Lecture 19
Gases II
Tutorial

1) A rigid 4.5 L sealed vessel contains 0.250 moles $N_{2(g)}$, 0.165 moles $Ar_{(g)}$, and 0.100 moles $He_{(g)}$. The total pressure in the vessel is 1.75 atm.
   a. Find the mole fraction of each gas.

$$0.250 + 0.165 + 0.100 = 0.515 \text{ mol total} \qquad X_{\text{Ar}} = \frac{n_{\text{Ar}}}{\text{total moles}} = \frac{0.165 \text{ mol}}{0.515 \text{ mol}} = 0.320$$

$$X_{\text{N}_2} = \frac{n_{\text{N}_2}}{\text{total moles}} = \frac{0.250 \text{ mol}}{0.515 \text{ mol}} = 0.485 \qquad X_{\text{He}} = \frac{n_{\text{He}}}{\text{total moles}} = \frac{0.100 \text{ mol}}{0.515 \text{ mol}} = 0.194$$

   b. Find the partial pressure of each gas.

$$P_{\text{N}_2} = P_{\text{total}} X_{\text{N}_2} = (1.75 \text{ atm})(0.485) = 0.849, \qquad P_{\text{He}} = P_{\text{total}} X_{\text{He}} = (1.75 \text{ atm})(0.194) = 0.340$$

$$P_{\text{Kr}} = P_{\text{total}} X_{\text{Ar}} = (1.75 \text{ atm})(0.320) = 0.560$$

2) A gaseous solution contains 45.0% O_2 and 55.0% N_2 by mass. Find the mole fraction of each substance in the solution.

Assume 100*g sample*

$$45.0\text{g O}_2 \times \frac{1 \text{ mol O}_2}{32.00 \text{ g O}_2} = 1.41 \text{ mol O}_2$$

$$55.0\text{g N}_2 \times \frac{1 \text{ mol N}_2}{28.02 \text{ g N}_2} = 1.96 \text{ mol N}_2$$

$$1.41 + 1.96 = 3.37 \text{ mol total}$$

$$X_{\text{O}_2} = \frac{n_{\text{O}_2}}{\text{total moles}} = \frac{1.41 \text{ mol O}_2}{3.37 \text{ mol total}} = 0.418, \qquad X_{\text{N}_2} = \frac{n_{\text{N}_2}}{\text{total moles}} = \frac{1.96 \text{ mol N}_2}{3.37 \text{ mol total}} = 0.582$$

3) A rigid 2.5 L sealed vessel contains $Kr_{(g)}$ and $Xe_{(g)}$ with partial pressures of 0.333 atm and 0.756 atm respectively. Find the mole fraction of each gas.

$$\text{Total Pressure} = P_{\text{Kr}} + P_{\text{Xe}} = 0.333 \text{ atm} + 0.756 \text{ atm} = 1.089 \text{ atm}$$

$$P_{\text{Kr}} = P_{\text{total}} X_{\text{Kr}}, \quad X_{\text{Kr}} = \frac{P_{\text{Kr}}}{P_{\text{total}}} = \frac{0.333 \text{ atm}}{1.089 \text{ atm}} = 0.306$$

$$P_{\text{Xe}} = P_{\text{total}} X_{\text{Xe}}, \quad X_{\text{Xe}} = \frac{P_{\text{Xe}}}{P_{\text{total}}} = \frac{0.756 \text{ atm}}{1.089 \text{ atm}} = 0.694$$

4) A rigid 12.0 L sealed vessel containing 2.1 mol of $O_{2(g)}$, 3.0 mol of $H_{2(g)}$, and 2.7 mol of $Kr_{(g)}$ has an internal temperature of 35°C.

a. Calculate the partial pressure of each gas.

$$PV = nRT$$
$$P_{O_2} = \frac{nRT}{V} = \frac{(2.1\text{ mol})(0.0821\text{ Latm/molK})(308\text{ K})}{12.0\text{ L}} = 4.4\text{ atm}$$
$$P_{H_2} = \frac{nRT}{V} = \frac{(3.0\text{ mol})(0.0821\text{ Latm/molK})(308\text{ K})}{12.0\text{ L}} = 6.3\text{ atm}$$
$$P_{Kr} = \frac{nRT}{V} = \frac{(2.7\text{ mol})(0.0821\text{ Latm/molK})(308\text{ K})}{12.0\text{ L}} = 5.7\text{ atm}$$

b. What is the total pressure in the vessel?

P_{total} = 4.4 atm + 6.3 atm + 5.7 atm = 16.4 atm

c. Find the mole fraction of each gas in the vessel.

$$n_{total} = 2.1 + 3.0 + 2.7 = 7.8\text{ mol total}$$
$$X_{H_2} = \frac{n_{H_2}}{n_{total}} = \frac{3.0\text{ mol}}{7.8\text{ mol}} = 0.38$$
$$X_{O_2} = \frac{n_{O_2}}{n_{total}} = \frac{2.1\text{ mol}}{7.8\text{ mol}} = 0.27$$
$$X_{Kr} = \frac{n_{Kr}}{n_{total}} = \frac{2.7\text{ mol}}{7.8\text{ mol}} = 0.35$$

d. A lab technician ignites the mixture in the flask and the following reaction occurs: $2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(g)}$. Find the mole fraction of each gas in the mixture after the reaction.

