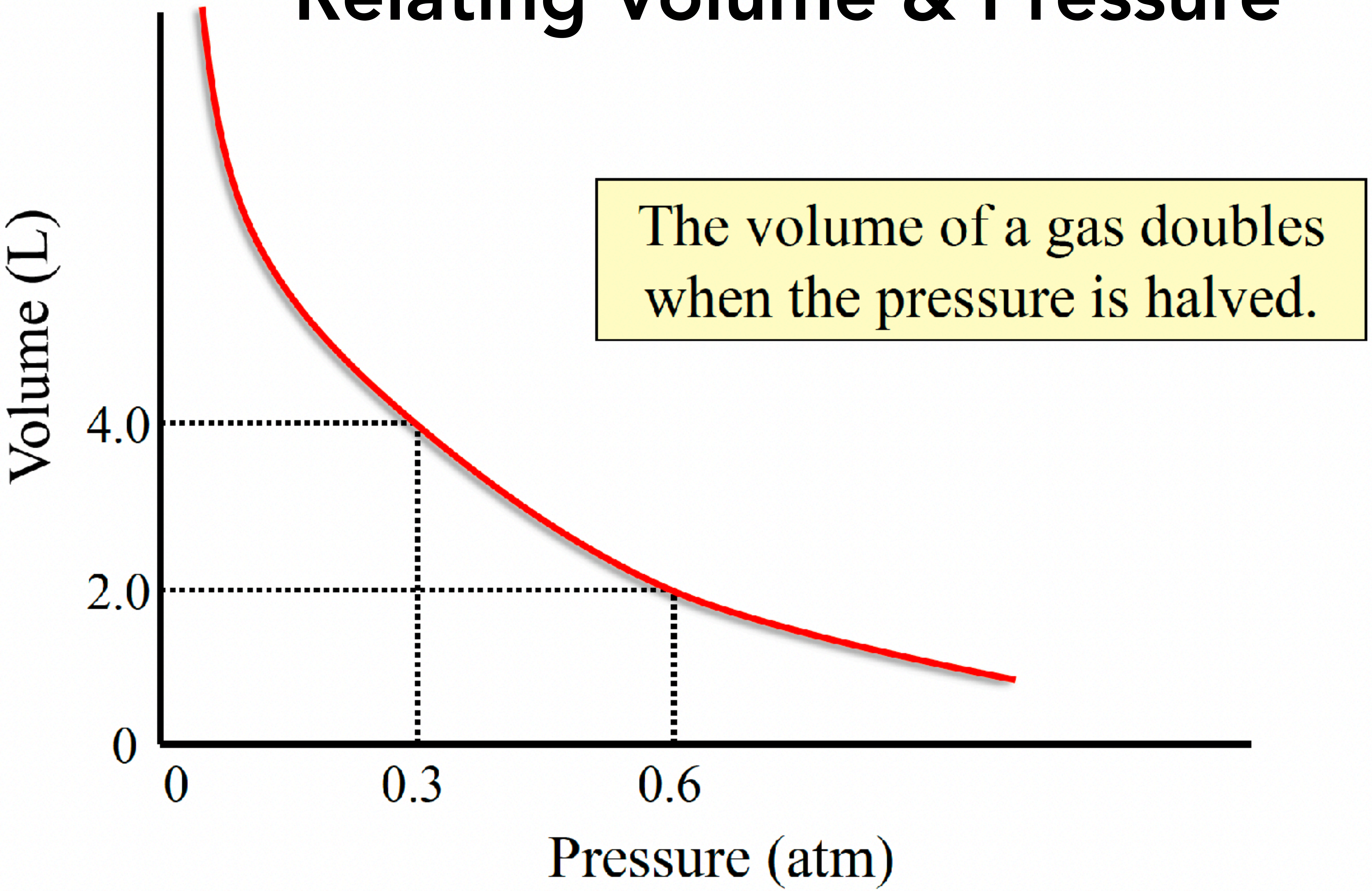
