Boyles Law

At constant temperature the volume occupied by a fixed amount of gas is inversely proportional to the pressure on the gas

$$V \sim \frac{1}{P}$$

or

$$V = \frac{k_1}{P}$$

Boyles Law Example

	Pressure	Volume
Initial	2.00 atm	100 cm^3
Final	?	350 cm^3

Charles' Law

The volume V of a fixed amount of gas at constant pressure is proportional to the absolute temperature, T

$$V \sim T$$

or

$$V = k_2 T$$

Avogadros' Hypothesis

Equal volumes of gas, at the same temperature and pressure contain the same number of molecules.

Avogadros' Law

At constant temperature and pressure the volume of a gas is proportional to the number of moles of gas.

$$V \sim n$$

or

$$V = k_3 n$$

Ideal Gas Laws

$$\frac{PV}{nT} = \text{constant}$$

Boyle's Law

$$V = \frac{k_1}{P} \quad ; \quad V = \frac{nT\,\text{constant}}{P}$$

Charles' Law

$$V = k_2 T \quad ; \quad V = \frac{n\ \text{constant}}{P} T$$

Avogadro's Law

$$V = k_3 n \quad ; \quad V = \frac{T\,\text{constant}}{P} n$$

$$\frac{PV}{nT} = \text{constant} = R$$

Standard Temperature & Pressure
STP

$$PV = nRT$$

$$\text{Temperature} = 0\ ^{0}C, \quad \text{Pressure} = 1\ at$$

$$T = 273.15K$$

$$V = \frac{n(mol)\ 0.08206(L\ atm/mol\ K)\ 273}{1\ atm}$$

$$V = 22.4(L/mol)n(mol)$$

$$\frac{V}{n} = 22.4L$$

Ideal Gas Law Example

	Initial	Final
Property		
Moles	0.5	0.5
Temperature	0 ^{0}C	?
Volume	V_i	$V_f = V_i / 2$
Pressure	1 atm	2.2 atr

Ideal Gas Law Example

Property	Initial	Final
Moles	n	n
Temperature	22 ^{0}C	-21 ^{0}C
Volume	6 L	?
Pressure	1 atm	0.45 at

Gas Density
&
Molecular Weight (Molar Mass)

$$d(g/L) = \frac{n(mol)M(g/mol)}{V(L)} = \frac{nM}{V}$$

$$PV = nRT$$

$$P = \frac{n}{V}RT$$

$$P\ M = (\frac{n}{V}M)RT = d\ R\ T$$

Volumes of gases in chemical reaction

Safety air bags are inflated by nitrogrn gas via:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2$$

If an air bag has a volume of 36L and to be filled with nitrogen gas at a pressure of 1.15 atm and a temperatur of 26 ^{0}C, how many grams of

$$NaN_3$$

must be decomposed?

Example of using density measurements to determine a molecular weight

1. A flask is evacuated and found to weigh 134.567g

2. Its then filled with gas to a pressure of 735 torr at 31 ^{0}C

3. Reweigh and find mass 137.456g

4. Fill flask with water and found to weigh 1067.9g

5. Density of water at 31 ^{0}C is 0.997g/mL

Gas Mixtures & Partial Pressure

In a mixture of gases the pressure exerted by a particular gas is called the partial pressure of the gas.

In a mixture of N gases there will be N partial pressures.

Dalton's Law of Partial Pressure

The total pressure in the system is the sum of the partial pressures of the individual components.

$$P = P_1 + P_2 + P_3 + \ldots + P_N$$

Partial Pressure Example

Given gaseous mixture:

6.00 g of O_2 and 9.00 g of CH_4

Volume = 15.0L

Temperature = 0 ^{o}C

What is the partial pressure of each gas and the total pressure?

Mole Fraction

$$P_i = n_i \frac{RT}{V}$$

$$P_{total} = n_{total} \frac{RT}{V}$$

$$\frac{P_i}{P_{total}} = \frac{n_i}{n_{total}} = X_i$$

X_i is the mole fraction of species i in the mixture.

Note:

$$P_i = X_i P_{total}$$

$$n_i = X_i n_{total}$$

Mole Fraction Example

Given:

1.5 mol % CO_2

18.0 mol % O_2

80.5 mol % Ar

$P_{total} = 745\ torr$

What is the partial pressure of O_2 ?

If

$V = 120L\ \ \&\ \ T = 295K$

How many moles of O_2 ?

Example of gas collection over water

$$NH_4NO_2(s) \rightarrow N_2(g) + 2H_2O(l)$$

$V_{gas} = 511 mL$

$T = 26\ ^0C$

$P_{total} = 745\ torr$

How many grams of

NH_4NO_2

were decomposed?

Kinetic Molecular Theory of Gases

1. Gases consist of large numbers of molecules that are in continuous random motion.

2. The volume of all the molecules of the gas is negligible compared to the total volume in which the gas is contained.

3. Attractive and repulsive forces between gas molecules are negligible.

4. Collisions between molecules are perfectly elastic. Energy can be transferred between molecules.

5. The average kinetic energy of the molecules is proportional to the absolute temperature.

Pressure & Temperature in Kinetic Theory of Gases

Pressure

Caused by collisions of gas molecules with the walls of the container.

Magnitude of pressure is a reflection of how often and how vigorously the molecules collide with the wall.

Temperature

A measure of the average kinetic energy of the gas molecules. When the temperature doubles (on the Kelvin scale) the average kinetic energy doubles.

Kinetic Molecular Theory and the Gas Laws

Boyle's Law

Increase the volume at a constant temperature

Charles' Law

Increase the volume at constant pressure

Example of Molecular Speed Calculation

Calculate the rms of a
Nitrogen molecule at 25 ^{0}C

From Kinetic Theory

$$u = \sqrt{\frac{3RT}{M}}$$

Effusion and Diffusion

Effusion is the escape of a gas molecule through a tiny hole into an evacuated space

Diffusion is the spread of one substance through space or another substance

Example of Graham's Law of Effusion

An unknown gas composed of homonuclear diatomic molecules effuses at a rate that is only 0.355 times that of oxygen gas at the same temperature. What is the identity of the unknown gas?

The van der Waals Equation

$$P = \frac{nRT}{V}$$

Correct for Volume of Molecules

$$V_{ideal} = V - V_{molecules} = V - b$$

Correct for Molecular Interactions

$$P_{\text{measured}} = P_{\text{ideal}} - P_{\text{interactions}}$$

$$P_{\text{interactions}} \sim \left(\frac{n}{V}\right)^2$$

so

$$P_{\text{interactions}} = a\left(\frac{n}{V}\right)^2$$

Final Equation

$$P = \frac{nRT}{V - b} - a\left(\frac{n}{V}\right)^2$$

$$\left(P + a\frac{n^2}{V^2}\right) = \frac{nRT}{V - b}$$

Example of van der Waals Equation

What is the pressure exerted by

1 mole of Cl_2 gas in 22.4 liters

at 0 ^{0}C ?