General Chemistry I
June 23, 2020

1. **A particular balloon is designed by its manufacturer to be inflated to a volume of no more than 2.50 L. If the balloon is filled with 2.00 L helium at sea level, is released, and rises to an altitude at which the atmospheric pressure is only 500. mm Hg, will the balloon burst?**

   We know that pressure and volume are inversely proportional, and that the product of pressure and volume equals some constant.

$$P_1V_1 = P_2V_2$$

$$(2.00\ L)(760\ mm\ Hg) = (500\ mm\ Hg)V_2$$

$$V_2 = \frac{(2.00\ L)(760\ mm\ Hg)}{500\ mm\ Hg} = 3.04\ L$$

   Since the volume exceeds the maximum (2.50 L), yes the balloon will burst.

2. **A mixture of NH_3 (g) and N_2H_4 (g) is placed in a sealed container at 300 K. The total pressure is 0.50 atm. The container is heated to 1200 K at which time both substances decompose completely according to the following unbalanced equations:**

$$2\boldsymbol{NH_3}(\boldsymbol{g}) \rightarrow \boldsymbol{N_2}(\boldsymbol{g}) + 3\boldsymbol{H_2}(\boldsymbol{g})$$

$$\boldsymbol{N_2H_4}(\boldsymbol{g}) \rightarrow \boldsymbol{N_2}(\boldsymbol{g}) + 2\boldsymbol{H_2}(\boldsymbol{g})$$

   After decomposition is complete, the total pressure at 1200 K is found to be 4.5 atm. Find the mole percent of N_2H_4 (g) in the original mixture. Assume two significant figures for the temperature.

   This is a tough problem, but first think about what variables are remaining constant and which ones are changing. Temperature, pressure, and moles of gas (n) are changing, while volume (of the sealed container) and R (by definition) are not changing.

$$PV = nRT$$

$$\frac{V}{R} = \frac{nT}{P}$$

   If V/R remains constant, then

$$\frac{n_{initial}T_{initial}}{P_{initial}} = \frac{V}{R} = \frac{n_{final}T_{final}}{P_{final}}$$

Now that the relevant relationships have been fleshed out, since we don't know the amount of NH_3 and N_2H_4 present originally, use variables to represent the moles of each of them. Let n_1 and n_2 represent the moles of initial amounts of NH_3 and N_2H_4 gas respectively.

$$Initial\ moles\ of\ gas = n_{initial} = n_1 + n_2$$

Now, notice that the decomposition of NH_3 produces 4 moles of gas for every 2 moles of NH_3. In other words, 2 moles of gas are produced per mole of NH_3 that undergoes decomposition. Similarly, per mole of N_2H_4 that is decomposed, 3 moles of gas are produced.

$$n_{final} = 2n_1 + 3n_2$$

Plug this all into the equation at the top of this page:

$$\frac{(n_1 + n_2)(300\ K)}{0.50\ atm} = \frac{(2n_1 + 3n_2)(1200\ K)}{4.5\ atm}$$

$$\frac{2n_1 + 3n_2}{n_1 + n_2} = \frac{(300\ K)(4.5\ atm)}{(1200\ K)(0.50\ atm)}$$

$$\frac{2n_1 + 3n_2}{n_1 + n_2} = 2.25$$

$$2n_1 + 3n_2 = 2.25n_1 + 2.25n_2$$

$$0.75n_2 = 0.25n_1$$

$$n_1 = \frac{0.75n_2}{0.25} = 3n_2$$

$$\%n_1 + \%n_2 = 100\%$$

$$3 * \%n_2 + \%n_2 = 100\%$$

$$4 * \%n_2 = 100\%$$

$$\%n_2 = 25\%$$

Thus, N_2H_4 made up 25% of the original mixture.

3. **5.00 g of solid calcium carbonate reacts with 100.0 mL of 0.200 M hydrochloric acid, represented by the following unbalanced equation.**

$$\boldsymbol{CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2}$$

What volume of carbon dioxide gas is produced at a pressure of 750.0 mm Hg and a temperature of 22.0°C?

This is a limiting reactant problem! Keep in mind that if you are given amounts of two different reactants, you will most likely have to find a limiting reactant.

$$5.00\ g\ CaCO_3 * \frac{1\ mol\ CaCO_3}{100.09\ g\ CaCO_3} * \frac{1\ mol\ CO_2}{1\ mol\ CaCO_3} = 0.050\ mol\ CO_2$$

$$0.200\ M\ HCl \rightarrow \frac{0.200\ mol\ HCl}{1\ L} * 0.1\ L = 0.02\ mol\ HCl$$

$$0.02\ mol\ HCl * \frac{1\ mol\ CO_2}{2\ mol\ HCl} = 0.01\ mol\ CO_2$$

Now, we can use the ideal gas law to solve for volume of carbon dioxide gas produced. Be sure to convert mm Hg to atm (or use the appropriate R value) and to convert temperature to Kelvin.

