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

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

$$\rightarrow P_1V_1 = P_2V_2$$

True at constant temperature

Charles's Law:

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

True at constant pressure, and using ABSOLUTE temperature

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

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!

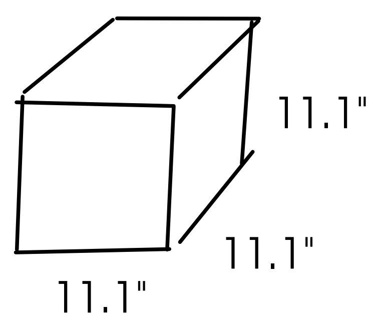
Avogadro's law:

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

1 mol gas molecules @ 0°C and 1 atm

"STP"
Standard Temperature and Pressure

volume = 22.4 L



= 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

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.

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$; Since P = constant $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$V_1 = 3.5\,L$ | $V_2 = ?$

$T_1 = 27.0°C = 300.2\,K$ | $T_2 = -5.0°C = 268.2\,K$

$\frac{(3.5\,L)}{(300.2\,K)} = \frac{V_2}{(268.2\,K)}$; $V_2 =$ 3.1 L 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?

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$P_1 = 1.00\,atm$ | $P_2 = ?$

$V_1 = 2.25\,L$ | $V_2 = 1.00\,L$

$T_1 = 25.0°C = 298.2\,K$ | $T_2 = 31.0°C = 304.2\,K$

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

Calculate the mass of 22650* L of oxygen gas at 25.0 C and 1.18 atm pressure.

↖ O_2

O_2: 32.00 g O_2 = mol O_2

*Volume of a 10'x10'x8' room

Use the ideal gas equation to find MOLES of gas. Them, we will convert moles of gas to MASS using the formila weight of oxygen gas.

$$PV = nRT$$

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

P = 1.18 atm

V = 22650 L

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

T = 25.0°C = 298.2 K

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

Now convert moles oxygen to mass...

$$1092.222357\ mol\ O_2 \times \frac{32.00\ g\ O_2}{mol\ O_2} = 35000\ g\ O_2$$

35.0 kg

~77 lb

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 25.0 grams 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.

① $84.007\ g\ NaHCO_3 = mol\ NaHCO_3$

② $2\ mol\ NaHCO_3 = 2\ mol\ CO_2$

$$25.0\ g\ NaHCO_3 \times \underbrace{\frac{mol\ NaHCO_3}{84.007\ g\ NaHCO_3}}_{①} \times \underbrace{\frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3}}_{②} = 0.2975942481\ mol\ CO_2$$

③ $PV = nRT$

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

$P = 0.950\ atm$ $\quad n = 0.2975942481\ mol\ CO_2$

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

$$V = \frac{(0.2975942481\ mol\ CO_2)\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)}{(0.950\ atm)} = 7.67\ L \text{ of } CO_2$$