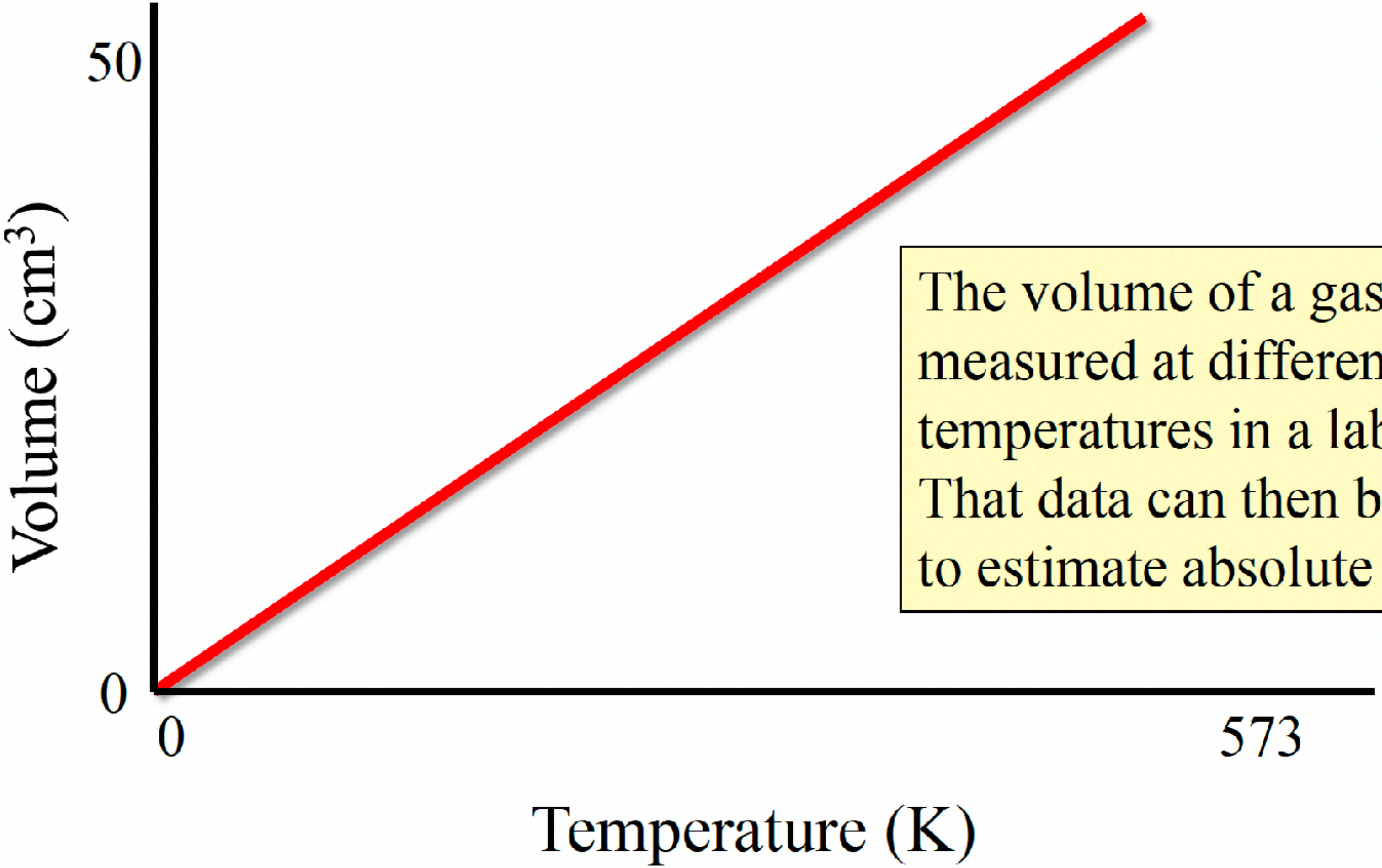
3.4 Ideal Gas Law

