Chemistry 111 Laboratory
Experiment 5: The Reaction of Aluminum and Zinc with Hydrochloric Acid

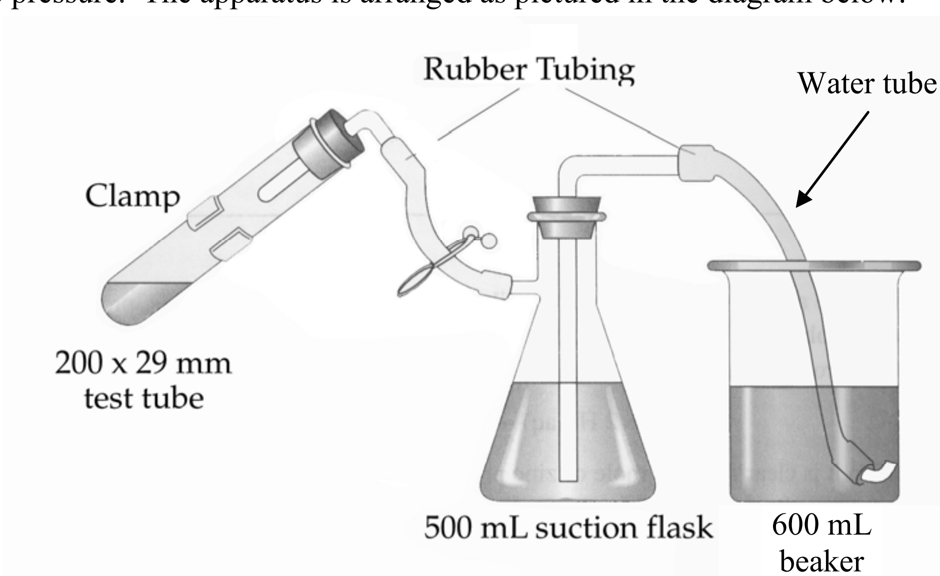
Introduction

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, and thereby assess the accuracy of the technique. 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 mathematical relationships to carry out the calculations, and finally to report the composition of your unknown alloy. Be sure to complete the Advance Study Assignment for this lab! Completing it is essential to your understanding of this experiment.

Experimental Procedure

This is the first of several labs in which we will outline the general concept behind the steps you will want to follow, but not provide a step-by-step procedure. In order to succeed in these labs, you will need to read through and understand the entire lab before you actually attempt to perform it! As always, you will want to carefully record your observations and document all data in your laboratory notebook. However, it will now be more important than ever that you clearly outline the steps you followed in performing the experiment, as different individuals will interpret these more general instructions into different actual procedures.

Perhaps the most convenient method of performing this experiment uses the following equipment: a (large) 200 x 29 mm test tube, a 500 mL suction flask, a 600 mL beaker, some rubber and glass tubing, a pinch clamp, and a small glass vial. The laboratory is assumed to have the usual equipment, including clamps to hold everything in place, analytical and top-loading balances, graduated cylinders, and a weather station that provides the ambient temperature and atmospheric pressure. The apparatus is arranged as pictured in the diagram below.



The reaction occurs in the test tube, generating hydrogen gas that expands through the gas tube into the sidearm of the suction flask. At the start of the experiment, the 500 mL flask is filled with water almost up to the sidearm, while the 600 mL beaker is nearly empty. As the hydrogen generated in the test tube pushes into the flask, water is displaced and forced through the water tube and out into the beaker. The volume of the displaced water is determined from the difference in the mass of the beaker and its contents before and after the experiment, 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 both the beginning and end of the experiment*.

First, you will need to accurately weigh out a sample – pure Al, pure Zn, or an alloy of these two – into a glass vial. This determination should be as accurate as possible, and thus carried out with an analytical balance. The vial will be lowered into an excess of 6 M HCl in the large test tube in such a way that it does not react immediately. We like this approach:

1. Dispense 10 mL of 6 M HCl into the large test tube, using a repipette. Make sure that the acid runs down the walls of the test tube, so that the sides of the test tube are wet. **Danger: 6 M HCl will burn skin, clothes, and lab books! It looks like water, but it must be treated with great respect. Immediately clean up *any* spills of this strong acid.**
2. Bring the large test tube back to your lab station.
3. Holding the test tube in your hands, tilt it to an approximately 70° angle. Place the glass vial with your sample in it into the large test tube, resting it against the wall of the test tube, and gently let it go. Since the tube is wet, the vial should stop almost immediately. Gently rotate the test tube along its long axis in order to get the vial to drop to slowly move toward the bottom. When the vial is about 2 centimeters above the acid, turn the test tube back to vertical, so that the vial drops into the liquid. The vial should float in the acid, and no reaction should take place (yet)! *If you do get any liquid inside the vial, and the reaction starts, you'll have to start over.*
4. Clamp your test tube in place, vertically, so that it will not react until you want it to.

Next, you will want to push the stopper with the gas delivery tube tightly into the test tube, and disconnect the quick-disconnect joint in the gas tube line. Remembering that we need to start with the water tube and suction flask full of water, and know the initial mass of the 600 mL collection beaker, we suggest something along these lines:

1. Fill the 600 mL beaker with water, nearly to the top.
2. Place the end of the water tube in the 600 mL beaker.
3. Using a pipette bulb, draw air out of the sidearm of the filter flask until the 600 mL beaker is almost empty, but stop before you draw up any air bubbles. (You may have to draw out a couple pipette bulbs worth of air. The pipette bulb should fit the quick-disconnect end nicely, but you'll have to hold it in place.)
4. If there are any air bubbles in the water line, push some of the water back out of the suction flask and into the beaker by squeezing air back in through the sidearm flask with the pipette bulb.
5. Repeat steps 4 and 5 until all air bubbles have been flushed out of the water line.

