GASES

- Gases differ from the other two phases of matter in many ways:

  - They have very low viscosity (resistance to flow), so they flow from one place to another very easily.

  - They will take the volume of their container. In other words, gas volumes are variable.

  - They are the least dense of all three phases.

  - Most gases are transparent, and many are invisible.

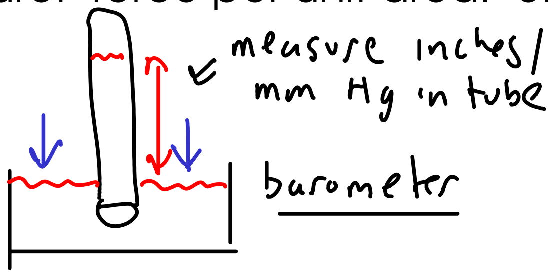
  - Gases show a much larger change of volume on heating or cooling than the other phases. ← thermal expansion!

  - Gases react to changes in temperature and pressure in a very similar way. This reaction often does not depend on what the gas is actually made of.

KINETIC THEORY

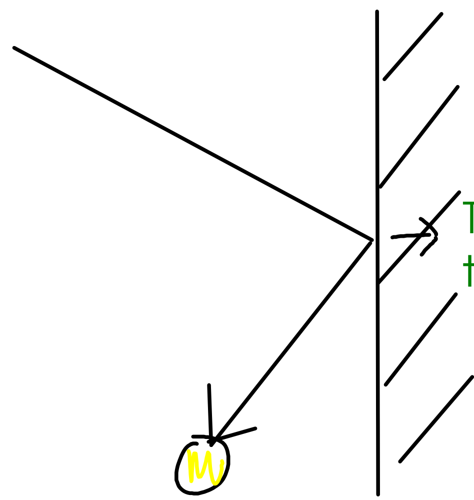
- is a way to explain the behavior of gases.
- views the properties of gases as arising from them being molecules in motion.

- Pressure: force per unit area. Units: Pascal, bar, mm Hg, in Hg, atm, etc.



760 mm Hg = 1 atm

- According to kinetic theory, pressure is caused by collisions of gas molecules with each other and the walls of the container the gas is in.



This collision exerts a force on the wall!

136- Temperature:

- a measure of the average kinetic energy of the molecules of the gas

$$E_K = \frac{1}{2} m v^2$$

m → mass; v → velocity

- The faster the gas molecules move, the higher the temperature!

- The temperature scales used when working with gases are ABSOLUTE scales.

- ABSOLUTE: scales which have no values less than zero.

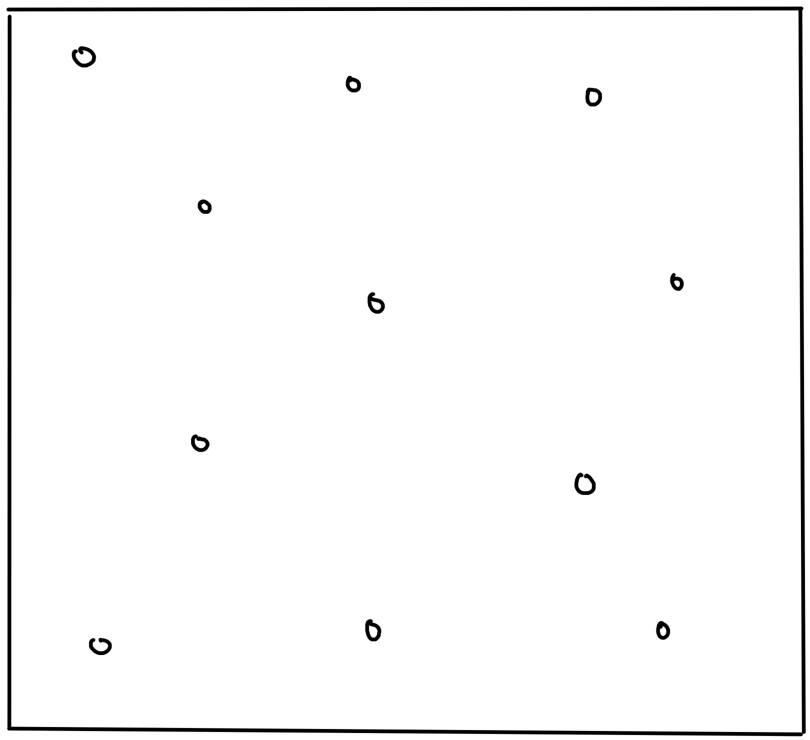
- KELVIN: metric absolute temperature scale.