- Gas Laws
- Ideal Gas Law
- Dalton's Law of Partial Pressures
- Mole Fractions

Relating Volume & Pressure

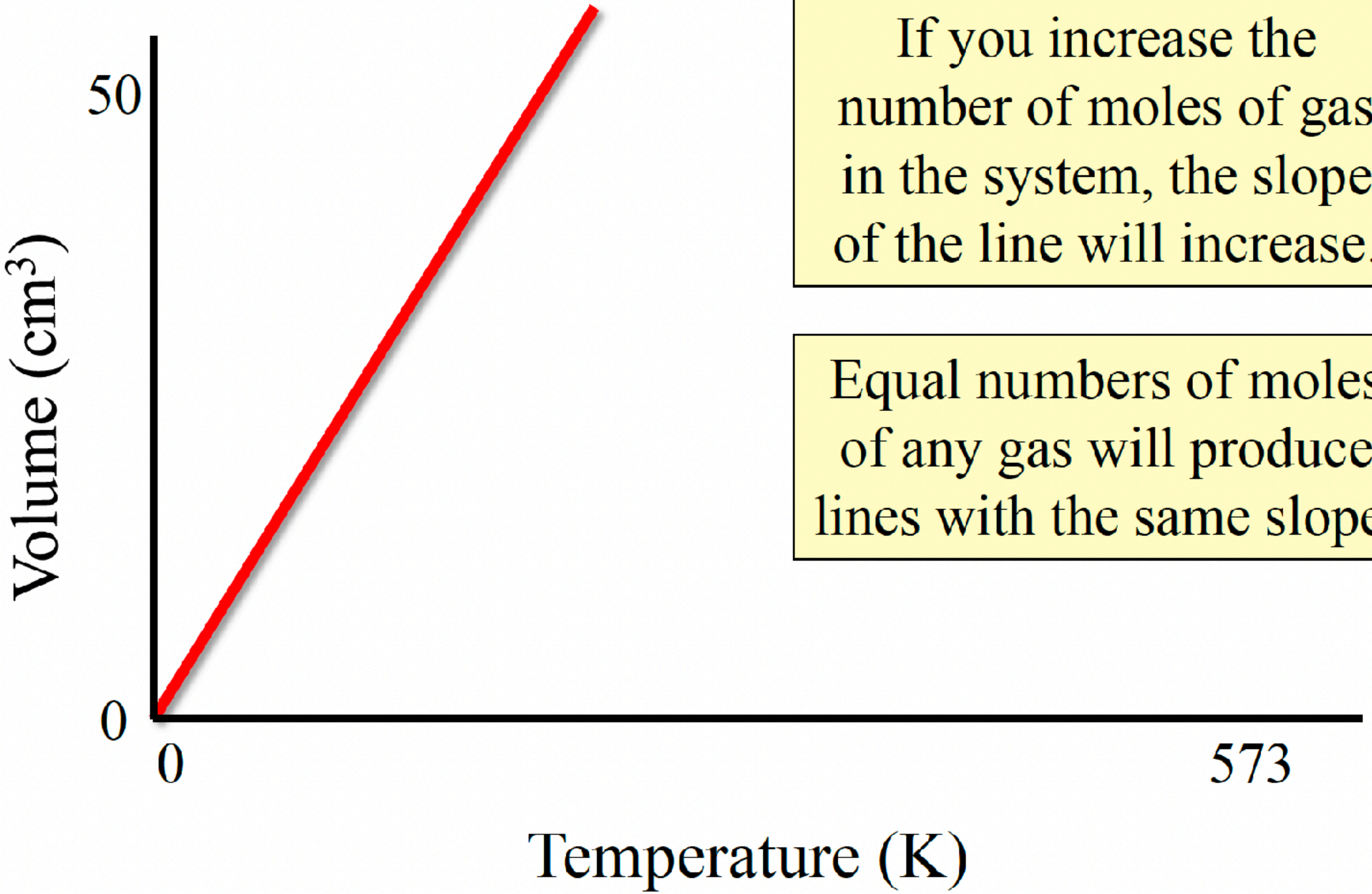


Relating Volume & Temperature



The volume of a gas can be measured at different temperatures in a laboratory. That data can then be plotted to estimate absolute zero.

