Reaction of Aluminum and Zinc with Hydrochloric Acid

Introduction

Many metals react with acids to form hydrogen gas. In this experiment, you will use the reactions of aluminum and zinc with hydrochloric acid to determine the atomic mass of one of these metals and to find the composition of an aluminum-zinc alloy. The general strategy involves reacting a known mass of metal with an excess of 6 M HCl. The H_2 is collected and its volume is measured. From this result, it is possible to calculate the number of moles of H_2 formed. This in turn permits the calculation of the number of moles of Al or Zn reacted and present in the original sample. If the metal sample is pure Al or Zn, one can then calculate its atomic mass. If the sample is an alloy—a mixture of Al and Zn—the percentage of the two elements in the alloy can be calculated (assuming known atomic masses). Your assignment is to plan and carry out the experiment using the equipment provided, to develop and use the necessary mathematical relationships, and to write a report. Please turn to the Advance Study Assignment on pages 3-4. Completing this is essential to your understanding of this lab.

Experimental Procedure

Perhaps the most convenient method of performing this experiment uses the following equipment: a 200 x 29 mm test tube, a 500 mL suction flask, a 400 mL beaker, some rubber and glass tubing, a pinch clamp, and some water-soluble gelatin capsules. The laboratory is assumed to have the usual equipment, including analytical and top-loading balances, graduated cylinders, thermometers, and a barometer.

The apparatus is arranged as pictured in the diagram. The reaction occurs in the test tube, generating hydrogen gas that expands through the rubber tube into the side arm of the suction flask. At the start of the experiment, the flask is about two-thirds full of water. As the hydrogen enters the flask, water is displaced and forced up the glass tube and out into the empty 400 mL beaker. The volume of the displaced water is determined either

with a graduated cylinder or by weighing it and using the known density of water. The volume of the water is assumed to equal the volume of the evolved hydrogen gas. Note, however, that in order for this to be true, the tube from the suction flask to the beaker must be filled with water at the beginning and the end of the experiment. One way to do this is in the following manner. Fill the suction flask about two-thirds full of water and firmly insert the stopper. Put about 200 mL of water into the beaker and place the end of the tube from the stopper in the suction flask under the water level. Then temporarily attach a short length of rubber tubing to the glass tube that goes through the test tube stopper. Open the pinch clamp and use a rubber bulb to apply suction to this tube. When the rubber and glass tubes running from the beaker to the suction flask are completely filled with water, close the pinch clamp and remove the temporary length of tubing. Empty any water from the beaker, replace the tubing in it, and you are ready to start the experiment.

Once the apparatus is assembled, an accurately weighed sample--pure Al, pure Zn, or the alloy—is placed in one of the gelatin capsules, which is dropped into an excess of 6 M HCl in the test tube. The stopper with the gas delivery tube is tightly placed in the test tube and the pinch clamp is opened. When the acid "eats" through the capsule, the reaction will begin, hydrogen will be produced, and the water will be displaced into the beaker. When the reaction is complete, close the pinch clamp, remove the tubing from the beaker, and determine the volume of the displaced water. Don't forget to measure the temperature of the water, which should be pretty close to the temperature of the hydrogen gas, and record the barometric pressure.

You may modify this experimental procedure if you wish, but if you intend to do so, make sure you discuss your proposed changes with your laboratory instructor. It is a good idea to do some preliminary calculations to determine the quantity of reactants (metal and acid) to use. If the mass of the metal is too small, the volume of hydrogen formed will be small and the percent error will tend to be large. On the other hand, if the mass of the metal sample is too large, the volume of hydrogen may be greater than the volume of water available for displacement. A ten-fold molar excess of HCl should ensure complete reaction of the metal in a reasonable amount of time.

Do at least two trials to determine the atomic mass of either aluminum or zinc and at least two trials to determine the percent composition by mass of your unknown alloy.

Report

When you have completed your experimental work, write a report that includes a description of any deviations from the experimental procedures suggested above, your raw data, sample calculations, results of your individual trials, average values obtained for atomic mass and percent aluminum in your alloy sample (be sure these results are reported to the correct number of significant figures!), and a discussion of both systematic and random errors.

(Originally written by A. Truman Schwartz 7/13/2001)

Advance Study Assignment

To help you formulate an experimental and computational strategy, answer the following questions

1. Write two balanced "molecular" equations, one for the reaction of aluminum with hydrochloric acid and the other for the reaction of zinc with hydrochloric acid.

2. Write down the relationship between the number of moles of H_2 formed and the number of moles of Zn reacted, assuming a complete reaction. Similarly, write down the relationship between the number of moles of H_2 formed and the number of moles of Al reacted.

   Note that these relationships are key to this experiment.

3. Write the equation that you will use to calculate the number of moles of H_2 present in a known volume of hydrogen gas. What other variables must be known to permit this calculation?

4. (a) A student performing this experiment on a sample of pure Zn decides that she wants to generate 150 mL of H_2 measured at a barometric pressure of 743.3 mm Hg and a temperature of 22.0^{o}C. Calculate the mass of Zn required.

   (b) Assume the student wishes to use ten times as many moles of HCl as Zn. What volume of 6 M HCl would be required?

Advance Study Assignment—continued

5. Now consider an alloy (of mass m_o) containing only aluminum and zinc. Both the Al and Zn react completely with HCl to form H_2. Derive an equation that expresses the number of moles of hydrogen gas formed as a function of the mass percent of aluminum in the alloy sample and the total mass m_o of the alloy. (Please talk with one of the Chemistry 11 instructors or the tutors at the MAX Center if you get stuck!)

6. Rearrange the equation from number 5 so that it expresses the mass percent of aluminum as a function of moles of hydrogen formed.