Name: Date:

AP Practice Gas Law Problems 2

A mixture of $H_2(g)$, $O_2(g)$, and 2 millilitres of $H_2O(l)$ is present in a 0.500 litre rigid container at 25°C. The number of moles of H_2 and the number of moles of O_2 are equal. The total pressure is 1,146 millimetres mercury. (The equilibrium vapor pressure of pure water at 25°C is 24 millimetres mercury.)

The mixture is sparked, and H_2 and O_2 react until one reactant is completely consumed.

(a) Identify the reactant remaining and calculate the number of moles of the reactant remaining.

(b) Calculate the total pressure in the container at the conclusion of the reaction if the final temperature is 90°C. (The equilibrium vapor pressure of water at 90°C is 526 millimetres mercury.)

(c) Calculate the number of moles of water present <u>as</u> <u>vapor</u> in the container at 90°C.

Answer:

(a) $2\ H_2 + O_2 \rightarrow 2\ H_2O$

mol H_2 = mol O_2 initially, but 2 mole H_2 react for every 1 mol of O_2, therefore, O_2 is left.

$P_T = P_{H2} + P_{O2} + P_{H2O}$

$1146 \text{ mm Hg} = P_{H2} + P_{O2} + 24 \text{ mm Hg}$

$P_{H2} + P_{O2} = 1122 \text{ mm Hg}$

$1122 \text{ mm Hg} / 4 = P_{O2}$ left ($^1/_2$ of initial P_{O2} which is $^1/_2$ total)

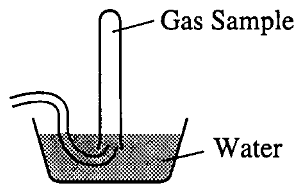
$P_{O2} = 280.5 \text{ mm Hg}$

$$n = \frac{PV}{RT} = \frac{\left(\frac{280.5}{760}\text{ atm}\right)(0.500\text{ L})}{0.0821\frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\ (298\text{K})} = 7.55\times10^{-3}\text{ mol } O_2$$

(b) $\frac{280.5\text{mmHg}}{298\text{K}} = \frac{P_{O_2}}{363\text{K}};\ P_{O_2} = 342\text{mmHg}$

$P_T = P_{O2} + P_{H2O} = (342 + 526)\text{mm Hg} = 868 \text{ mm Hg}$

(c) $n = \frac{PV}{RT} = \frac{\left(\frac{526}{760}\text{atm}\right)(0.500\text{L})}{(0.0821\frac{\text{L\_atm}}{\text{mol\_K}})(363\text{K})} = 0.0116\text{ mol}$



A student collected a sample of hydrogen gas by the displacement of water as shown by the diagram above. The relevant data are given in the following table.

GAS SAMPLE DATA	
Volume of sample	90.0 mL
Temperature	25°C
Atmospheric Pressure	745 mm Hg
Equilibrium Vapor Pressure of H_2O (25°C)	23.8 mm Hg

(a) Calculate the number of moles of hydrogen gas collected.

(b) Calculate the number of molecules of water vapor in the sample of gas.

(c) Calculate the ratio of the average speed of the hydrogen molecules to the average speed of the water vapor molecules in the sample.

(d) Which of the two gases, H_2 or H_2O, deviates more from ideal behavior? Explain your answer.

Answer:

(a) $P_{H2} = P_{atm} - P_{H2O} = (745 - 23.8)$ mm Hg

= 721.2 mm Hg

n = (PV)/(RT) = (721.2 mm Hg × 90.0 mL)/(62400 mm Hg.mL/mol.K × 298.15K)

= 3.49×10^{-3} mol

(b) n_{H2O} = (23.8 mm Hg × 90.0 mL)/(62400 mm Hg.mL/mol.K × 298.15K) × 6.022×10^{23} molecules/mol = 6.93×10^{19} molecules

(c) $(mass_{H2})(velocity_{H2})^2 = (mass_{H2O})(velocity_{H2O})^2$

$2(v_{H2})^2 = 18(v_{H2O})^2$

$v^2_{H2}/ v^2_{H2O} = 9$; $v_{H2}/ v_{H2O} = 3$

(d) H_2O deviates more from ideal behavior:

(i) greater number of electrons = greater van der Waal attraction

(ii) it is a polar molecule with strong polar attraction

(iii) it hydrogen bonds to other water molecules

(iv) larger molecule and is slower at a given temp. and occupies more space.

A rigid 5.00 L cylinder contains 24.5 g of $N_2(g)$ and 28.0 g of $O_2(g)$

(a) Calculate the total pressure, in atm, of the gas mixture in the cylinder at 298 K.

(b) The temperature of the gas mixture in the cylinder is decreased to 280 K. Calculate each of the following.

(i) The mole fraction of $N_2(g)$ in the cylinder.

(ii) The partial pressure, in atm, of $N_2(g)$ in the cylinder.

(c) If the cylinder develops a pinhole-sized leak and some of the gaseous mixture escapes, would the ratio $\frac{N_2(g)}{O_2(g)}$ in the cylinder increase, decrease, or remain the same? Justify your answer.

A different rigid 5.00 L cylinder contains 0.176 mol of $NO(g)$ at 298 K. A 0.176 mol sample of $O_2(g)$ is added to the cylinder, where a reaction occurs to produce $NO_2(g)$.

(d) Write the balanced equation for the reaction.

(e) Calculate the total pressure, in atm, in the cylinder at 298 K after the reaction is complete.

Answer:

(a) $24.5 \text{ g } N_2 \times \frac{1 mol}{28.0 g} = 0.875 \text{ mol } N_2$

$28.0 \text{ g } O_2 \times \frac{1 mol}{32.0 g} = 0.875 \text{ mol } O_2$

$$P = \frac{nRT}{V} = \frac{1.75\text{mol} \quad 0.0821\frac{\text{L•atm}}{\text{mol•K}} \quad 298\text{K}}{5.00\text{L}}$$

= 8.56 atm

(b) (i) $\frac{0.875 \text{ mol } N_2}{1.75 \text{ mol mix}} = 0.500 \text{ mole fraction } N_2$

(ii) $\frac{P_1}{T_1} = \frac{P_2}{T_2};\ P_2 = \frac{P_1T_2}{T_1} = \frac{(8.56\text{atm})(280\text{K})}{298\text{K}}$

= 8.05 atm × mole fraction = 8.05 atm × 0.500

= 4.02 atm N_2

(c) decrease; since N_2 molecules are lighter than O_2 they have a higher velocity and will escape more frequently (Graham's Law), decreasing the amount of N_2 relative to O_2

(d) $2\ NO + O_2 \rightarrow 2\ NO_2$

(e) all 0.176 mol of NO will react to produce 0.176 mol of NO_2, only $^1/_2$ of that amount of O_2 will react, leaving 0.088 mol of O_2, therefore, 0.176 + 0.088 = 0.264 mol of gas is in the container.

$$P = \frac{nRT}{V} = \frac{0.264\text{ mol} \quad 0.0821\frac{\text{L•atm}}{\text{mol•K}} \quad 298\text{ K}}{5.00\text{L}}$$

= 1.29 atm