7.A.2	In a sample containing a mixture of ideal gases, the pressure exerted by each component (the partial pressure) is independent of the other components. Therefore, the total pressure of the sample is the sum of the partial pressures.
SAP-7.A.3	Graphical representations of the relationships between P, V, T, and n are useful to describe gas behavior.
EQUATION(S):	
	$PV = nRT$
	$P_A = P_{total} \times \chi_A$ where χ_A = moles A/total moles (mole fraction)
	$P_{total} = P_A + P_B + P_C + \ldots$

on formula chart!

NOTES:

The gas laws describe how the properties of a gas respond under changing conditions.

Law	Relationship	Formula
Boyle's Law	As gas pressure increases, gas volume decreases	$P_1V_1 = P_2V_2$
Charles's Law	As gas pressure increases, gas volume decreases	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Avogadro's Law	As the number of moles of a gas increases, gas volume increases	$\frac{V_1}{n_1} = \frac{V_2}{n_2}$

Source 1: http://chm2046l.weebly.com/crash-courses-on-ideal-gas-law.html

THE IDEAL GAS LAW

The ideal gas law, **PV=nRT**, is used to relate the pressure, volume, moles, and temperature of a sample of gas by using the gas constant, R, at a given state/conditions.

P = pressure in atm
V = volume in L
n = moles of gas
R = universal gas constant (0.08206 L atm/mol K)
T = temperature in **Kelvin (Celcius + 273.15)**

There are several R values listed on the equation sheet, they differ in the units for pressure.

R =62.36 L torr/mol K (for torr or mmHg) and R = 8.314 J/mol K (1 J = 1 L kPa)

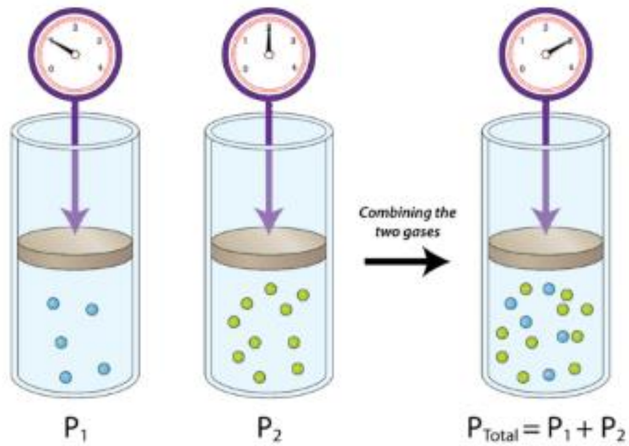
Always check your units when completing an Ideal Gas Law calculation to make sure that the units all cancel out.

The ideal gas formula can be used to solve for molar mass or density of a gas.

$$\text{Molar Mass} = \frac{\text{Density (g/L)} \times R \times \text{Kelvin Temperature}}{\text{Pressure}}$$

Dalton's Law of Partial Pressures

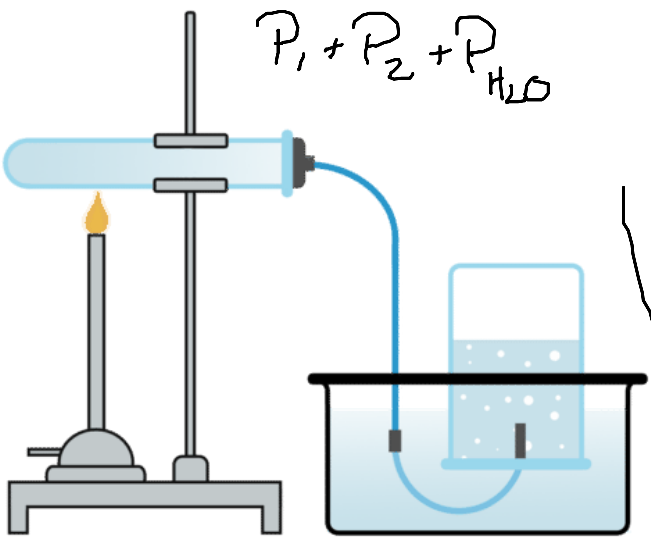
According to **Dalton's Law of Partial Pressure**, the sum of all the partial pressures of each gas in a mixture of gasses is equal to the total pressure. In mathematical notation, this is expressed by saying: $P = P_A + P_B + P_C$... where A, B, and C are different gasses.



