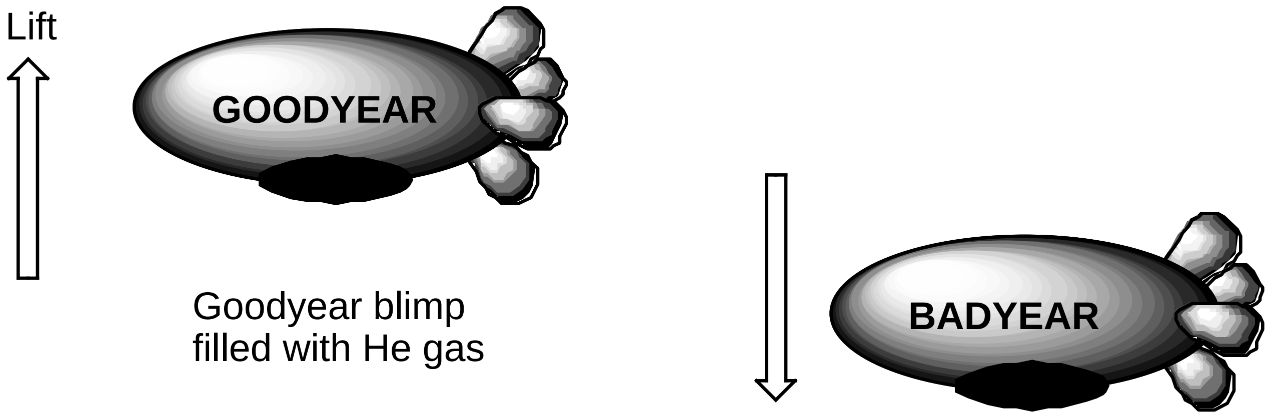
Gas Density



Goodyear blimp filled with He gas

Weight

Badyear blimp filled with Cl_2 gas

At STP(1.00 atm, 273 K) 1.00 mole gas = 22.4 L

Gas density: d = mass/Volume = molar mass/molar volume

d_{He} = 4.00g/22.4L = 0.179 g/L
d_{Cl_2} = 70.9g/22.4L = 3.17 g/L

Average density of atmosphere

80% N_2 gas 20% O_2 gas

d_{N_2} = 28.0g/22.4L = 1.25 g/L
d_{O_2} = 32.0g/22.4L = 1.43 g/L

$d_{avg.}$ = 0.800 x 1.25 g/L + 0.200 x 1.43 g/L
= 1.27 g/L

Goodyear blimp
filled with He gas

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Gas density: d = mass/Volume = molar mass/molar volume

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What is the density of He gas at a pressure of 744 torr and 29˚C?

d = molar mass /molar volume (at non-STP conditions)

Find the new volume using the Ideal Gas Law

Temp K = ˚C + 273 = 302 K

Since the Pressure is in torr, use R = 62.364 L torr/mole K

V(non-STP) = nRT/P,

d = molar mass/V(non-STP) = 4.00g x P/nRT

d = 4.00g x 744 torr/ 1 mole x 302K x 62.364 L torr $mole^{-1}$ k-1

d = 0.158 g/L

MIXTURES OF GASES

IN GAS MIXTURES, EACH COMPONENT BEHAVES INDEPENDENTLY OF THE OTHERS

EACH GAS COMPONENT HAS ITS OWN INDIVIDUAL PRESSURE – THE TOTAL PRESSURE OF A MIXTURE IS THE SUM OF THE INDIVIDUAL COMPONENT PRESSURES.

DALTONS LAW:

$$P_T = P_1 + P_2 + P_3 + \ldots\ldots P_z$$

ASSUMING THAT EACH GAS BEHAVES IDEALLY:

$P_1 = n_1RT/V$ $\quad$ $P_2 = n_2RT/V$, $\quad$ $P_3 = n_3RT/V$ ect.

