AP Chemistry – Gas Laws

4 Properties Used to Describe Gases

1. Moles (n) – quantity of a gas
2. Temperature (Kelvin) – Avg KE of molecules
   think Boltzmann distribution
   ("Heat'em up, Speed'em up")
3. Volume (Liters) – amount of space occupied
4. Pressure (atm) – caused by collisions of gas
   molecules with side of container
   (more collisions = more pressure)

Pressure Conversions

1 atm = 760 mm Hg = 101.3 kPa = 760 Torr

(to convert from one to the other multiply by ratio)

Ex. Convert 345 mm Hg to atm

$$345 \text{ mm Hg} = \frac{1 \text{ atm}}{760 \text{ mm Hg}} = 0.454 \text{ atm}$$

Temperature Conversions

Most of your temps will be either Celsius or Kelvin

Most Likely	Less Likely
Celsius to Kelvin	Fahrenheit to Celsius
°C + 273 = K	$°C = (F - 32) \times \frac{5}{9}$

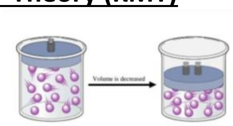
Kinetic Molecular Theory (KMT)

Assumptions of KMT:

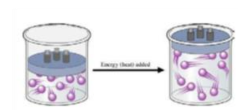
1. All particles in constant, random motion
2. All collisions are perfectly elastic
3. Volume of particles is negligible
4. Average KE of molecules is its temp in Kelvin

- It is also assumed that gas molecules have no IMFs
- Remember gases are compressible and take the shape of the container

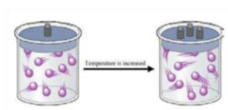
Be able to explain all 4 situations to the right →



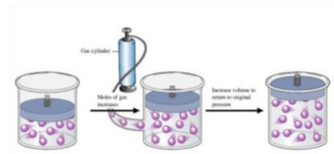
Pressure/Volume relationship
(Constant: Temp and moles)



Temp/Volume relationship
(Constant: Pressure and moles)



Pressure/Temp relationship
(Constant: Volume and moles)

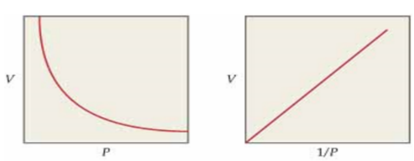


moles/Volume relationship
(Constant: Pressure and Temp)

Pressure and Volume Relationship (Boyles Law)

Pressure and Volume are INVERSELY RELATED

$$P_1V_1 = P_2V_2$$



Taking the INVERSE of one of the variables
Will give you a linear relationship!

These are the only 2 variables (P/V) that are INVERSELY RELATED

As pressure goes up, volume goes down
(at constant T/n)

STP

Standard Temperature and Pressure

1 atm

273 K

Pressure/Temp Relationship

(Gay-Lussacs Law)

Pressure and Temperature are DIRECTLY RELATED

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Moles/Volume Relationship

(Avagadros Law)

Volume and number of moles are DIRECTLY RELATED

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Important because it tells us that the same # of moles of 2 different gases will occupy same volume!

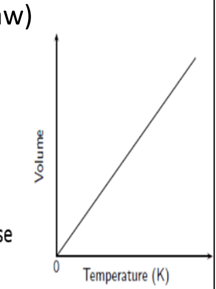
Volume/Temp Relationship

(Charles Law)

Volume and Temperature (in Kelvin) are DIRECTLY RELATED

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

If volume is increases, temp will increase
(at constant P/n)



IDEAL GAS LAW (piv-nert)

Used when gases are at NON-STADARD CONDITIONS to relate P/T/n/V to each other

Trick alert: one hint to use piv-nert is there will not be any before/after changes

You can also use PV=nRT to remember ALL of the gas laws above!

$$PV=nRT$$

As long as P is in atm

$$R = 0.0821 \frac{L*atm}{K*mole}$$

Gas Stoichiometry

Gas stoichiometry simply combines PV=nRT and stoichiometry

Scenario 1: START with gas at non-STP conditions
- start with PV=nRT and solve for moles of gas then use moles in stoich

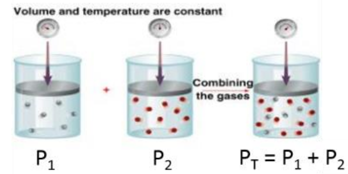
Scenario 2: END with gas at non-STP conditions
- start with stoich and solve for moles of gas then use moles in PV=nRT

Start with gas… Start with PV=nRT

End with gas… End with PV=nRT

Trick alert: you might have to do both!