Relating Volume & Temperature

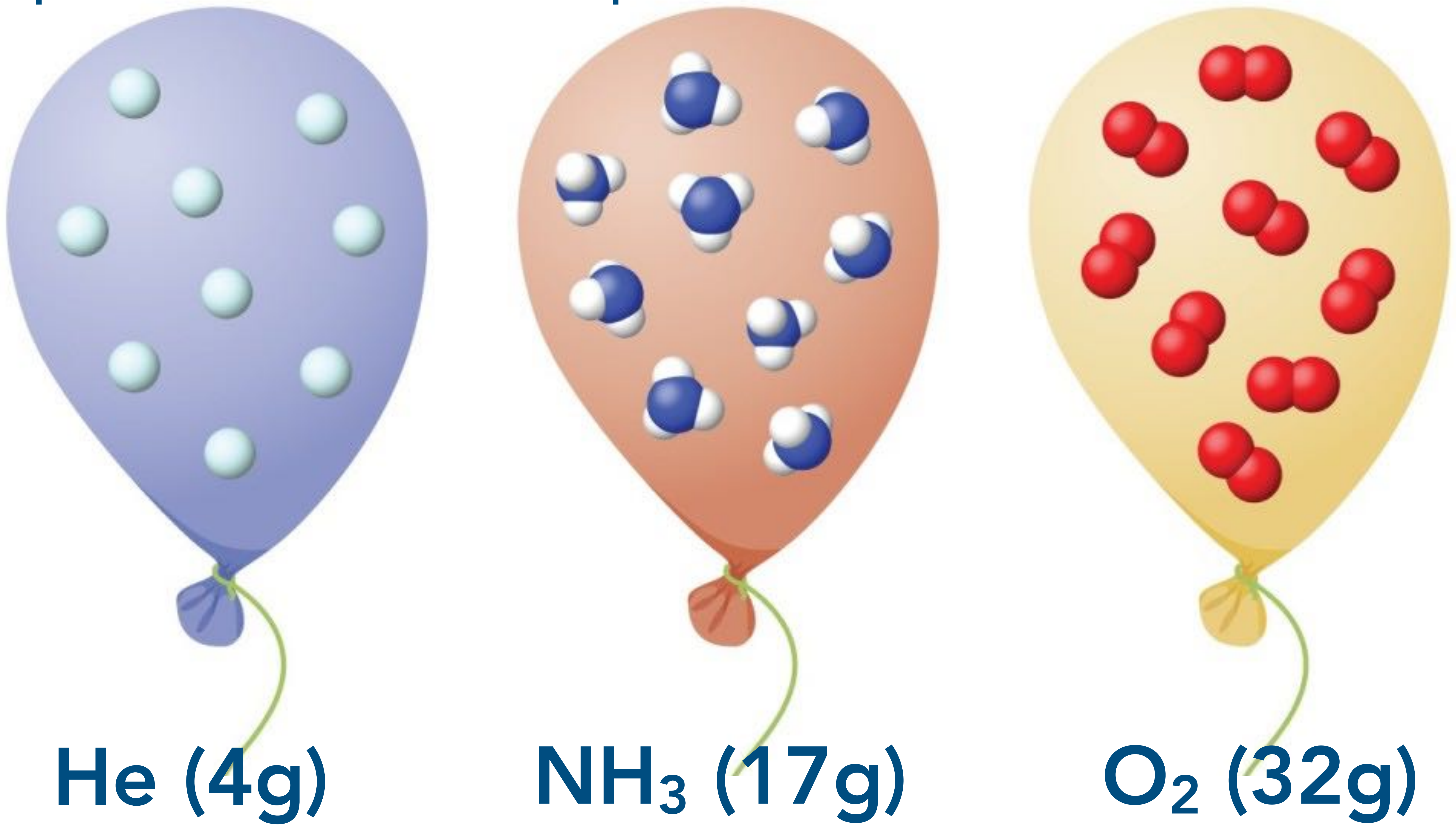


If you increase the number of moles of gas in the system, the slope of the line will increase.

Equal numbers of moles of any gas will produce lines with the same slope.

