Worksheet 8 - Ideal Gas Law

I. Ideal Gas Law

The findings of 19th century chemists and physicists, among them Avogadro, Gay-Lussac, Boyle and Charles, are summarized in the **Ideal Gas Law**:

$$PV = nRT$$

P = pressure **V** = volume **n**= moles of gas,
R = universal gas constant **T** = temperature.

The value of **R** varies with the units chosen:

R = 0.08206 **L atm** / **mol K**
R = 8.314 **J** / **mol K**

In all cases, the **temperature must be expressed in K**, degrees kelvin.

1. To standardize results, chemists often use a set of experimental conditions, called **standard temperature and pressure** (**STP**).

   a) Standard pressure = ______ atm = ______ torr = ______ mm Hg

   b) Standard temperature = ______ ^{o}C = ______ K

   c) What is the standard molar volume of an ideal gas?

There are many types of Gas Law problems, but they can generally be grouped into two main types:

i. **Predicting the properties of a system** - One variable will be unknown, but the other three are known, and no changes occur. For these problems, use **PV = nRT**. The units must be liters, atmospheres, moles and absolute temperature (K), since these are the units of **R**.

ii. **Changing conditions** - A change in any one of the four variables, will lead to changes in the others. There will be a set of **initial conditions** and a set of **final conditions**.

$$\mathbf{P_i\, V_i = n_i\, R\, T_i} \quad \text{and} \quad \mathbf{P_f\, V_f = n_f\, R\, T_f}$$

Since R is a constant, this can be re-written as:

$$\frac{P_i V_i}{n_i T_i} = R = \frac{P_f V_f}{n_f T_f}$$

where **i** means initial state and **f** means final state.

2. As you saw in lecture, when 1.10 g of magnesium reacted with 300.0 mL of 0.800 M HCl, the products were hydrogen gas and magnesium chloride. What volume of hydrogen gas would be collected if the reaction had been run at STP?

   a) Write the balanced chemical reaction

   b) Determine if there is a limiting reagent

   c) Determine the moles of hydrogen gas produced

   d) Determine the volume of the hydrogen gas at STP

   e) The reaction was actually carried out at room temperature, 25.0^{o}C. What was the volume of hydrogen gas produced under these conditions?

3. A gas that occupies a volume of **6.75 L** at **89.0 atm** will occupy what volume at **68.55 mm Hg** if the temperature remains constant?

   a) Which equation will allow you to solve for the missing information?

   b) What information do you know?

   P_i = ________ P_f = ________

   V_i = ________ V_f = ________

   T_i = ________ T_f = ________

   n_i = ________ n_f = ________

   c) Solve for the final volume.

4. A 500.0 mL sample of gas was collected at 20.0^{o}C and 720.0 mm Hg. What is its volume at STP?

   a) Which equation will allow you to solve for the missing information?

   b) What information do you know?

   c) Solve for the final volume.

5. What volume of O_2 gas, measured at 24^{o}C, is needed to completely burn all of the methane (CH_4) in a 3.00 L container at the same T and P?

The Ideal Gas Law can be re-arranged to calculate the molar mass of unknown gases.

$$PV = nRT \qquad n = \frac{\text{mass (g)}}{\text{molar mass (g/mol)}}$$

$$PV = \frac{\text{mass}}{\text{molar mass}}(RT) \qquad \frac{\text{mass x R x T}}{\text{P x V}} = \text{molar mass}$$

Knowing that the units for **density** are **mass/volume**, re-write this equation so that it equates **density** with **molar mass.**

6. Using the equation, derived above, determine the density of CO_2 at 745 mm Hg and 65^oC?

7. A sample of gas of mass 2.929 g occupies a volume of 426 mL at 0^oC and 1.00 atm pressure. What is the molecular weight of the gas?

8. An unknown gas has a density of 3.167 g/L at STP. What is the identity of the gas? (Ar, O_2, Cl_2, HF, H_2O)

9. 0.30 g of a gas occupy a volume of 82.0 mL at 3.00 atm pressure and 27^{o}C. Calculate the molar mass of the gas.

10. Calculate the density of SF_6 at STP.