SINCE $\quad P_T = P_1 + P_2 + P_3 = n_1RT/V + n_2RT/V + n_3RT/V$

$$P_T = (n_1+n_2+n_3)RT/V$$

OR:

$$P_T = n_TRT/V$$

THUS FOR AN IDEAL GAS IT IS THE TOTAL MOLES OF PARTICLES THAT ARE IMPORTANT…NOT THE IDENTITY OF THESE PARTICLES.

THE ABOVE STATEMENT TELLS US TWO THINGS ABOUT IDEAL GASES:

1. THE VOLUME OCCUPIED BY THE INDIVIDUAL IDEAL GAS PARTICLE MUST NOT BE VERY IMPORTANT.

2. THE FORCES BETWEEN THE PARTICLES MUST NOT BE VERY IMPORTANT.

IDEAL GAS PROPERTIES

A. Collection of randomly moving molecules.
B. Molecules occupy no space (infinitely small relative to the total space).
C. Molecules move in straight lines
D. Collisions are perfectly elastic.
   This means there can be no force of attraction between the molecules.

EXAMPLE 1:

Mixtures of O_2 gas and He gas are often used as breathing mixtures for scuba diving in deep dives as a way to avoid the bends. For a particular dive, 46 L of O_2 at 25 ˚C and 1.0 atm and 12 L of He at 25 ˚C and 1.0 atm were both pumped into a 5.0 L scuba tank. Calculate the partial pressure of each gas and the total pressure at 25 ˚C

<u>Solution</u>

Because the pressure of each gas depends on the number of moles of each gas present we must first calculate the number of moles of each gas.

$$n_{O2} = PV/RT = 46 \text{ L} \times 1.0 \text{ atm}/ 0.08206 \text{ L atm mol}^{-1} \text{K}^{-1} \times 298 \text{ K} = 1.9 \text{ mole}$$

$$n_{He} = PV/RT = 12 \text{ L} \times 1.0 \text{ atm}/ 0.08206 \text{ L atm mol}^{-1} \text{K}^{-1} \times 298 \text{ K} = 0.49 \text{ mole}$$

The tank containing the mixture has a volume of 5.0 L

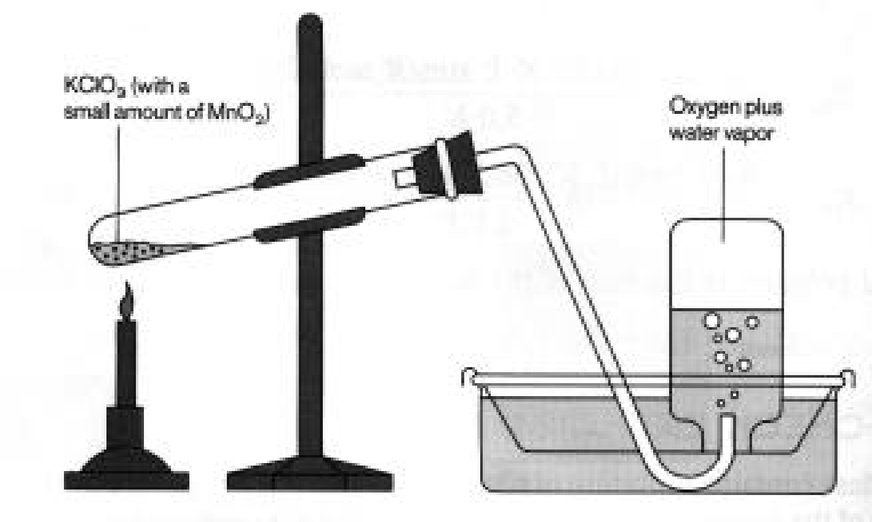
$$P_{O2} = nRT/V = 1.9 \text{ mol} \times 0.08206 \text{ L atm mol}^{-1} \text{K}^{-1} \times 298 \text{ K} /5.0\text{L} = 9.3 \text{ atm}$$

$$P_{He} = nRT/V = 0.49 \text{ mol} \times 0.08206 \text{ L atm mol}^{-1} \text{K}^{-1} \times 298 \text{ K} /5.0\text{L} = 2.4 \text{ atm}$$

$$P_T = P_{O2} + P_{He} = 12 \text{ atm}$$

EXAMPLE 2

A sample of solid $KClO_3$ is heated in the apparatus below and decomposed according to the reaction: $2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$ The oxygen thus produced is collected by displacement of water at 22 ˚C. The resulting mixture of O2 gas and water vapor has a pressure of 754 torr and a volume of 0.65 L. Calculate the partial pressure of O2 and the number of moles of O2 collected. The partial pressure of water vapor at 22˚C is 21 torr.