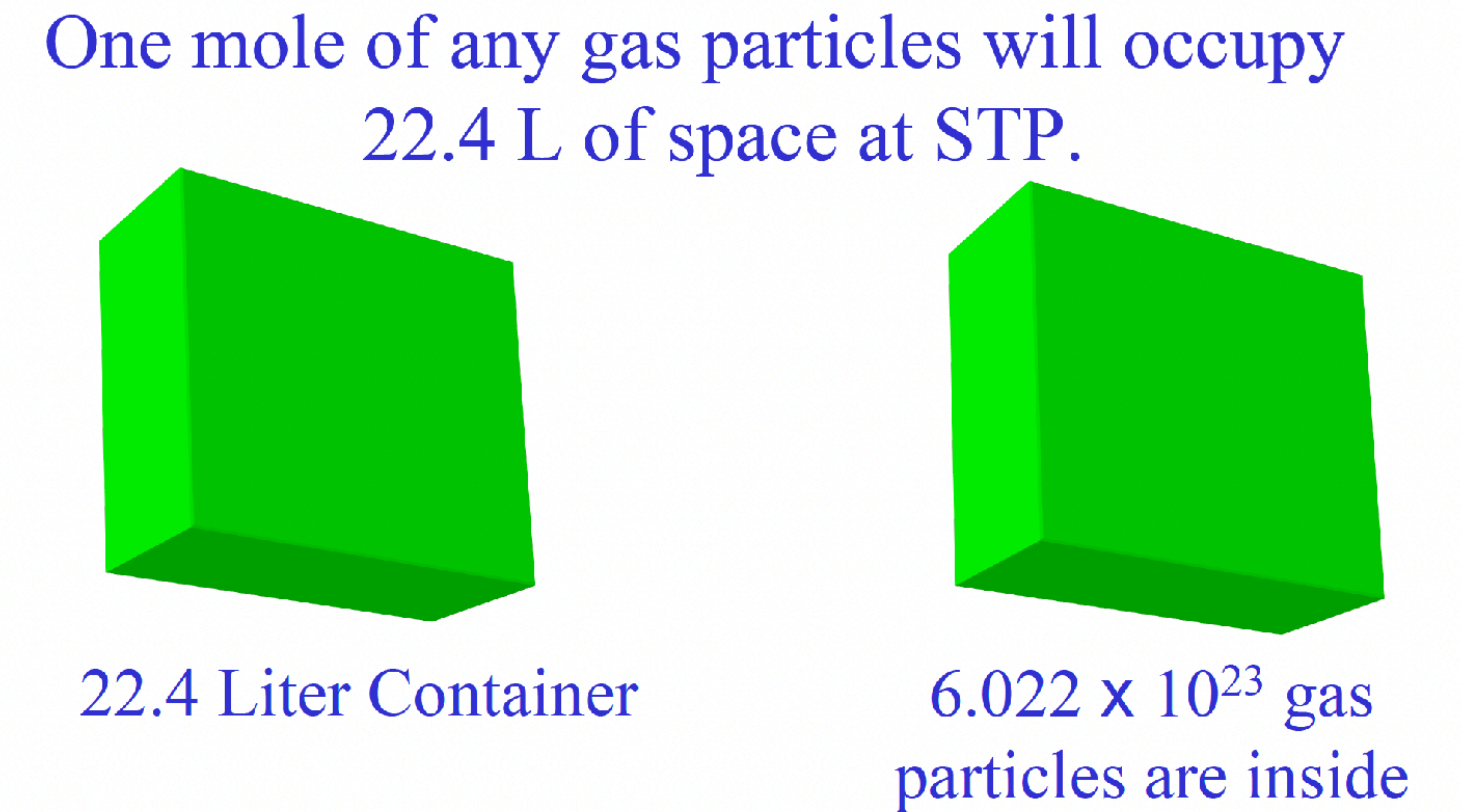
Avogadro's Principle

Equal volumes of different gases at the same temperature and pressure contain equal numbers of particles.