Source 2: https://byjus.com/chemistry/daltons-law-of-partial-pressure/

This is often used when gases are collected "over water" as shown in the image below:

$P_1 + P_2 + P_{H_2O}$



As the gas is produced, the water is displaced and the water in the inverted vessel will empty while the gas is collected. This method allows for the gas to be measured and minimizes the amount of room air that contaminates the sample. However, as the gas travels through the water it will pick up water vapor which will contribute to the gas produced. The amount of water vapor that is picked up is a function of the temperature of the gas and can be subtracted using Dalton's law of partial pressures. When the water is subtracted out the gas is described as "dry."

https://d2vlcm61l7u1fs.cloudfront.net/media%2F1b9%2F1b94906f-2399-496c-b679-2bf0d19d193e%2FphpaJ7HyG.png

https://flexbooks.ck12.org/cbook/ck-12-chemistry-flexbook-2.0/section/14.14/primary/lesson/gas-collection-by-water-displacement-chem

Water Vapor Pressure Table

Temperature (°C)	Pressure (mmHg)	Temperature (°C)	Pressure (mmHg)	Temperature (°C)	Pressure (mmHg)
0.0	4.6	19.5	17.0	27.0	26.7
5.0	6.5	20.0	17.5	28.0	28.3
10.0	9.2	20.5	18.1	29.0	30.0
12.5	10.9	21.0	18.6	30.0	31.8
15.0	12.8	21.5	19.2	35.0	42.2
15.5	13.2	22.0	19.8	40.0	55.3
16.0	13.6	22.5	20.4	50.0	92.5
16.5	14.1	23.0	21.1	60.0	149.4
17.0	14.5	23.5	21.7	70.0	233.7
17.5	15.0	24.0	22.4	80.0	355.1
18.0	15.5	24.5	23.1	90.0	525.8
18.5	16.0	25.0	23.8	95.0	633.9
19.0	16.5	26.0	25.2	100.0	760.0

Mole Fractions

Mole fraction is denoted by χ_A and equals moles A/total moles.

$$\chi_A = \frac{\text{mole } A}{\text{total moles}}$$

If a mixture is 3.0 mol O_2 and 4.0 mol H_2, the mole fraction of [O_2 = 3.0 moles/(3.0+4.0 moles) = 0.43] NO units

To find the partial pressure multiply the mole fraction by the total pressure of the mixture. (partial pressure = χ_A * total pressure)

I DO:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

When heated strongly, solid calcium carbonate decomposes to produce solid calcium oxide and carbon dioxide gas, as represented by the equation above. A sample of $CaCO_3(s)$ is placed in a rigid 35 L reaction vessel from which all the air has been evacuated. The vessel is heated to 437°C at which time the pressure of $CO_2(g)$ in the vessel is constant at 1.00atm

find moles PV = nRT then mol → g

Calculate the number of grams of $CaCO_3(g)$ that reacted to produce the carbon dioxide gas.

PV = nRT

mol → g

$$n = \boxed{\frac{(1.00\ atm)(35\ L)}{(.08206\ \frac{atm\cdot L}{mol\cdot K})(710\ K)}} \times \left[\frac{1\ mol\ CaCO_3}{1\ mol\ CO_2} \times \frac{100.1\ g}{1\ mol} = 60.\ g\ CaCO_3\right]$$

(n = moles of CO_2 at end of reaction) **(stoichiometric ratio)** **(molar mass of $CaCO_3$)**

WE DO:

A basketball is left outside in winter when the temperature is -2.00 C, has a volume of 6.88 L and the pressure inside the basketball is 0.795 atm.

