Dalton's Law of Partial Pressure

While studying the composition of air, John Dalton found that as far as pressure is concerned, when unreactive gases are combined, each gas acts as though it were the only gas in the mixture. In other words, each gas exerts the same pressure in a mixture as it would if it were alone in the container.

Where each different gas is identified as Gas A, Gas B, Gas C, etc., we show this as: *(The total pressure of the mixture is the sum of the individual gas pressures)*

$$\mathbf{P_{TOTAL} = \Sigma\, P_A + P_B + P_C \ldots}$$

For example, if the partial pressure of nitrogen were 200 torr, that of oxygen 250 torr, and that of carbon dioxide 300 torr, the total pressure of the mixture would be:

$$\mathbf{P_{TOTAL} = P_{N_2} + P_{O_2} + P_{CO_2} \quad = 200\ torr + 250\ torr + 300\ torr = \boxed{750\ torr}}$$

The composition of a gas mixture is often described in terms of **mole fractions** of the component gases. The **mole fraction** is simply the number of moles of that gas per the total moles of the gaseous mixture:

Mole Fraction: $\dfrac{n_A}{n_T}$

- n_A → Number of moles of Gas A
- n_T → Total number of moles of all Gases in the mixture

Because the pressure of a gas is proportional to moles for fixed volume and temperature, the mole fraction also equals the partial pressure divided by the total pressure:

Mole fraction of Gas A = $\dfrac{n_A}{n_T} = \dfrac{P_A}{P_T}$

- P_A → Pressure of Gas A
- P_T → Total Pressure of all gases

An additional descriptive quantity is **Mole Percent**.
This is simply the mole fraction X 100.

Example Problem:

A 1.00 L sample of dry air at 25°C and 786 mmHg contains 0.925 g N_2, plus other gases including oxygen, argon and carbon dioxide.

a) What is the partial pressure (in mmHg) of N_2 in the air sample?

b) What is the mole fraction and mole percent of N_2 in the mixture?

Hint:

Identify each of the given values and remember that:

1. *Each gas in a mixture follows the Ideal Gas Law.*
2. *According to Dalton's Law, in a mixture each gas acts as though it were the only gas in the container.*

The pressure given is the Total Pressure. Calculate the Partial Pressure of N_2.

SOLUTION:

To calculate the partial pressure of N_2 you convert 0.925 g N_2 to moles and plug it into the Ideal Gas Law Equation or simple substitute n for mass/MWt in the Ideal Gas Law Equation: Listing the Givens:

P_T = 786 mmHg
V = 1.00 L
g = 0.925 g
n = mass/MWt
MWt = 14.0 g/mol (2) = 28.0 g/mol
R = 62.4 mmHg (match R with Pressure Unit)
T = 25°C + 273 = 298 K

$$PV = nRT$$

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

$$P_N = \frac{0.0330\text{ mol} \cdot 62.4\text{ L mmHg} \cdot 298\text{K}}{1\text{ L} \quad \text{mol K}}$$

$$n = \frac{0.925\text{ g}}{28.0\text{g/mol}} = 0.0330\text{ mol}$$

a) P_N = 614 mmHg

b) The mole fraction of N_2 in air is: $\frac{P_N}{P_T} = \frac{614\text{ mmHg}}{786\text{ mmHg}} =$ **0.782**

The **mole percent** would be 0.780 X 100 = **78.2 mole percent N_2**