Standard Temperature & Pressure (STP)

0°C (273 K) and 1 atm for gases



Ideal Gas Equation

PV = *n*RT

P = pressure (atm)

V = volume (L)

n = number of moles

R = Gas constant ($0.0821\ L \bullet atm \bullet K^{-1} \bullet mol^{-1}$)

T = temperature (K)

Example #1: Ideal Gas Equation

A 8.5 L tank contains Helium gas at 16.9 atm and 25°C. How many moles of He are available for making balloons?

$PV = nRT$

Example #2: Ideal Gas Equation

If all of the helium is used to fill 1.5 L red balloons at 0.99 atm and 32°C, how many balloons will you end up with?

$PV = nRT$

Example #3: Ideal Gas Equation

An unknown gas is collected in an 850.0 mL vessel at 1.02 atm and 23°C. The evacuated vessel has a mass of 138.45 g and the vessel and gas have a combined mass of 140.12 g. Find the molar mass of the gas.

$$PV = nRT$$

Example #4: Ideal Gas Equation

An unknown gaseous hydrocarbon has a density of 3.24 g/L at 1.00 atm and 28°C. Find its molar mass.

$PV = nRT$

The Combined Gas Law

If the pressure, volume or temperature of a system changes, but the number of moles remains the same, the combined gas law equation can be derived from the ideal gas law equation in order to solve the problem.