Solution:

We know the total pressure (754 torr) and the partial pressure of water (21 torr).

$P_T = P_{O2} + P_{H2O}$, $P_{O2} = P_T - P_{H2O}$ = 754 –21 torr = 733 torr

We can calculate the number of moles of O_2 collected

n = PV/RT = 733 torr x 0.65 L / 62.365 L torr mol^{-1} K^{-1} x 295K = 0.026 mole

EXAMPLE 3

What is the weight of $KClO_3$ required to obtain 1.3 L of O_2 under the above conditions?

Solution

Determine the number of moles of O_2 in the volume given above by first remembering that the partial pressure of O_2 in the mixture is 733 torr.

n = PV/RT = 733 torr x 1.3L / 62.365 L torr mol^{-1} K^{-1} x 295K = 0.052 mole

Solve the Stoichiometry relation: Moles O_2 → Moles $KClO_3$ → grams $KClO_3$

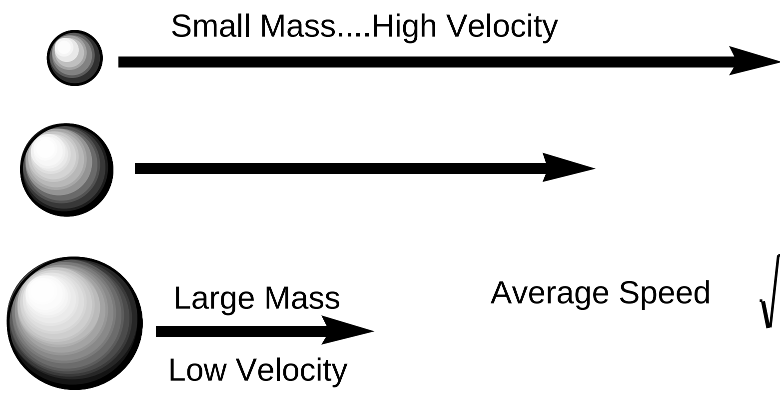
?g $KCLO_3$ = 0.052 mol O_2 x 2 mol $KClO_3$/3 mol O_2 x 122.5 g $KClO_3$/mol $KClO_3$
= 0.42 g $KClO_3$

MOLECULAR MOTION

WHY CAN YOU SMELL COFFEE BREWING IN THE KITCHEN WHEN YOU ARISE IN THE MORNING?

WHY DOES A JETLINER LOOSE PRESSURIZATION FROM A SMALL CRACK IN A WINDOW WHEN FLYING AT ALTITUDE?

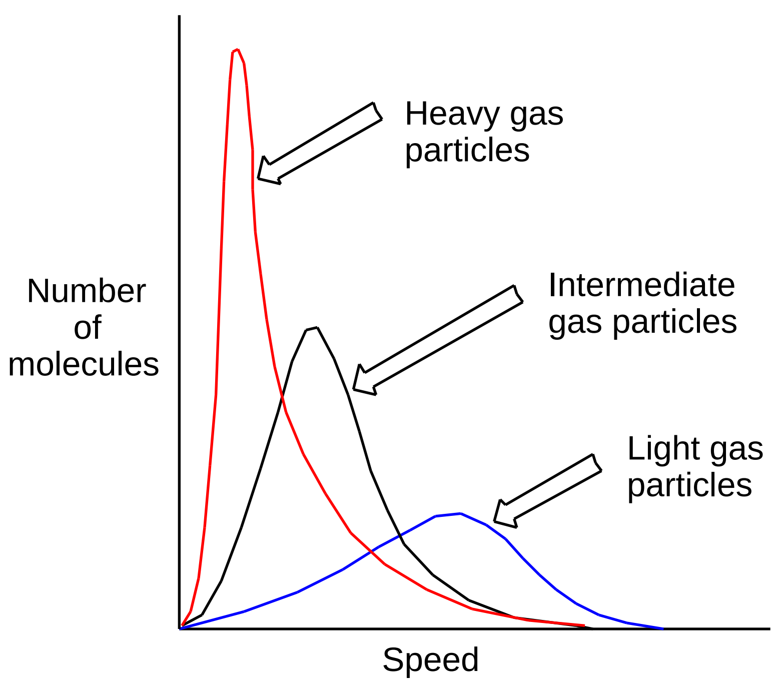
THE ANSWERS TO THESE QUESTIONS ARISE FROM OUR CONSIDERATION OF MOLECULAR MOTION…. REMEMBER AN IDEAL GAS IS A COLLECTION OF RANDOMLY MOVING PARTICLES WHICH MOVE IN A STRAIGHT LINE.



