Lesson 8: Dalton's Law

Objectives: By the end of today's class you will combine your understanding of stoichiometry with Dalton's Law for Partial Pressures to calculate partial pressures, total pressure and mole fraction of a mixture of gases.

What we've learned so far…

- **Stoichiometric factors** relate **gas quantities** to **quantities of other reactants or products**.

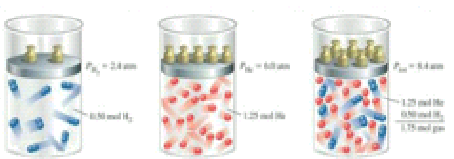
  Ex. $2\ CO + O_2 \rightarrow 2CO_2$

- **Ideal gas equation** relates the **amount of a gas** to **volume**, **temperature** and **pressure**.

  $$PV = nRT$$

Dalton's Law of Partial Pressures

- What happens when two gases are mixed…..



Dalton's Law

- Different types of gases in a mixture act independently of each other.
- The total pressure of a mixture of gases is the sum of the partial pressures of the components of the mixture.

$$P = P_A + P_B$$

- Partial pressures are the pressures that each gas would have if present alone in a container of the **same volume** and temperature.

$$P_A = \frac{n_A RT}{V} \qquad P_B = \frac{n_B RT}{V}$$

***This assumes: $V = V_A = V_B$

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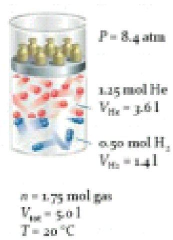
Dalton's Law

We can also say, the total volume of a mixture of gases is the sum of the volumes of the components of the mixture at a pressure equal to the total pressure.

$$V = V_A + V_B$$

$$V_A = \frac{n_A RT}{P} \qquad V_B = \frac{n_B RT}{P}$$

***This assumes: $P_{tot} = P_A = P_B$



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Dalton's Law

$$\frac{P_A}{P} = \frac{\frac{n_A RT}{V}}{\frac{nRT}{V}} = \frac{n_A}{n}$$

Assumes gases individually occupy same volume as total volume.

or

$$\frac{V_A}{V} = \frac{\frac{n_A RT}{P}}{\frac{nRT}{P}} = \frac{n_A}{n}$$

Assumes gases individually under same pressure as total pressure.

$$\frac{n_A}{n} = \frac{P_A}{P} = \frac{V_A}{V} = x_A$$

where x_A is the **molar fraction** of gas A in the gas mixture!

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Example 1:

The chemical composition of air that is exhaled is different from ordinary air. Is the density of expired air greater or less than that of ordinary air at the same temperature and pressure?

Volumetric Analysis

	Air	Exhaled air	M (g/mol)
N_2	78.08	74.2	28
O_2	20.95	15.2	32
CO_2	0.036	3.8	44
H_2O		5.9	18
Ar	0.93	0.9	40

mole fractions

$PV = nRT$

$PV = \frac{m}{M}RT$

$\frac{MP}{RT} = \frac{m}{V} = \rho$

$\rho \propto M$

Air $M = 29.0$ g/mol

Exhaled Air $M = 28.7$ g/mol

Example 2:

$R = 0.082058 \frac{l\text{-atm}}{mol\text{-}K}$

2.00 g of He and 2.00 g of H_2 are placed in a 15 l container at 30 °C. What are their partial pressures and the total pressure (in atm)?

$P_{He} = \frac{mRT}{MV} = \frac{(2.00)(0.082058)(303.15)}{(4.0026)(15)} = 0.8287$ atm

$P_{H_2} = 1.658$ atm

$P_{tot} = P_{He} + P_{H_2}$

Example 3:

A 2.35 l container of H_2 at 762 mmHg and 24 °C is connected to a 3.17 l container of He at 728 mmHg and 24 °C. After mixing, what is the total pressure, in mmHg, with the temperature remaining at 24 °C?

initial

① n_{He} $\boxed{\text{He } 3.17\ l}$ 728 mmHg 24°C

② n_{H_2} $\boxed{H_2\ 2.35\ l}$ 762 mmHg 24°C

final

③ $\boxed{\text{He } H_2\ V = 5.52\ l}$ $n = n_{He} + n_{H_2}$ T = 24° P = ? 742 mmHg

$PV = nRT$

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

$\frac{P_1V_1}{RT} + \frac{P_2V_2}{RT} = \frac{P_3V_3}{RT}$

$P_1V_1 + P_2V_2 = P_3V_3$

$\therefore P_3 = \frac{P_1V_1 + P_2V_2}{V_3}$

$= \frac{(728)(3.17) + (762)(2.35)}{5.52}$

Example 4:

A mixture of methane, CH_4, and acetylene, C_2H_2, occupies a certain volume at a total pressure of 63 mmHg. The sample is then burned to CO_2 and H_2O. The CO_2 alone is collected and its pressure found to be 96 mmHg in the same volume and in the same temperature as the original mixture.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$
$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$$

What was the mole fraction of methane in the mixture before combustion?

0.476

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$PV = nRT \quad \because V \;\&\; T$ are const.

$\therefore P \propto n$

$63\,mmHg = P_{CH_4} + P_{C_2H_2} \quad (1)$

$96\,mmHg = P_{CO_2} = P_{CO_2 \text{ from } CH_4} + P_{CO_2 \text{ from } C_2H_2}$

$\Downarrow$

$96\,mmHg = P_{CH_4} + 2P_{C_2H_2} \quad (2)$

$(2) - (1):$

$33\,mmHg = P_{C_2H_2}$

$\therefore 30\,mmHg = P_{CH_4}$

$\chi_{CH_4} = \dfrac{P_{CH_4}}{P_{tot}} = \dfrac{30}{63}$

Example 5:

Ethylene, C_2H_4, reacts with hydrogen in the presence of a platinum catalyst to form ethane, C_2H_6, according to the reaction:

$$C_2H_4 + H_2 \rightarrow C_2H_6$$

A mixture of C_2H_4 and H_2 known only to contain more moles of H_2 than of C_2H_4 has a pressure of 52 mmHg in an unknown volume. After the gas has been passed over the platinum catalyst, its pressure is 34 mmHg in the same volume and temperature.

What mole fraction of the original mixture is ethylene?

0.346

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Suggested Readings

6.6 Mixture of Gases

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