CHEM 231

Experiment 9

Molar volume of gases

You will carry out three reactions producing oxygen (O_2), hydrogen (H_2), and carbon dioxide (CO_2) gases. In each case, the volume of the gas produced can be measured by water displacement. Also, in each case, it is possible to calculate the number of moles of gas. By dividing the volume by the number of moles, you obtain a quantity called the molar volume. Thus, the experiment allows you to compare the molar volumes of three different gases.

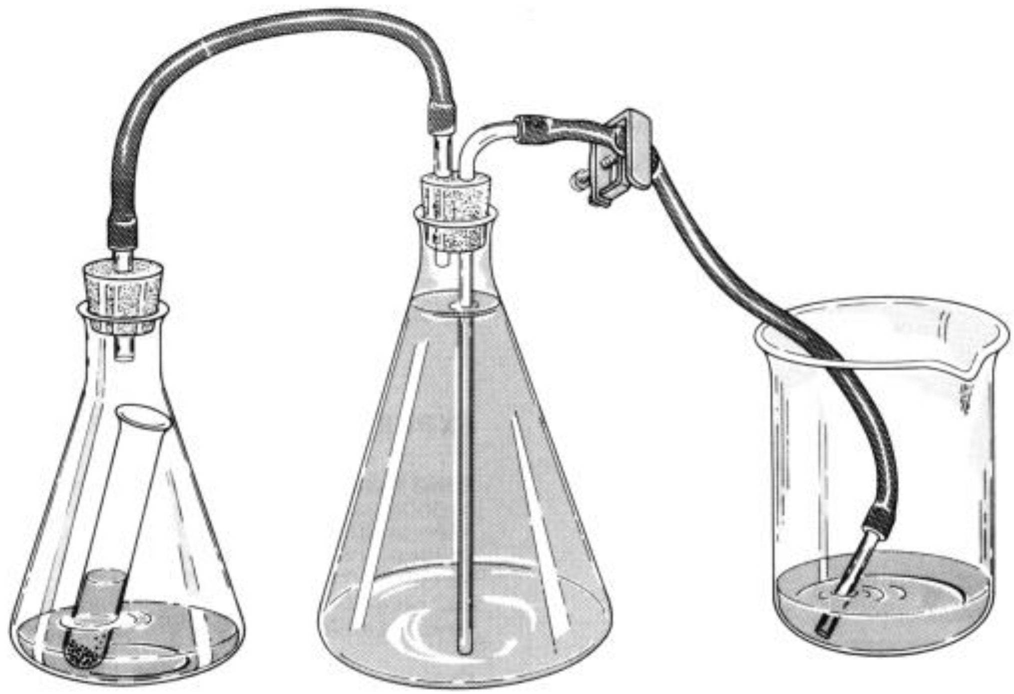
Background

The in the gas phase, matter is considerably less dense than in the liquid or solid phases. Or, in other words, the volume occupied by a gas is very large compared to the same amount of liquid or solid. Gases are also very compressible, meaning that their volumes can be readily changed by the application of pressure or by a change in temperature. Under the proper conditions, many substances display very simple universal relationships among these properties. Collectively, these relationships are called gas laws. For example, there is a simple relationship between volume and pressure called Boyle's Law.

In this experiment, you will attempt to confirm one of the universal gas laws. In 1811, Amadeo Avagadro postulated what has come to be known as Avagadro's Law. It is often stated as: "Equal volumes of gases, at the same temperature and pressure, contain the same number of molecules." We commonly express number of molecules as "moles." Therefore, Avagadro's Law implies that molar volumes of different gases should be the same provided that the volumes are measured under the same temperature and pressure conditions.

Procedure

The basic apparatus for measuring gas displacement is shown in the accompanying figure. Each reaction consists of a liquid reactant and a solid reactant. The liquid is placed in the Erlenmeyer flask and the solid in a small vial or test tube inside the flask so that it will not come into contact with the liquid until the apparatus is shaken. When it is, gas is forced from this flask into another Erlenmeyer flask containing a large volume of water. The gas pushes water from this flask through rubber tubing into a beaker. When the reaction is complete, the volume of the displaced water is measured; this is equal to the volume of the gas produced.



The following is a step by step procedure for carrying out any of the reactions. The stopper, tube, and test clamp assemblies will already be prepared for you. Refer to the figure to see how everything fits together.

(1) Measure and/or weigh the reactants and place them in the small Erlenmeyer flask. Do not seal it yet.

(2) Fill the large Erlenmeyer flask almost completely with water as shown in the figure.

(3) Add some water (the amount is not critical) to the large beaker. Approximately one fourth full is convenient.

(4) Place the 2-hole stopper with the long glass tube into the large flask and the other end of the rubber tube into the beaker as shown in the figure. Leave the pinch clamp open and do not yet seal the reaction flask with the other stopper. The glass tube on the large flask should reach almost to the bottom.