Average Speed $\sqrt{\frac{1}{MOLARMASS}}$

THE VELOCITY OF THSES IDEAL GAS PARTICLES IS RELATED TO THE MASS OF THE PARTICLES.

Maxwel Distribution of Speed for Different Mass



Average Speed $\sqrt{\frac{1}{MOLARMASS}}$

THE GRADUAL DISPERSAL OF ONE SUBSTANCE THROUGH ANOTHER SUBSTANCE IS CALLED **DIFFUSION**…. THE GAS PARTICLES RESPONSIBLE FOR THE SPECIAL AROMA OF COFFEE DIFFUSE THROUGH THE GAS PARTICLES OF THE ATMOSPHERE.

THE RAPID ESCAPE OF A SUBSTANCE THROUGH A SMALL HOLE INTO A VACUUM IS CALLED **EFFUSION**.

THE RATES OF BOTH DIFFUSION AND EFFUSION ARE PROPORTIONAL TO THE GAS PARTICLE'S VELOCITY AND INVERSELY PROPORTIONAL TO THE PARTICLES MASS. THIS CAN BE DESCRIBED BY GRAHAM'S LAW.

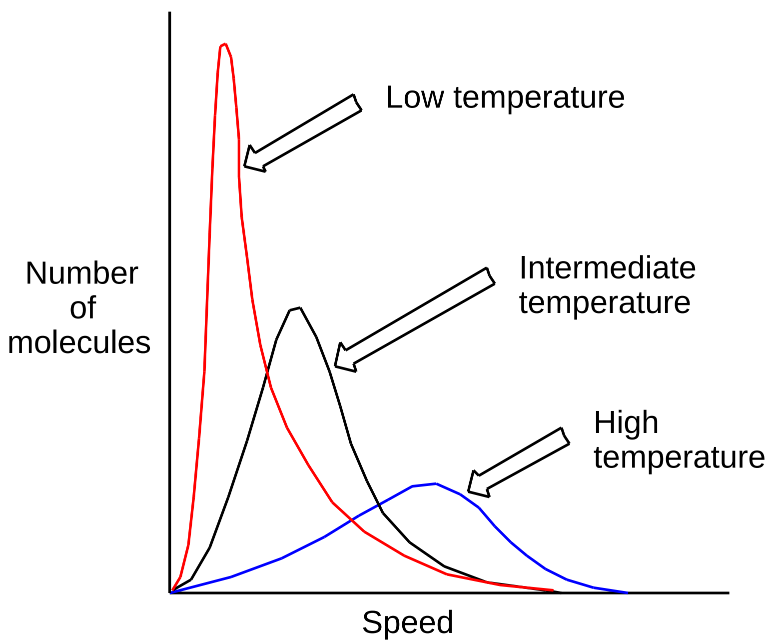
RATE OF EFFUSION(DIFFUSION) $\sqrt{\frac{1}{MOLARMASS}}$

