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

$$P_1 V_1 = \text{constant} \qquad P_2 V_2 = \text{constant}$$

$$\rightarrow \boxed{P_1 V_1 = P_2 V_2}$$

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 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!

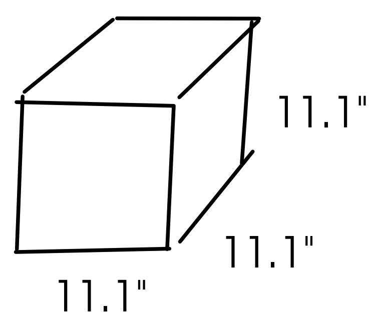
Avogadro's law:

- 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

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.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}; \text{ const } P, \text{ so } \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$V_1 = 3.5 L$

$T_1 = 27.0°C = 300.2 K$

$V_2 = ?$

$T_2 = -5.0°C = 268.2 K$

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

$V_2 = $ **3.1 L in 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?

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

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

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

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

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

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

1 - Calculate the moles of oxygen gas using the IDEAL GAS EQUATION.

2 - Convert the moles of oxygen gas to mass using the FORMULA WEIGHT.

(1) $PV = nRT$

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

$P = 1.18\ atm$ $\quad R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

$V = 22650\ L$ $\quad T = 25.0°C = 298.2\ K$

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

(2)

$$1092.222357\ mol\ O_2 \times \frac{32.00\ g\ O_2}{mol\ O_2} = \boxed{35\bar{0}00\ g\ O_2}$$

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 g 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.