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

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

$$\rightarrow \boxed{P_1V_1 = P_2V_2}$$

True at constant temperature

Charles's Law:

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

True at constant pressure, and using ABSOLUTE temperature

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

True at constant pressure, and using <u>ABSOLUTE</u> 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!

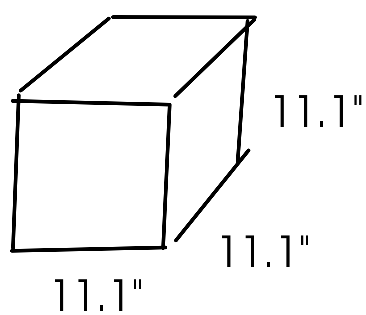
Avogadro's law:

- 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 this 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 sodium bicarbonate to moles (formula weight of sodium bicarbonate)
2 - Convert moles sodium bicarbonate to moles carbon dioxide using chemical equation
3 - Convert moles carbon dioxide to volume using the ideal gas equation

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

$$25.0\ g\ NaHCO_3 \times \underbrace{\frac{mol\ NaHCO_3}{84.007\ g\ NaHCO_3}}_{①} \times \underbrace{\frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3}}_{②} = 0.297594\ mol\ CO_2$$

③ $PV = nRT \rightarrow V = \frac{nRT}{P}$

$n = 0.297594\ mol\ CO_2$ $P = 0.950\ atm$

$R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$ $T = 25.0^\circ C = 298.2\ K$

$V = ???\ L$

$$V = \frac{(0.297594\ mol\ CO_2)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)}{(0.950\ atm)} = \boxed{7.67\ L\ CO_2}$$

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

STP: 0°C, 1 atm

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

Solve this one using the combined gas law. We know all the initial conditions (P, V, and T)

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

$P_1 = 0.950$ atm

$V_1 = 7.67$ L

$T_2 = 0°C = 273$ K

$T_1 = 25.0°C = 298.2$ K

$P_2 = 1$ atm

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{(0.950 \text{ atm})(7.67 \text{ L})(273 \text{ K})}{(298.2 \text{ K})(1 \text{ atm})} = 6.67 \text{ L } CO_2 \text{ @ STP}$$

Alternate solution: Since we knew the number of moles, we could also use the ideal gas equation to solve this problem. You'll get the same answer doing it that way.