$$P_iV_i = nRT_i$$

$$\frac{P_iV_i}{T_i} = nR$$

$$\frac{P_iV_i}{T_i} = \frac{P_fV_f}{T_f}$$

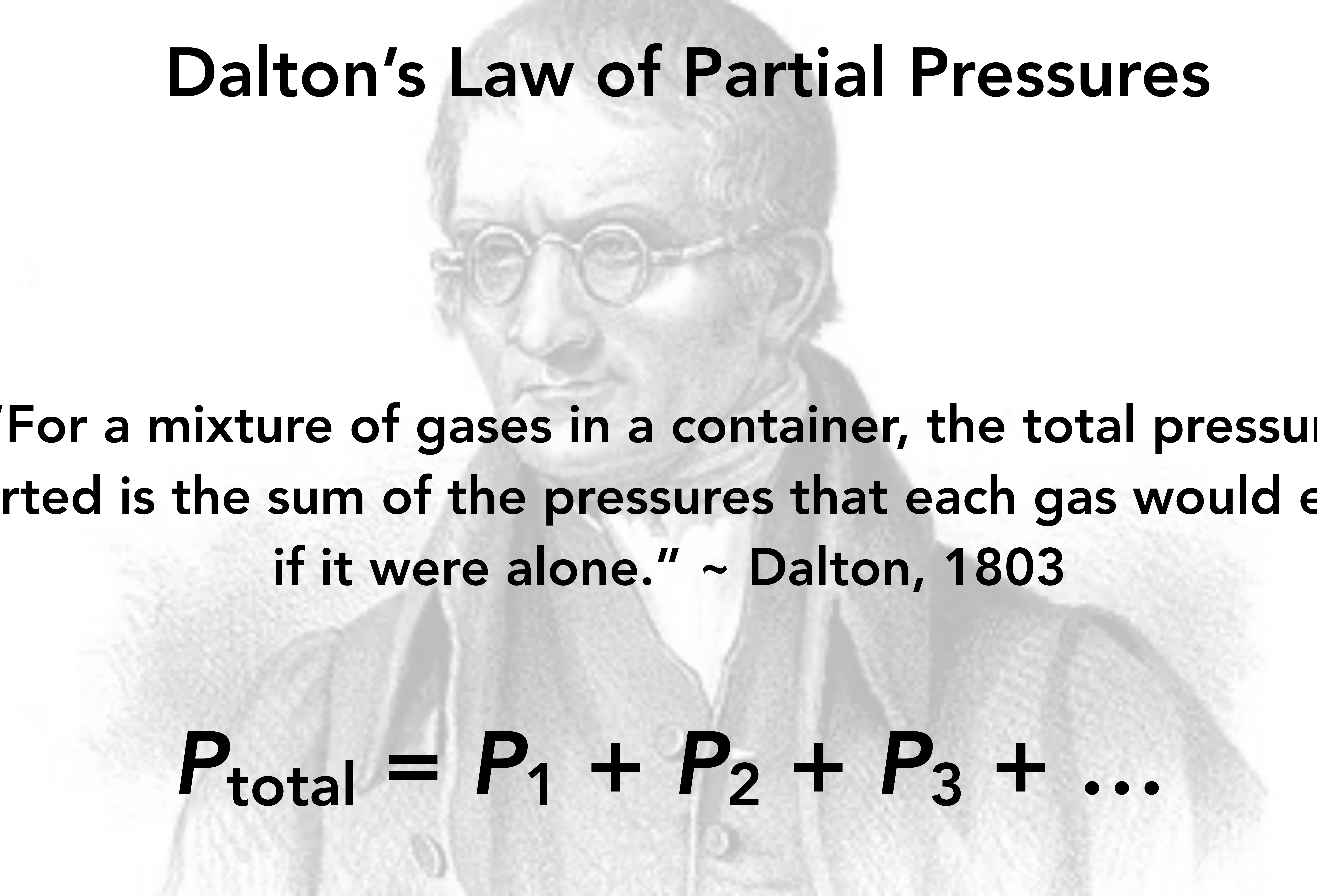
$$P_fV_f = nRT_f$$

$$\frac{P_fV_f}{T_f} = nR$$

$$\frac{P_i V_i}{T_i} = \frac{P_f V_f}{T_f}$$

Example: Combined Gas Law

A cylinder of gas is kept at a constant volume as the temperature increases from 24.1˚C to 326.4˚C. If the initial pressure is 1.01 atm, what is the final pressure in mm Hg?



Dalton's Law of Partial Pressures

"For a mixture of gases in a container, the total pressure exerted is the sum of the pressures that each gas would exert if it were alone." ~ Dalton, 1803

$$P_{total} = P_1 + P_2 + P_3 + \ldots$$

Example: Partial Pressures

100.8 g of O_2 and 289.8 g of N_2 are pumped into a 6.00 L SCUBA tank that is kept at 20˚C.

(a) Find the partial pressure of each gas.

(b) Find the total pressure in the tank.

Calculating Mole Fractions

Mole Fraction – the percent composition by moles of a single component in a mixture, represented in its decimal form.

$$X_A = \frac{\text{Moles of one component } (n_A) \text{ in a mixture}}{\text{Sum of the moles of all components in the mixture}}$$

$$X_A = \frac{n_A}{n_A + n_B + n_C + n_D + \cdots + n_Z}$$

$$X_A = \frac{n_A}{n_A + n_B + n_C + n_D + \cdots + n_Z}$$

Example 1: Mole Fraction

Find the mole fraction of each component in a gaseous solution that contains:

6.70 mol He, 2.50 mol Ar and 1.60 mole Cl_2

$$X_A = \frac{n_A}{n_A + n_B + n_C + n_D + \cdots + n_Z}$$

Example 2: Mole Fraction

A gaseous solution contains Ne, H_2 and He. The mole fractions of Ne and H_2 are known to be 0.233 and 0.478, respectively. What is the mole fraction of He?