How many moles of gas are in a basketball? What is the partial pressure of oxygen in the basketball?

Component	Mole fraction
N_2	0.780
O_2	0.209
Ar	0.009

$$0.209 = \frac{mol\ O_2}{(0.780 + 0.209 + 0.009)} = 1.66\ atm\ O_2$$

YOU DO: Mole fraction

1) A gas mixture at 20.0°C and 2.0 atm contains 0.40 mol of H_2, 0.15 mol of O_2, and 0.50 mol of N_2. Assuming ideal behavior, what is the partial pressure of hydrogen gas (H_2) in the mixture?

$$\frac{40}{105} = .38 \times 762$$

2) 193 mL of oxygen, O_2, was collected over water on a day when the atmospheric pressure was 762.0 mmHg. The temperature of the water was 23.0 °C.

PP *(At 23.0° C the vapor pressure of water is 21.1 mmHg)*

a) What is the partial pressure of the oxygen gas collected?

Ideal 740.9

b) How many moles of oxygen were collected?

$$(740 \times .193/62.4)/295 = n\ \boxed{.00777}$$

Stoich

c) How many grams of oxygen were collected?

m→g

$$\frac{.00777}{1} \times \frac{32.0}{1\ mol\ O} = .249$$

128/5

3) An ideal gas sample has a mass of 1.28 grams in a 0.500 L container. The temperature of the container is 127° C and the pressure of the gas is 2.00 atm. What is the molar mass of the gas?

$MM = \frac{DRT}{P}$

$D = \frac{m}{V}$

$mm = \frac{2.56 \cdot .08206 \cdot 400K}{2}$ (K)

$\boxed{41\ g/m}$

4) Given the following reaction: $2NO\ (g) + O_2\ (g) \rightarrow 2NO_2\ (g)$

STP = 22.4L = 1mol

How many liters of gaseous ~~oxygen are needed~~ to produce 6.50 L of gaseous nitrogen dioxide, if both gases are being measured at STP?

$\boxed{3.25\ L}$

2 1 5 3:2 — 6.25

5) Air at 30,000 feet is at a temperature of -35.0 C. Air is a mixture that is 78.0% nitrogen, 21.0% oxygen and 1.0% argon. If .594 moles of air are captured in a 45.0 L container from a plane flying at 30000 feet:

a. Calculate the total pressure in the container.

$x \cdot 45 = .594 \cdot .08206 \cdot 238 = \boxed{.258\ atm}$

b. Calculate the partial pressures of each gas.

PP = .2012 + .05418 + .00258

6) $2\ KClO_3 \rightarrow 2KCl + 3O_2$

How many grams of potassium chlorate, $KClO_3$, were reacted if 5.30 liters of oxygen, O_2, were produced at 117. °C and 0.995 atm?

$5.27 = x \cdot .08206 \cdot 390$

x = .165

2 · .165/3 = .1097

114 × .1098 = 12.86

7) What is the density of NO_2 gas at 25.0 °C and 2.56 atm?

4.81

$2.56 \cdot x = 46 \times .08206 \cdot 298$

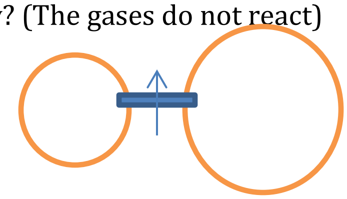
$m/V = MP/RT$

8) By what factor will the pressure of a sample of a gas change if the volume is reduced by 1/3 while the kelvin temperature is doubled?

Changes by $\frac{2}{3}$

9) What is the final pressure in the container shown below after the valve is opened and the gases are allowed to flow? (The gases do not react)

N_2
2.00 atm
2.00 L



O_2
4.00 atm
3.00 L