$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{(0.01\ mol)\left(0.08206\ \frac{L * atm}{mol * K}\right)(295.15\ K)}{0.9868\ atm} = 0.245\ L$$

4. **Using the molecular orbital model, describe the bonding, magnetism, and relative bond orders in the following species:**

O_2, O_2^-, O_2^{2-}

Valence e^-

O_2 : 12

O_2^- : 13

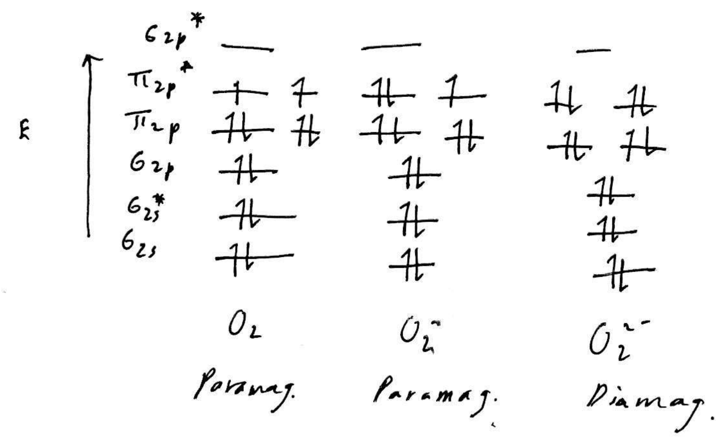
O_2^{2-} : 14

Bond order

O_2 : $(8-4)/2 = 2$

$O_2^- = (8-5)/2 = 1.5$

$O_2^{2-} = (8-6)/2 = 1$



5. **A quantity of N_2 gas originally held at 5.25 atm pressure in a 1.00-L container at 26°C is transferred to a 12.5-L container at 20°C. A quantity of O_2 gas originally at 5.25 atm and 26°C in a 5.00-L container is transferred to this same container. What is the total pressure in the new container?**

Apply the ideal gas law to both N_2 and O_2 gas in their original containers to find the moles of each.

$$PV = nRT$$

$$n_{N_2} = \frac{PV}{RT} = \frac{(5.25\ atm)(1.00\ L)}{\left(0.08206\ \frac{L * atm}{mol * K}\right)(299.15\ K)} = 0.21386\ mol\ N_2$$

$$n_{O_2} = \frac{PV}{RT} = \frac{(5.25\ atm)(5.00\ L)}{\left(0.08206\ \frac{L * atm}{mol * K}\right)(299.15\ K)} = 1.06932\ mol\ O_2$$

If we sum these two numbers, that represents the total moles of gas in the new container. Use the ideal gas law again to find the total pressure in the new container.

$$PV = nRT$$

$$P = \frac{nRT}{V} = \frac{(1.2832\ mol)\left(0.08206\ \frac{L * atm}{mol * K}\right)(293.15\ K)}{12.5\ L} = 2.47\ atm$$

6. **6.3 mg of a boron hydride is contained in a flask of 385 mL at 25.0°C and a pressure of 11 torr.**
   a. **Determine the molar mass of the hydride. (1 atm is equal to 760 torr)**

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(0.01447\ atm)(0.385\ L)}{\left(0.08206\ \frac{L * atm}{mol * K}\right)(298.15\ K)} = 2.2776 * 10^{-4}\ mol\ compound$$

$$Molar\ mass = \frac{6.3 * 10^{-3} g}{2.2776 * 10^{-4} mol} = 27.66 \frac{g}{mol}$$

   b. **Which of the following hydrides is contained in the flask, BH_3, B_2H_6, or B_4H_{10}?**

B has a molar mass of 10.81 g/mol. So that rules out BH_3 and B_4H_{10}. Check B_2H_6 to make sure it works.

$$Molar\ mass\ B_2H_6 = 10.81 \frac{g}{mol}(2) + 1.008 \frac{g}{mol}(6) = 27.67 \frac{g}{mol}$$

Thus, B_2H_6 is the boron hydride in the flask

7. Draw a likely spatial orientation of a single water molecule with a single molecule of NaCl