Notes: Dalton's Law of Partial Pressures

1. Finding the Partial Pressures of Gases in a Mixture of Gases Given The Number of Moles

Imagine this situation: a flask contains the following mixture of gases

2.00 moles of $N_2(g)$
3.00 moles of He (g)
5.00 moles of $CO_2(g)$

The total pressure of all the gases together in the flask is 760.0 torr.

Question: What is the partial pressure of each of the gases?

Step 1: Find the mole fraction of each of the gases. The mole fraction of any one gas is the number of moles of that gas divided by the total number of moles of gases, or

$$\chi = \frac{\text{moles one gas}}{\text{total moles}}$$ (note that the greek symbol χ (chi) represents the mole fraction)

In this situation,

$$\chi_{N_2} = \frac{2.00 \text{ moles}}{2.00 \text{ moles} + 3.00 \text{ moles} + 5.00 \text{ moles}} = .200$$

$$\chi_{\text{He}} = \frac{3.00 \text{ moles}}{2.00 \text{ moles} + 3.00 \text{ moles} + 5.00 \text{ moles}} = .300$$

$$\chi_{\text{CO}_2} = \frac{5.00 \text{ moles}}{2.00 \text{ moles} + 3.00 \text{ moles} + 5.00 \text{ moles}} = .500$$

Step 2: For each gas, multiply the mole fraction by the total pressure to find the partial pressure of that gas:

$$P_x = \chi_x \bullet P_{\text{Total}}$$

$$P_{N_2} = \chi_{N_2} \bullet P_{\text{Total}}$$
$$P_{N_2} = .200 \bullet 760.0 \text{ torr} = 152 \text{ torr}$$

$$P_{\text{He}} = \chi_{He} \bullet P_{\text{Total}}$$
$$P_{\text{He}} = .300 \bullet 760.0 \text{ torr} = 228. \text{ torr}$$

$$P_{CO_2} = \chi_{CO_2} \bullet P_{\text{Total}}$$
$$P_{CO_2} = .500 \bullet 760.0 \text{ torr} = 380 \text{ torr}$$

So the partial pressure of the nitrogen gas is 152 torr, the partial pressure of the helium gas is 228 torr, and the partial pressure of the carbon dioxide gas is 380 torr. Notice how they all add up to 760 torr.

2. Finding the Number Of Moles Given the Partial Pressures of the Gases

A second situation: a flask contains a mixture of gases with the following partial pressures
386 torr $Cl_2(g)$
129 torr $SO_2(g)$
567 torr Ar(g)
There are a total of 20.00 moles of gases in the flask.

Question: What is the number of moles of each of the gases?

Step 1: Find the mole fraction of each of the gases.

Get the total pressure first:

$$P_{Total} = P_{Cl_2} + P_{SO_2} + P_{Ar}$$

$$P_{Total} = 386 \text{ torr} + 129 \text{ torr} + 567 \text{ torr} = 1082 \text{ torr (Yes, it has all 4 sig figs. This is adding.)}$$

We've seen that $P_x = \chi_x \bullet P_{Total}$. We can rewrite this to have $\chi_x = \frac{P_x}{P_{Total}}$

so $\chi_{Cl_2} = \frac{P_{Cl_2}}{P_{Total}}$ and $\chi_{SO_2} = \frac{P_{SO_2}}{P_{Total}}$ and $\chi_{Ar} = \frac{P_{Ar}}{P_{Total}}$

$$\chi_{Cl_2} = \frac{386 \text{ torr}}{1082 \text{ torr}} \qquad \chi_{SO_2} = \frac{129 \text{ torr}}{1082 \text{ torr}} \qquad \chi_{Ar} = \frac{567 \text{ torr}}{1082 \text{ torr}}$$

$$\chi_{Cl_2} = .357 \qquad \chi_{SO_2} = .119 \qquad \chi_{Ar} = .524$$

Step 2: Multiply the mole fraction of each of the gases times the total number of moles.

Cl_2: .357 x 20.00 moles = 7.14 moles Cl_2

SO_2: .119 x 20.00 moles = 2.38 moles SO_2

Ar: .524 x 20.00 moles = 10.5 moles Ar

That's it!