(5) Get a siphon started between the large flask and the beaker by blowing into the (yet unattached) tube on the one-hole stopper. Blow hard enough to force all the air out of the tube between the flask and the beaker. When the siphon is started, you should be able to move water back and forth between the flask and the beaker simply by raising and lowering the beaker.

(6) Raise the beaker so that the flask is filled nearly to thetop with water. Close the pinch clamp to stop the siphon transfer. **Discard all of the water in the beaker.**

(7) Place the one-hole stopper on the reaction beaker and tightly close it. Be sure that both flasks are tightly closed so that there are no air leaks.

(8) Open the pinch clamp. When you do, you may see a small amout of water flow from the flask to the beaker. This is normal and will not lead to errors in the results. (Do not discard this water.)

(9) Shake the reaction flask to allow the solid and liquid to mix. As gas is produced you should see water forced from the large flask to the beaker. Allow the reaction to go to completion. If all of the water is forced out of the large flask, you will need to redo the experiment with smaller amounts.

(10) After the reaction is complete, with the stoppers on and the flasks still tightly sealed, adjust the heights of the beaker and the large flask so that the water levels are equal. This assures that the pressure is the same throughout the apparatus and is equal to the pressure of the atmosphere. Water may flow between the flask and the beaker as you adjust the levels.

(11) With the water levels equalized, close the pinch clamp stopping the siphon action. Measure the volume of the water contained in the beaker with a graduated cylinder. This represents the volume of gas produced in the reaction.

(12) Disassemble the apparatus and clean up.

Part 1: Molar volume of oxygen (O_2) gas

Oxygen will be produced by the decomposition of hydrogen peroxide:

$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

The liquid reactant is 30 mL of a 3% hydrogen peroxide solution. The solid reactant is approximately 0.5 g of potassium iodide. (The potassium iodide is only a catalyst, not really a reactant.) Add these reactants to the reaction flask as described above so that they do not mix until you begin the reaction.

In this part, the amount of oxygen produced will be determined by the mass change of the reaction vessel containing the reactants. The entire reaction vessel should be weighed as precisely as possible before the reaction begins and then again when it is complete. The difference will be the mass of oxygen.

Carry out the reaction using the general procedure described above, finding the volume of gas produced from the water displaced. Reweigh the reaction flask.

The difference in masses is the mass of oxygen gas produced. Use this to calculate the number of moles of oxygen. (Mass divided by molecular weight.) Divide the volume of O_2 by the number of moles of O_2 to obtain the molar volume of oxygen. Express the result in Liters.

Part 2: Molar volume of oxygen (CO_2) gas

Carbon dioxide will be produced by the reaction of sodium bicarbonate with hydrochloric acid:

$NaHCO_3(s) + HCl\ (aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

The liquid reactant is 20 mL of a 6**M** hydrochloric acid solution and the solid reactant is 1 gram of sodium bicarbonate. The sodium bicarbonate should be precisely weighed. Unlike Part 1, in which the amount of gas was determined by mass difference, in this case it is determined only by the mass of solid sodium bicarbonate used.

Weigh sodium bicarbonate as precisely as possible on an analytical balance. Assemble the reaction vessel with the solid sodium bicarbonate and the hydrochloric acid. Take care to keep the reactants from mixing. Before continuing, find (a) moles of sodium bicarbonate and (b) moles of CO_2 expected from the above reaction assuming that all of the sodium bicarbonate reacts.

Carry out the reaction as described above, and find the volume of gas produced from the water displaced.

Divide the volume of CO_2 by the number of moles of CO_2 to obtain the molar volume of oxygen. Express the result in Liters.

Part 3: Molar volume of oxygen (H_2) gas

Hydrogen will be produced by the reaction of magnesium metal with hydrochloric acid:

$Mg(s) + 2HCl\ (aq) \rightarrow 2MgCl_2(aq) + H_2(g)$

The liquid reactant is 20 mL of a 6**M** hydrochloric acid solution and the solid reactant is 0.3 gram of magnesium metal. The magnesium should be precisely weighed. Just as in Part 2, in which the amount of gas is determined by the mass of magnesium used.

Weigh magnesium as precisely as possible on an analytical balance. Assemble the reaction vessel with the solid magnesium and the hydrochloric acid. Take care to keep the reactants from mixing. Before continuing, find (a) moles of magnesium and (b) moles of H_2 expected from the above reaction assuming that all of the smagnesium reacts.

Carry out the reaction as described above, and find the volume of gas produced from the water displaced.

Divide the volume of H_2 by the number of moles of H_2 to obtain the molar volume of hydrogen. Express the result in Liters.

Conclusions and report

The final report should show all of your calculations. Compare the molar volumes of the three gases and comment on the results in light of Avagadro's Law.