SINCE TWO GASES OF DIFFERENT MOLAR MASSES MOVE AT DIFFERENT SPEEDS, IT MAKES SENSE THAT THE TIME IT TAKES FOR TWO DIFFERENT GASES TO ESCAPE THROUGH A SMALL HOLE IN A CONTAINER SHOULD BE RELATED TO THEIR MOLAR MASSES.

$$\frac{t_{effuse}(A)}{t_{effuse}(B)} = \frac{\sqrt{mollarmassA}}{\sqrt{mollarmassB}}$$

THE SPEED OF AN IDEAL GAS IS ALSO RELATED TO THE TEMPERATURE OF THE GAS

Maxwel Distribution of Speed by Temperature



Average Speed $\sqrt{temperature}$

Average Speed of Gases

A RELATIONSHIP EXISTS AMONG AVERAGE SPEED, MOLECULAR MASS AND TEMPERATURE…..**THE ROOT MEAN SQUARE OF THE VELOCITY**

$$\sqrt{\overline{\mu^2}} = \sqrt{\frac{3RT}{M}}$$

IFTHE MOLAR MASS IS KEPT CONSTANT, DOUBLING THE TEMPERATURE RESULTS IN A SPEED INCREASE OF $\sqrt{2}$ OR 1.4

IF THETEMPERATURE IS KEPT CONSTANT, DOUBLING THE MOLAR MASS RESULTS IN A SPEED INCREASE OF $\sqrt{1/2}$ OR O.707 (ACTUALLY A DECREASE)

Ideal gas properties (Kinetic model of gases)

a. Collection of randomly moving molecules.

10. Molecules occupy no space (infinitely small relative to the total space).
11. Molecules move in straight lines
12. Collisions are perfectly elastic.
    This means there can be no force of attraction between the molecules.

Real gas properties

a. At low pressures (one atmosphere or below) real gases follow the ideal gas laws relatively well.

b. At high pressures the calculated values from the ideal gas law equations will be off somewhat from the actual values. This is due to the fact that there is some attractions between reall gas atoms or molecules.

IDEAL GAS LAW PROBLEMS

Useful conversions that you should use when working the gas problems

1 atmosphere = 14.7 lbs/in^2 = 760 mm Hg = 760 Torr = 101.325 kPa

R = 0.08206 L atm mol^{-1} k^{-1} = 62.364 L torr mol^{-1} k^{-1}

Calculations

PV = nRT, n =PV/RT, P = nRT/V, V = nRT/P

Since n = PV/RT, when we change any conditions on a given amount of gas, we can calculate the new total conditions using the following relationship.

$P_1V_1/T_1 = P_2V_2/T_2$

At STP 1.00 mole of any gas has a volume of 22.4 L, at non-STP use Ideal Gas Law to determine molar volume

Gas density: d = m/V or molar mass/molar volume

1. Calculate the volume which 10 g of nitrogen gas will occupy at standard conditions

2. What will be the pressure of 10 g of nitrogen at 20°C in a 1 L flask?

3. If 1 L of methane at 20° C and atmospheric pressure is allowed to expand to 2.25 L, what will be the new pressure?

4. What is the density of nitrogen gas at 750 Torr and 23.0°C?

5. How many moles of nitrogen gas will occupy 2.50 L at 14.7 lb/in^2 and 25.0°C?

6. What will be the pressure in kPa for 1.00 mole of nitrogen gas in a 2.00 liter container at 0.00°C?

7. What is the molecular mass of an unknown gas if 10.00 g of the gas occupies 20.0 L at 2.00 atmospheres of pressure and 20.0°C?

8. What is the molecular weight of a gas which diffuses exactly four times faster than Cl_2 gas?

9. A 10.0 L container at 25.0° and 1.20 atmospheres pressure contains nitrogen gas. If 0.538 moles of hydrogen gas is forced into the container, what will be the new pressure inside the container?

10. How many moles of O_2 are present in a 5.00L volume of O2 collected by water displacement at a pressure of 755 torr. At the temperature of 20˚C water vapor has a partial pressure of 23 torr.

11. What volume of O_2 at STP is required to completely combust 35.0 L of methane gas at the same temperature and pressure. The unbalanced equation for methane combustion is given as:

$CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$