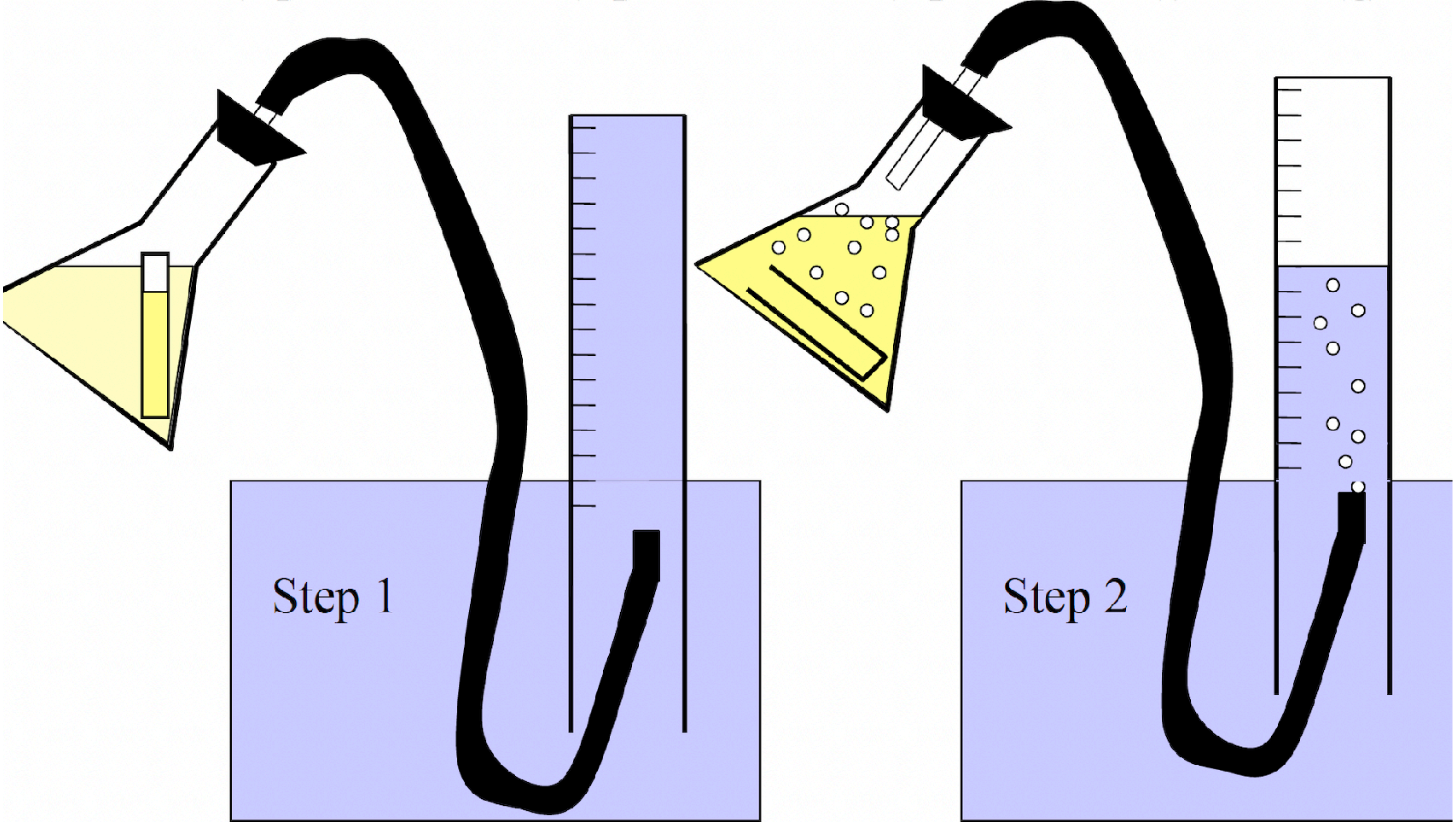
Mole Fractions & Partial Pressures

You can find the partial pressure of any component in a gas mixture by multiplying the total pressure by its mole fraction.

The mole fraction of $O_2(g)$ in a container at 0.97 atm is found to be 0.210. What is the partial pressure exerted by $O_2(g)$?

$$P_{O_2} = X_{O_2} \bullet P_{total}$$

$$H_2O_{2(aq)} + NaClO_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + O_{2(g)}$$



Collecting Gases Over Water

A 0.129 g sample of an unknown gas was collected over water at 25.0˚C and 1.01 atm. The collection cylinder contained 37.45 mL of gas after the sample was released. The vapor pressure of water is 23.76 mm Hg at 25.0˚C. Find the molar mass of the unknown gas.

Step 1: Convert mm Hg to atm.

Step 2: Find the partial pressure of the unknown gas.

Step 3: Find the moles of the gas (PV=nRT).

Step 4: Determine molar mass.