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. This statement, known as **Dalton's law of partial pressures**, can be expressed as:

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

The symbols P_1, P_2, P_3, and so on represent the **partial pressure** of each gas (the pressure each gas would exert if it were alone in the container).

Assuming that each gas behaves ideally, the partial pressure of each gas can be determined using the ideal gas law:

$$P_1 = \frac{n_1 RT}{V}, \qquad P_2 = \frac{n_2 RT}{V}, \qquad P_3 = \frac{n_3 RT}{V}, \qquad \cdots$$

The total pressure of the mixture can thus be represented as

$$\begin{aligned} P_{total} &= \frac{n_1 RT}{V} + \frac{n_2 RT}{V} + \frac{n_3 RT}{V} + \cdots \\ &= (n_1 + n_2 + n_3 + \cdots)\left(\frac{RT}{V}\right) \\ P_{total} &= n_{total}\left(\frac{RT}{V}\right) \end{aligned}$$

where n_{total} is the sum of the number of moles of the various gases.

Example 1

Mixtures of helium and oxygen can be used in scuba diving tanks to help prevent "the bends." For a particular dive, $46\ L\ He$ at $25°C$ and $1.0\ atm$ and $12\ L\ O_2$ at $25°C$ and $1.0\ atm$ were pumped into a tank with a volume of $5.0\ L$. Calculate the partial pressure of each gas and the total pressure in the tank at $25°C$.

Mole Fraction

The mole fraction is the ratio of the number of moles of a given component in a mixture to the total number of moles in the mixture. The Greek letter chi (χ) is used to represent the mole fraction.

$$\chi_1 = \frac{n_1}{n_{total}}$$

The mole fraction can also be represented in terms of pressures:

$$\chi_1 = \frac{P_1}{P_{total}}$$

Example 2
The partial pressure of oxygen was observed to be $156\ torr$ in air with a total atmospheric pressure of $743\ torr$. Calculate the mole fraction of O_2 present.

Example 3
The mole fraction of nitrogen in air is 0.7808. Calculate the partial pressure of N_2 in air when the atmospheric pressure is $760\ torr$.

Worksheet

1. For scuba dives below 150 feet, helium is often used to replace nitrogen in the scuba tank. If $15.2\ g$ of $He(g)$ and $30.6\ g$ of $O_2(g)$ are added to a previously evacuated $5.00\ L$ tank at 22°C, calculate the partial pressure of each gas present as well as the total pressure in the tank.

2. A mixture of $1.00\ g$ of $H_2(g)$ and $1.00\ g$ of $He(g)$ is placed in a $1.00\ L$ container at 27°C. Calculate the partial pressure of each gas and the total pressure.

3. At 0°C a $1.0\ L$ flask contains $5.0 \times 10^{-2}\ mol$ of $N_2(g)$, $1.5 \times 10^{2}\ mg$ of $O_2(g)$, and $5.0 \times 10^{21}\ molecules$ of $NH_3(g)$. What is the partial pressure of each gas, and what is the total pressure in the flask?

4. A mixture of cyclopropane and oxygen is sometimes used as a general anesthetic. Consider a balloon with an anesthetic mixture of cyclopropane and oxygen at $170\ torr$ and $570\ torr$, respectively. Calculate the mole fraction of cyclopropane in the mixture.

5. The partial pressure of $CH_4(g)$ is $0.175\ atm$ and that of $O_2(g)$ is $0.250\ atm$ in a mixture of the two gases.

   a) What is the mole fraction of each gas in the mixture?

   b) If the mixture occupies a volume of $10.5\ L$ at 65°C, calculate the total number of moles of gas in the mixture.

   c) Calculate the number of grams of each gas in the mixture.