$$K = 273.15 + {}^\circ C$$

Quick comparison of temperature scales!

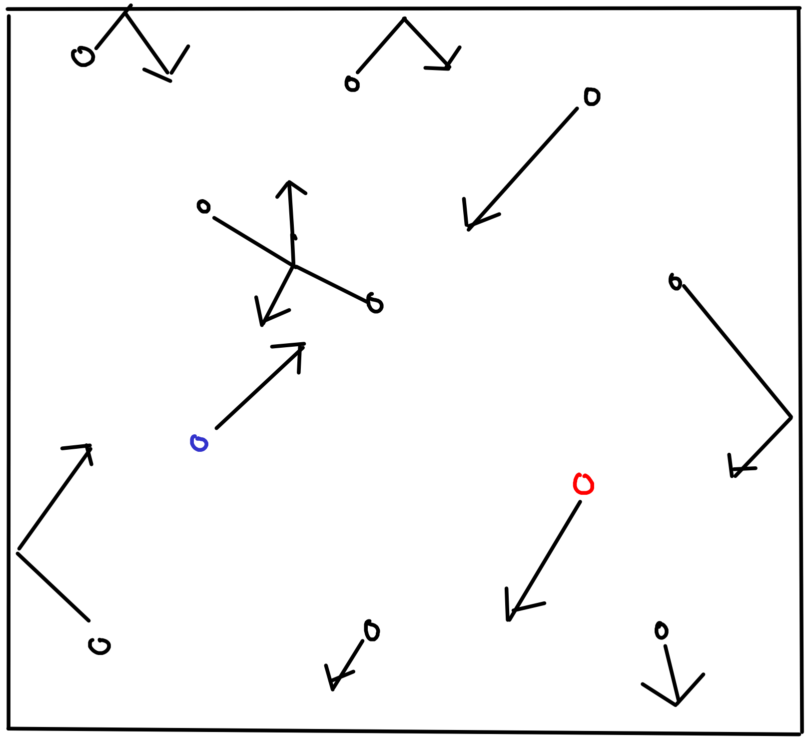
°F	°C	K	
212	100	373	Water boils
77	25	298	Room temperature
32	0	273	Water freezes
-460	-273	0	Absolute zero!

THE KINETIC PICTURE OF GASES



(1) Gas molecules are small compared to the space between the gas molecules!

LOW DENSITY!



(2) Gas molecules are constantly in motion. They move in straight lines in random directions and with various speeds.

(3) Attractive and repulsive forces between gas molecules are so small that they can be neglected except in a collision.

- Each gas molecule behaves independently of the others.

(4) Collisions between gas molecules and each other or the walls are ELASTIC.

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

How does this picture explain the properties of gases?

- Gases expanding to fill their container? Agrees with kinetic picture, since gas molecules are independent
- Thermal expansion of gas at constant pressure? Agrees, because the container has to EXPAND to keep the pressure (from collisions) constant when the gas molecules move faster.
- Pressure increases with temperature at constant volume: Agrees, because the number and force of collisions increases with molecular speed.

GAS LAWS

- were derived by experiment long before kinetic theory, but agree with the kinetic picture!

