GAS LAWS

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

Boyle's Law:

$$PV = constant$$

True at constant temperature

$$P_1 V_1 = constant \qquad P_2 V_2 = constant$$

$$\rightarrow \boxed{P_1 V_1 = P_2 V_2}$$ True at constant temperature

Charles's Law:

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

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:

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

Must use ABSOLUTE temperature units!

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$
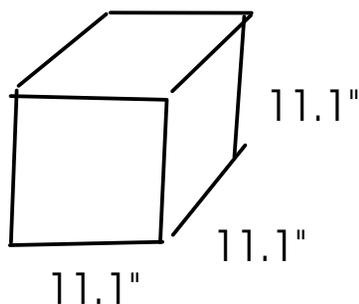
Must use ABSOLUTE temperature units!

└ 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

"STP"

Standard Temperature and Pressure

volume = 22.4 L

11.1"
11.1"
11.1"

= 22.4 L

Ideal gas law:

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

... but this constant actually depends on the <u>amount</u> of gas!

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

The ideal gas constant.

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

... combining these together ...

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

$$\boxed{PV = nRT}$$

P = pressure atm

V = volume L

T = ABSOLUTE temperature K

R = ideal gas constant

n = number of moles of gas molecules

A balloon is taken from a room where the temperature is 27.0 C to a freezer where the temperature is -5.0 C. If the balloon has a volume of 3.5 L in the 27.0 C room, what is the volume of the balloon in the freezer. Assume pressure is constant.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \text{ , P constant, so } \frac{V_1}{T} = \frac{V_2}{T_2}$$

$$\frac{(3.5L)}{(300.2K)} = \frac{V_2}{(268.2k)}$$

$V_1 = 3.5L$

$T_1 = 27.0°C = 300.2K$

$V_2 = ?$

$T_2 = -5.0°C = 268.2K$

$$\boxed{3.1L = V_2}$$ ...is the volume in the freezer.

2.25 L of nitrogen gas is trapped in a piston at 25.0 C and 1.00 atm pressure. If the piston is pushed in so that the gas's volume is 1.00 L while the temperature increases to 31.0 C, what is the pressure of the gas in the piston?
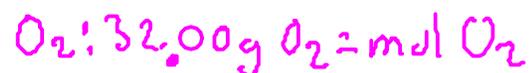
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$P_1 = 1.00 \text{ atm}$

$V_1 = 2.25L$

$T_1 = 25.0°C = 298.2K$

$P_2 = ?$

$V_2 = 1.00L$

$T_2 = 31.0°C = 304.2K$

$$\frac{(1.00 atm)(2.25L)}{(298.2K)} = \frac{P_2 (1.00L)}{(304.2K)} \text{ ; } \boxed{P_2 = 2.30 atm}$$

Calculate the <u>mass</u> of 22650 L of oxygen gas at 25.0 C and 1.18 atm pressure.

$\downarrow O_2$

$O_2: 32.00 g\ O_2 = mol\ O_2$

1 - Calculate the moles of oxygen gas using the ideal gas equation.
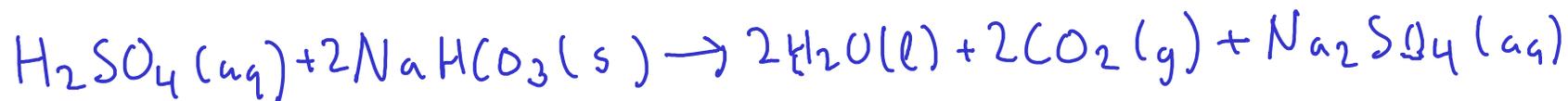2 - Convert moles oxygen gas to mass using formula weight.

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$P = 1.18\,atm$

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

$V = 22650\,L$

$T = 25.0\,^{\circ}C = 298.2\,K$

① $n_{O_2} = \dfrac{(1.18\,atm)(22650\,L)}{(0.08206 \frac{L \cdot atm}{mol \cdot K})(298.2\,K)} = 1092.222357\,mol\ O_2$

② $1092.222357\,mol\ O_2 \times \dfrac{32.00\,g\ O_2}{mol\ O_2} = \boxed{35000\,g\ O_2}\ (35.0\,Kg\ O_2)$

$\sim 77\,lb$

CHEMICAL CALCULATIONS WITH THE GAS LAWS

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

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

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 25.0 grams sodium bicarbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium bicarbonate to moles carbon dioxide gas. Use CHEMICAL EQUATION
3 - Convert moles carbon dioxide gas to volume. Use IDEAL GAS EQUATION.

① $84.007_g \, NaHCO_3 = mol \, NaHCO_3$ ② $2 mol \, NaHCO_3 = 2 mol \, CO_2$

$$25.0_g \, NaHCO_3 \times \frac{mol \, NaHCO_3}{84.007_g \, NaHCO_3} \times \frac{2 mol \, CO_2}{2 \, mol \, NaHCO_3} = 0.2975942481 \, mol \, CO_2$$
$$\qquad\qquad\qquad\qquad ① \qquad\qquad\qquad ②$$

③ $PV = nRT$ | $n = 0.2975942481 \, mol \, CO_2$ $T = 25.0°C = 298.2 \, K$

$V = \frac{nRT}{P}$ | $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$ $P = 0.950 \, atm$