	$2\ H_{2(g)}$	+ $O_{2(g)}$	$\rightarrow$ $2\ H_2O_{(g)}$
Initial	3.0 mol	2.1 mol	0
Change	-3.0	$-0.5(3.0)$	$+3.0$
Final	0 mol	0.6 mol	3.0 mol

Note: 1 mole of O_2 reacts for every 2 moles of H_2 that react
2 moles of H_2O are produced when 2 moles of H_2 react

Find New Mole Fractions

$$n_{total} = n_{O_2} + n_{H_2O} + n_{Kr} = 0.6 + 3.0 + 2.7 = 6.3\text{ mol total (Kr does not react)}$$
$$X_{O_2} = \frac{n_{O_2}}{n_{total}} = \frac{0.6\text{ mol}}{6.3\text{ mol}} = 0.10,\quad X_{Kr} = \frac{n_{Kr}}{n_{total}} = \frac{2.7\text{ mol}}{6.3\text{ mol}} = 0.43,\quad X_{H_2O} = \frac{n_{H_2O}}{n_{total}} = \frac{3.0\text{ mol}}{6.3\text{ mol}} = 0.48$$

5) A rigid 10.00 L sealed vessel contains 0.765 moles N_2 and 0.876 moles Cl_2. Find the density of the mixture in g/L.
(Hint: density = total mass / volume)

$$0.765 \text{ mol } N_2 \times \frac{28.02 \text{ g } N_2}{1 \text{ mol } N_2} = 21.4g\ N_2 \qquad 0.876 \text{ mol } Cl_2 \times \frac{70.90 \text{ g } Cl_2}{1 \text{ mol } Cl_2} = 62.1\text{g } Cl_2$$

$$\rho = \frac{mass}{volume} = \frac{21.4 \text{ g} + 62.1\text{g}}{10.00 \text{ L}} = 8.35 \text{ gL}^{-1}$$

6) Samples of $NO_{(g)}$ and $H_{2(g)}$ are placed in a rigid and evacuated container. When the equilibrium below is established, the partial pressure of H_2O gas is 0.254 atm. What is the partial pressure of $N_{2(g)}$ at equilibrium?

$$2\,NO_{(g)} + 2\,H_{2(g)} \rightleftharpoons N_{2(g)} + 2\,H_2O_{(g)}$$

	$2\,NO_{(g)}$ +	$2\,H_{2(g)}$ $\rightleftharpoons$	$N_{2(g)}$ +	$2\,H_2O_{(g)}$
Initial	?	?	0 atm	0 atm
Change			$+0.254 \div 2$	+0.254
Final			0.127 atm	0.254 atm

Initially, there was no N_2 or H_2O in the container. 1 mol of N_2 is produced for every 2 moles of H_2O that are produced. The partial pressure of N_2 will be half that of H_2O when equilibrium is established.

7) Chlorine gas was produced in a reaction and collected over water. A 65.20 mL sample of Cl_2 gas was collected over water at 25°C. The reading on the barometer in the laboratory was 1.01 atm. The vapour pressure of water is 23.76 mmHg at 25°C. Find the mass of Cl_2 gas collected.

$$23.76 \text{ mm Hg} \times \frac{1 \text{ atm}}{760 \text{ mm Hg}} = 3.13\times10^{-2}\text{atm}$$

$$P_{\text{total}} = P_{\text{Cl}_2} + P_{\text{H}_2\text{O}}$$

$$P_{\text{Cl}_2} = P_{\text{total}} - P_{\text{H}_2\text{O}} = 1.01 \text{ atm} - 3.13\times10^{-2}\text{atm} = 0.98 \text{ atm}$$

$$PV = nRT, \qquad n_{\text{Cl}_2} = \frac{P_{\text{Cl}_2}V}{RT} = \frac{(0.98 \text{ atm})(0.06520 \text{ L})}{(0.0821 \text{ Latm/molK})(298 \text{ K})} = 2.6\times10^{-3}\text{mol Cl}_2$$

$$2.6\times10^{-3}\text{mol Cl}_2 \times \frac{70.90 \text{ g Cl}_2}{1 \text{ mol Cl}_2} = 0.18 \text{ g Cl}_2$$

8) If the average kinetic energy per mole of $H_{2(g)}$ is 2.9 kJ/mol in a sealed container. What is the temperature of the system?

$$\text{KE}_{\text{average}}/\text{mol} = \frac{3}{2} \times RT$$

$$T = \frac{2(\text{KE}_{\text{average}}/\text{mol})}{3R}$$

$$T = \frac{2(2900\ \text{J/mol})}{3(8.314\ \text{J/molK})}$$

$$T = 230\ \text{K}$$

9) Find the molar mass of an unknown gas that has an average root mean square velocity of 167 m/s at 315K.

$$u_{rms} = \sqrt{\frac{3RT}{MM}}$$

$$MM = \frac{3RT}{(u_{rms})^2} = \frac{3(8.314\ \text{kg m}^2/\text{s}^2\text{Kmol})(315\ \text{K})}{(167\ \text{m/s})^2} = 0.282\ \text{kg/mol} = 28.2\ \text{g/mol}$$