Extra Sample Problems: Gas Laws

1. A 24.9mL volume of hydrochloric acid reacts completely with 55.0mL of aqueous sodium carbonate producing carbon dioxide, water and sodium chloride. The volume of CO_2 formed is 141mL at 27.0^oC and 727mmHg. What is the molarity of the HCl solution?

2. A 2.00L vessel containing carbon monoxide at 0.500atm is connected by a closed valve to a 1.00L container containing oxygen at 1.00atm. If the temperature is 300.K, when the valve is opened and the reactants combine to produce carbon dioxide, what are the partial pressures of the CO_2 produced and any excess reagent in the combined vessels?

3. At 25.0^oC and 380.mmHg, the density of sulfur dioxide is 1.31g/L. The rate of effusion of sulfur dioxide through an orifice is 4.48mL/s. What is the density of a sample of gas that effuses through an identical orifice at the rate of 6.78mL/s under the same conditions? What is the molar mass of the gas?

4. Consider two gases, A and B, each in a 1.0L container with both gases at the same temperature and pressure. The mass of gas A in the container is 0.34g and the mass of gas B in the container is 0.48g.

a. Which gas sample has the most molecules present?

b. Which gas sample has the largest average kinetic energy?

c. Which gas sample has the fastest average velocity?

5. Calculate the average kinetic energy and the root mean square (~average) velocity for a nitrogen molecule at 546K

6. Consider separate 1.0L samples of $He_{(g)}$ and $Xe_{(g)}$, both at 1.00atm and containing the same number of moles. What ratio of temperatures for the two samples would produce the same root mean square velocity?

Answers:

1. $2HCl + Na_2CO_3 \rightarrow CO_2 + H_2O + 2NaCl$

141 mL = .141L; 27.0°C = 300.15K;
727mmHg = .95658atm

There are .005473mol CO_2 produced.

.005473mol CO_2 (2mol HCl / 1mol CO_2) = .0109468mol HCl

.0109468mol HCl / .0249L = .4396 = **.440M**

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

Moles of CO
n = (.500atm)(2.00L)/(.0821Latm/molK)(300.K) = .0406mol CO

Moles of O_2

n = (1.00atm)(1.00L) / (.0821Latm/molK)(300.K) = .0406 mol O_2

Since CO and O_2 react in a 2:1 ratio .0203 mol of O_2 will be leftover and .0406 mol of CO_2 (1:1 with CO) will be produced.

P_{CO2} = nRT/V = (.0406mol)(.0821Latm/molK)(300.K)/(3.00L) = **.333atm**

P_{O2} = (.0203mol)(.0821Latm/molK)(300.K)/(3.00L) = **.167atm**

3. $4.48/6.78 = (d/1.31)^{1/2}$ d = 0.437 x 1.31 g/L = 0.572 g/L

MM = (MM SO_2) x 0.437 = 64.07g/mol x 0.437 = **28.0g/mol**

4. a. There will be the same number of molecules because equal volumes of gases under the same temperature and pressure will contain the same number of particles.

b. They will have the same average kinetic energy because all gases at the same temperature have the same average kinetic energy as given by $KE = 3RT/2N_A$.

c. The less massive gas (0.34g) will have the larger average (RMS) velocity, because kinetic energy is $KE = ½ mv^2$, so as the mass decreases, the velocity increases to keep the kinetic energy the same as the same temperature. This is also identified from the equation $ū = (3RT/MM)^{1/2}$, where MM is the molar mass, T is the temperature in Kelvin, R is the gas constant given by 8.314J/molK and ū is the RMS (average) velocity of the molecule.

5. KE = 3RT/2NA = $3(8.314J/molK)(546K) / 2(6.022x10^{23})$ = **$1.13x10^{-20}$J/molecule**.

$ū = (3RT/MM)^{1/2} = [(3)(8.314J/molK)(546K) / (.02802kg/mol)]^{1/2}$ = **697m/s**.

6. $(3RT_{He} / MM_{He})^{1/2} = (3RT_{Xe} / MM_{Xe})^{1/2}$

$3RT_{He} / MM_{He} = 3RT_{Xe} / MM_{Xe}$

$MM_{Xe} / MM_{He} = T_{Xe} / T_{He}$

T_{Xe} / T_{He} = (.1313kg/mol) / (.004003 kg/mol) = **32.8/1**