To prevent water from siphoning out of the suction flask or dribbling out of the water tube, pinch off the water tube with the pinch clamp. The mass of the 600 mL beaker and the water it contains can now be determined using a top-loading balance, and the beaker then returned to its original location, ready to collect displaced water. Re-connect the quick-connect in the gas line, and remove the pinch clamp from the water line. With the system sealed, no water should flow.

After verifying that nothing remains to block the escape of gas from the test tube (we don't want any explosions!), you are ready to initiate the reaction. To do so, remove the test tube from the clamp and tilt it toward horizontal until your sample vial fills with acid solution. The vial should then sink, and the test tube can be clamped back in place, standing straight up. Hydrogen will be produced as the acid eats into the metal, and water will be displaced into the beaker. When the reaction is complete (roughly 5 minutes, depending on your sample), replace the pinch clamp on the water line, remove the water tube from the beaker, and determine the volume of the displaced water. Don't forget to measure the atmospheric pressure and the ambient temperature in the room, which you will need for your ideal gas calculations.

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. In your ASA you performed 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. So be sure to use appropriate amounts of each reagent! Anything more than a five-fold molar excess of HCl should ensure complete reaction of the metal in a reasonable amount of time, but we have found 10 mL to be a particularly good volume for our vial-based reaction initiation method. Because the rate of the reaction increases as the heat released in the reaction increases the temperature of the reactants, using too much acid can actually slow the reaction down.

Do at least two trials to determine the atomic mass of pure alumin(i)um, and at least two trials to determine the percent composition by mass of your unknown alloy. (More trials will usually give you a better result, especially if your first two trials don't agree!) Be sure to record the number of your unknown alloy – you will be graded on accuracy!

Report

We'll be grading your lab book. Part of your grade will be based on the manner in which you present your data, so try to use tables and other organizational aids, as we have explicitly asked you to do in the labs prior to this one. Your lab book should include a description of your experimental procedure, your raw data, and your calculations. You should include the results of your individual trials, average values and uncertainties obtained for your atomic mass and the 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. A spreadsheet is a great way to do repetitive calculations like the ones in this lab! (If you use a spreadsheet, tape a copy of it into your lab book!)

Helpful Hints

1. The alloy samples (the unknowns for this lab) are metal turnings [basically, shavings of metal], and thus they do not pour very well. Tweezers are provided in the balance room to help you transfer the required amount of alloy directly into your sample vial.

2. The aluminum used in this experiment consists of very small beads, which can roll everywhere if you are not careful. We recommend weighing these beads out with a plastic weighing boat, as they may then be readily poured into your reaction vial by pinching the boat into a funnel shape and pouring carefully. [You'll get the best results if you *directly* determine the *actual* mass of Al *actually* transferred into your vial, rather than the amount you put into the boat, though! We know you can figure out how to do that!]

3. Remember that you don't need an *exact* amount of metal for this experiment, as long as you know *exactly* how much you used. If you calculate you need 0.232 g of metal to get 250 mL of gas, you don't need exactly 0.232 g: .20 g or 0.25 g would work fine, but in either case you would want to determine the precise mass you actually used – say 0.2023 g or 0.2492 g.

Safety Considerations:

Point the test tube away from people whenever it contains reactants.

Be very sure that the gas produced in the reaction has somewhere to go before you initiate the reaction: do not forget to remove the clamp!

Aqueous Hydrochloric Acid (HCl) is a strong acid. It is highly corrosive, and will cause burns. It will make holes in your clothes. Avoid all contact with it. HCl looks just like water, so be very sure to clean up any spills immediately. Just wiping up with a paper towel and throwing it in the trash is sufficient. Hydrochloric acid gives off HCl fumes, which can burn your nose; avoid the fumes above this reagent, especially the fumes in the test tube after the reaction is complete.

Waste Considerations:

HCl needs to be neutralized before it can be disposed of, and large amounts of Zn and Al are bad for the aquatic environment. So please dump any liquids containing acid or metal into the waste jugs provided. Please follow the posted instructions for retrieving your vial, and be careful – they often remain full of acid during this step!

Any dry spilled metal can be simply be brushed up and thrown in the trash. Please be conscientious and clean up any spills on the balances using the brushed provided

The water used in this experiment can be dumped down the drain.

Cleanup:

Please empty all water from the apparatus when you are done. Put your 600 mL beaker back in your drawer, and leave the rest of the apparatus out on the bench, as you found it.

Name________________________________

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Advance Study Assignment

To help you formulate an experimental strategy for this experiment, please answer the following questions on this sheet before you come to lab. (Attach additional pages if necessary). Also, prepare for lab by writing in the title of this experiment, the date, and a short introduction outlining the basic concept of the experiment in your lab notebook.

1. Write two balanced chemical reactions, one for the reaction of alumin(i)um 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: These relationships are key to this experiment!]

3. Write an equation that allows you to calculate the number of moles of H_2 present in a known volume of hydrogen gas. What 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 250 mL of H_2 measured at an absolute 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 five times as many moles of HCl as are required to react completely with this Zn (a "five-fold molar excess"). What volume of 6 M HCl would be required?

4. What mass of Alumin(i)um would be required to generate the same 250 mL of H_2 under the same conditions as those specified in the problem above?