Boyle's Law:

$$PV = \text{constant}$$

True at constant temperature

$$P_1V_1 = \text{constant} \qquad P_2V_2 = \text{constant}$$

$$\boxed{P_1V_1 = P_2V_2}$$

True at constant temperature

Charles's Law:

$$\frac{V}{T} = \text{constant}$$

True at constant pressure, and using ABSOLUTE temperature

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

True at constant pressure, and using ABSOLUTE temperature

Combined gas law:

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

Must use ABSOLUTE temperature units!

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Must use ABSOLUTE temperature units!

amount (moles) of gas must be constant!

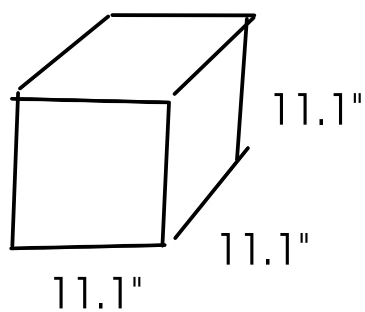
Avogadro's law:

- a mole of any gas at the same conditions has the same volume.

1 mol gas molecules @ 0°C and 1 atm

volume = 22.4 L

"STP"
Standard
Temperature
and
Pressure



= 22.4 L

Ideal gas law:

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

... but this constant actually depends on the amount of gas!

$$= n \times \text{"}R\text{"}$$

The ideal gas constant.

$$0.08206 \frac{L \cdot atm}{mol \cdot K}$$

... combining these together ...

$$\frac{PV}{T} = nR$$

$$PV = nRT$$

P = pressure atm

V = volume L

T = ABSOLUTE temperature K

R = ideal gas constant

n = number of moles of gas molecules

CHEMICAL CALCULATIONS WITH THE GAS LAWS

$FW_{NaHCO_3} = 84.007\ g/mol$

$$H_2SO_4(aq) + 2NaHCO_3(s) \rightarrow 2H_2O(l) + 2CO_2(g) + Na_2SO_4(aq)$$

Given 25.0 g of sodium bicarbonate and sufficient sulfuric acid, what volume of carbon dioxide gas would be produced at 25.0 C and 0.950 atm pressure?

1 - Convert mass of sodium bicarbonate to moles using formula weight.
2 - Convert moles sodium bicarbonate to moles carbon dioxide using chemical equation
3 - Convert moles carbon dioxide to volume using IDEAL GAS EQUATION.

$84.007\ g\ NaHCO_3 = mol\ NaHCO_3$ | $2\ mol\ NaHCO_3 = 2\ mol\ CO_2$

$$25.0\ g\ NaHCO_3 \times \frac{mol\ NaHCO_3}{84.007\ g\ NaHCO_3} \times \frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3} = 0.297594248l\ mol\ CO_2$$

(1) (2)

(3) $PV = nRT$

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

$n = 0.297594248l\ mol\ CO_2$ $T = 25.0°C = 298.2\ K$

$R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$ $P = 0.950\ atm$

$$V = \frac{(0.297594248l\ mol\ CO_2)\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)}{(0.950\ atm)} = 7.67\ L\ CO_2\ gas$$

What volume would the gas in the last example problem have at STP?

STP: "Standard Temperature and Pressure" (0 C and 1 atm)

We can use the combined gas law to change one set of conditions to another.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \; ; \; \frac{P_1 V_1 T_2}{T_1 P_2} = V_2$$

$P_1 = 0.950$ atm $P_2 = 1$ atm

$V_1 = 7.67$ L $V_2 = ?$ L

$T_1 = 298.2$ K $T_2 = 0°C = 273.2$ K

$$V_2 = \frac{(0.950 \text{ atm})(7.67 \text{ L})(273.2 \text{ K})}{(298.2 \text{ K})(1 \text{ atm})} = 6.68 \text{ L } CO_2 \text{ at STP}$$

Alternate solution: Since we know the number of moles of gas, we can just use the ideal gas equation with the pressure and temperature of STP. (The answer should be the same number, within rounding.)