Chemistry 110
Determination of the Molar Mass of a Gas
Carbon Dioxide

Purpose

To determine the Molar Mass of a gas by measuring the mass of a gas, the volume the gas occupies and the pressure of the gas at room temperature.

Ideal Gas Equation: $p V = n R T$

Re-arranged form: $MM = \frac{mass\ R\ T}{p\ V}$

% Relative Error: $\frac{Experimental\ MM\ -\ Actual\ MM}{Actual\ MM} \times 100\%$

Discussion

An understanding of the relationship between gas density and buoyancy is necessary … to be continued☺

Safety Precautions

No toxic or flammable gases will be used in this experiment.
Carefully adjust the flow rates of compressed air before connecting the tubing to the drying tube to avoid accidents from sudden pressure surges.

Pre-Lab Questions

1. Write the Ideal Gas Equation and give the units for each variable when R=0.08206 L atm/mol K.

2. Show that Boyle's Law, Charles's Law and Avogadro's Law can all be derived from the Ideal Gas Law.

3. If 100. mL of a gas in a sealed container exerts a pressure of 765 mm Hg, what volume will the same gas occupy at 1520 mmHg, assuming constant temperature?

4. A sample of oxygen gas has a volume of 125 mL at 25.0˚C, what volume will the same gas occupy at 150˚C, assuming constant pressure?

5. A sample of carbon dioxide at 50.0˚C occupies 75.0 mL and exerts a pressure of 18.4 psi. What will be the volume at STP?

6. A gaseous sample weighing 0.8968 grams was found to occupy 524 mL at 730 Torr at 82.4˚F. What is the Molar Mass of the gas? What is the gas?

7. Calculate the density of nitrogen gas at STP,
   a) using the Ideal Gas Equation

   b) using the Molar Volume and Molar Mass

8. Methane burns in oxygen to produce carbon dioxide and water. If 3.75 L of gaseous CH_4 is burned in an open container at STP, what volume of oxygen is required for complete combustion? What volume of carbon dioxide will be produced?

Procedure

Obtain a clean and thoroughly dried 125-mL or 250-mL Erlenmeyer flask and fit it with a one-hole rubber stopper. Also, obtain a glass tube that moves around freely in the hole (the hole in the stopper should be ~1mm larger that the glass tube). This will allow the gas being fed into the flask to flow out through this gap. Also, obtain a small cork that fits snuggly, plugging the hole of the rubber stopper.
The glass tube is to be connected to a section of rubber tubing which is connected to a drying tube, which is connected to another piece of tubing and then the compressed air valve. Adjust the flow of the compressed air, then connect to the flask and let the dry air fill the flask. The moist air will be driven out through the gap at the stopper and the dry air will replace it.
After ~7 minutes remove the glass tube and plug the hole in the stopper with the pre-fitted cork.
Weigh the flask, stopper, plug and dry air with the analytical balance and record the mass.
When handling the flask use a paper towel to protect it from your 'greasy' fingerprints☺
Repeat the filling (~3 minutes) and weighing process until your masses do not differ by more than 0.0005 grams.

You are looking for the _____ mass because _____ .

Prepare a carbon dioxide generator as shown by your instructor.
Use a 250-mL Erlenmeyer flask with a thistle tube reaching almost to the bottom of the flask that has a short right-angle exit tube. This apparatus will be connected to the drying tube, rubber tubing and collection flask used earlier when you are ready to generate the gas. Place ~30 grams of calcium carbonate (marble chips) in the flask and add ~20 mL of de-ionized water to cover the solid calcium carbonate and so the end of the thistle tube is under water.
Obtain ~ 20 mL of 6 M hydrochloric acid (HCl).
Attach the generator to the drying tube and collection flask and stabilize the set-up.
Add ~ 10 mL of the acid to the generator through the thistle tube to begin the production of carbon dioxide.
Check all the lines and eliminate any leaks, except at the rubber stopper/glass tube gap. The dry air should be driven out through this gap as the flask fills with carbon dioxide. There are two checks that can be done to verify the production of the gas, if you don't know how…ask me.
Let the generated run for ~25 minutes of consistent gas production. If the reaction slows during this time add more HCl. Remove the glass tube from the collection flask and plug the hole (with the same plug).
Weigh the flask, stopper, plug and carbon dioxide with the analytical balance and record the mass.
Repeat the filling (~10 minutes) and weighing process until your masses do not differ by more than 0.0005 grams.

You are looking for the _____ mass because _____ .

To measure the exact volume the gas occupies in the flask including any gaps or crevices, fill the collection flask with de-ionized water to the brim. Replace the rubber stopper, then the cork plug. Let the excess water spill over and dry the flask.
Weigh the flask, stopper, plug and water with the top-loading balance and record the mass.

Obtain the temperature and pressure from the digital instrument provided and perform any necessary unit conversions.

Calculate the Molar Mass of the Carbon Dioxide and the Percent Relative Error.

Report Sheet

1. Mass of flask, stopper, plug and dry air _____
2. Mass of flask, stopper, plug and CO_2 _____
3. Mass of flask, stopper, plug and water _____
4. Temperature of gas in flask _____
5. Barometric pressure _____
6. Density of dry air _____

7. Temperature of gas in flask, absolute _____
8. Pressure, atmospheres _____
9. Volume of gas in flask, Liters _____

10. Mass of dry air in flask _____
11. Mass of empty flask, stopper and plug _____
12. Mass of CO_2 _____
13. Calculated Molar Mass of CO_2 from experimental data _____

14. Actual Molar Mass of CO_2 _____
15. Percent Relative Error _____

Questions and Calculations

1. Write the complete balanced, molecular equation for the reaction that produces the carbon dioxide.

2. How many moles of $CaCO_3$ are in the 30.0 grams of $CaCO_3$ used?

3. How many Liters of CO_2 can be generated by this mass of $CaCO_3$ at STP?

4. What is the mass of one Liter of each of the following gases at STP.
   Use only the Atomic Masses and the Molar Volume
   a) Fluorine

   b) Ammonia

   c) Propane (C_3H_8)

5. A 1.60 gram sample of impure sodium acetate was mixed with excess sodium hydroxide and heat producing solid sodium carbonate and methane gas.
   a) Write the complete balanced, molecular equation for the reaction.

   b) The methane was collected over water at 27˚C and 747 Torr, producing a total volume of 320. mL of gas. Calculate the number of moles of methane gas that was collected.
   You will need to correct for the vapor pressure of the water

   c) Calculate the mass of sodium acetate that would be required to produce this amount of methane.

   d) Calculate the percent of pure sodium acetate in the impure sample.