Dalton's Law of Partial Pressures



All individual pressures ADD to total pressure

Dalton's Law:

$$P_T = P_1 + P_2 + \dots$$

Mole fractions can also be used to determine partial pressures

Mole fraction = $\frac{n_1}{n_T}$

$$P_1 = \left(\frac{n_1}{n_T}\right) \times P_T$$

Mole fractions represent percentage gas makes up of overall mixture (moles of gas directly related to pressure)

Densities of Gases

Density of a gas often used to determine the molar mass of the molecule

d = density (g/L)

$$MM = \frac{d\,R\,T}{P}$$

Memory trick: Molar Mass Kitty Cat

all good cats put dirt (dRT) over their Pee (P)

Dirt over P

or

$$MM = \frac{d\,R\,T}{P}$$

Collecting and Measuring Gases (Water Displacement Method)

Water displacement is one of the most common methods of gas collection

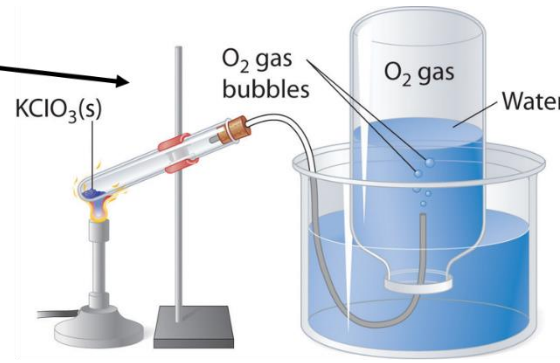
Gas collected from rxn bubbles into container and pushes out water

Amount of H_2O displaced can be used to get P_T

The partial pressure of water (P_{H_2O}) is known (and will be given) at all temperatures!

The trick is that…

$$P_T = P_{O_2} + P_{H_2O}$$



$2\ KClO_{3\ (s)} \rightarrow 2\ KCl_{\ (l)} + 3\ O_{2\ (g)}$

Molecular Speeds

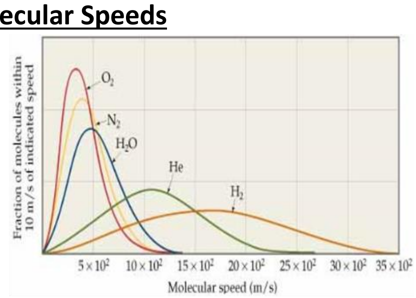
Average Velocity:

Must take into account mass and temperature

Called:

Root Mean Square Speed (rms)

$$v_{rms} = \sqrt{\frac{3RT}{MM}}$$



Moral of the story:

SMALLER molecules move FASTER (curve more flattened out)

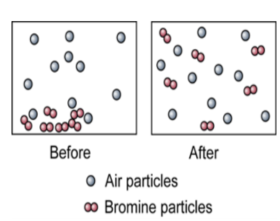
Speed of the molecule is inversely proportional to Molar Mass

Bigger moves slower!

Diffusion – Versus – Effusion

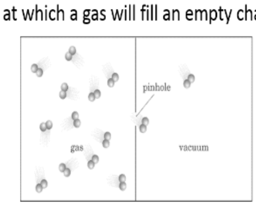
Diffusion

Diffusion describes mixing of gases (or the rate at which gases mix)



Effusion

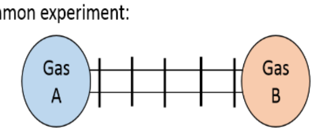
Effusion describes likelihood that molecule will pass through a small hole (rate at which a gas will fill an empty chamber)



Diffusion and effusion BOTH determined by speed of molecules!

The faster (or smaller) the molecules the faster the rate of each

Common experiment:



If gas A (MM= 18 g/mol) and gas B (MM=36 g/mol) released into tube, at what point will they react?