Experiment 6: Analysis of Al-Zn Alloy

Safety First!

Safety Goggles must be worn at all times in the Laboratory.

Potential Hazards

- HCl (hydrochloric acid) is corrosive, can cause painful chemical burns, and will eat holes in your clothes. Rinse hands with water if you get any on you. See your TA for help cleaning up a spill.
- H_2 (hydrogen) gas forms in the first step, and is flammable; keep away from any sources of flame.

Waste Disposal

- Pour your reacted alloy/acid solution into the labeled waste container in the lab.

Experiment Objective(s):

- Determine the mass percent composition of an alloy that contains aluminum and zinc by measuring the amount of hydrogen gas produce in a hydrogen displacement reduction-oxidation reaction.

Learning Objectives: In this experiment you will learn some techniques for the analysis of gas forming reactions, including how to safely react a metal in acid and to collect a gas over water. You will also practice stoichiometry and quantitative determination of gases using the ideal gas law.

Background:

In preparation for this experiment you should review chapter 5 , sections 5.4 – 5.6, of your textbook, Chemistry (Chang & Goldsby), Custom Edition for IIT, 2015.

An alloy is a metallic material which consists of more than one metal and often has different mechanical, electrical and chemical properties than the pure metals from which it was made. The composition of some alloys is a stoichiometric ratio of the pure metals, such as Fe_5Zn_{21} , where the ratio of 5 iron atoms per 21 zinc atoms is the most stable composition. Other alloys have variable compositions and the component metal atoms are not present in specific atomic ratios.

In this experiment, you will analyze alloys of aluminum and zinc. The composition of these alloys does not correspond to simple stoichiometric ratios and therefore alloys of different compositions are available. You will report the percent composition by mass of each pure metal present in your alloy sample.

Experiment 6: Analysis of Al-Zn Alloy

Both aluminum and zinc react in acidic solution to form ions and hydrogen gas according to the following equations:

$$Al(s) + 3H^{+}(aq) \rightarrow Al^{3+}(aq) + 3/2\ H_2(g) \qquad (1)$$

$$Zn(s) + 2H^{+}(aq) \rightarrow Zn^{2+}(aq) + H_2(g) \qquad (2)$$

Considering these equations, we can see that for each mole of aluminum that reacts with acid, 1.5 moles of $H_2(g)$ are formed. For each mole of zinc that reacts with acid, 1 mole of $H_2(g)$ is formed.

The alloy we wish to analyze is aluminum and zinc, therefore, the number of moles $H_2(g)$ produced is given by the following equation:

$$\left(\text{moles of Al in alloy } \times \frac{1.5 \text{ moles } H_2}{1 \text{ mole Al}}\right) + \left(\text{moles of Zn in alloy } \times \frac{1.0 \text{ moles } H_2}{1 \text{ mole Zn}}\right) \qquad (3)$$

Since we can weigh our alloy sample, it is more convenient to calculate the number of moles of $H_2(g)$ produced per gram of aluminum and zinc. This can be accomplished using the molecular masses of aluminum and zinc.

$$\frac{1.5 \text{ moles } H_2}{1 \text{ mole Al}} \times \frac{1 \text{ mole Al}}{27.0 \text{ g Al}} = \frac{.0555 \text{ mole } H_2}{\text{g Al}} \qquad (4)$$

$$\frac{1 \text{ moles } H_2}{1 \text{ mole Zn}} \times \frac{1 \text{ mole Zn}}{65.4\text{g Zn}} = \frac{.0153 \text{ mole } H_2}{\text{g Zn}} \qquad (5)$$

Since the amount of H_2 produced by 1*g* of zinc is not the same as the amount of H_2 produced by 1g of aluminum, it is possible to calculate the percentages of aluminum and zinc in an alloy from the amount of hydrogen that is produced in the reaction of the alloy with acid.
Substituting the values from eq.(4) and eq (5) into eq (3) gives.

$$n_{H_2} = \frac{0.0556 \text{ moles } H_2}{\text{g Al}} \times m_{Al} + \frac{0.0153 \text{ moles } H_2}{\text{g Zn}} \times m_{Zn} \qquad (6a)$$

$$n_{H_2} = \frac{0.0556 \text{ moles } H_2}{\text{g Al}} \times m_{Al} + \frac{0.0153 \text{ moles } H_2}{\text{g Zn}} \times (m_{alloy} - m_{Al}) \qquad (6b)$$

where n_{H2} = total number of moles of H_2 produced in reaction with the alloy sample, m_{Al} = mass of aluminum in the alloy, m_{Zn} = mass of zinc in the alloy, m_{alloy}= total mass of the alloy sample.

Experiment 6:
Analysis of Al-Zn Alloy

In this experiment you will measure the volume of hydrogen evolved in the reaction and from the ideal gas law determine the number of moles, using:

$$n_{H_2} = \frac{P_{H_2}V}{RT} \qquad (7)$$

where R is the ideal gas law constant, T is the temperature of the gas, V is the volume of gas evolved and P is its pressure.

The **ideal gas constant, R,** is 0.08206 L•atm/mol•K. The **temperature, T**, will be measured with a thermometer in the laboratory.

The **volume, V,** will be measured by allowing the H_2 gas produced during the reaction to displace water from the apparatus shown in Figure 1. The displaced water is collected and its mass is measured. The volume of the gas is equal to the volume of the water which is calculated by dividing the mass of the water by the density of water (1.00g / mL).

The **pressure** of the H_2 gas can be calculated by knowing the total barometric pressure and the vapor pressure of water.

$$P(bar) = P(H_2O) + P(H_2) \qquad (8a)$$

$$P(H_2) = P(bar) - P(H_2O) \qquad (8b)$$

Because we are collecting the H_2 gas over water, there will be two gases present in the flask; hydrogen gas and water vapor. The total pressure in the flask will be due to these two gases. Therefore, in order to determine the partial pressure due to hydrogen only, $P(H_2)$, we will need to subtract the partial pressure of water, $P(H_2O)$, from the total pressure in the flask which is equal to the barometric pressure in the laboratory.

The barometric pressure can be read from a barometer. We will obtain our value from the daily weather report and it will also be written on the whiteboard in the laboratory. The vapor pressure of water is dependent on the temperature. The value can be obtained from Table 1.

When you have determined the necessary values from your data, using the calculations described, use eq. 6 to calculate the masses of aluminum and zinc in your alloy sample and report the percentages of aluminum and zinc based on the sample's total mass.

Experiment 6: Analysis of Al-Zn Alloy

Procedures:

Equipment and Chemicals

- Suction flask (side-arm Erlenmeyer)
- Large test tube
- Ring stand and test tube clamp
- Two sets of rubber stopper/glass tubing assemblies.
- Pinch clamp
- 2 lengths of rubber tubing
- Unknown Al-Zn alloy turnings (0.1-0.2 g)
- Empty gelatin capsule
- 400-mL beaker
- 10 mL of 6M HCl(aq)

Follow the procedures outline on the following pages; record data, observations, and any deviations from the prescribed procedure as you work; use blue or black ink. You must have the "landscape pages" with your data and observations signed by your TA before you leave the lab, and you will submit them with your lab report. Be sure to always record the units and the correct number of significant figures for every measured value.

Experiment 6: Analysis of Al-Zn Alloy

Pre-lab Questions (10pts)

*Pre-lab questions must be completed and turned in at the beginning of the lab period. If you have not completed the pre-lab questions, you will **not** be allowed to complete the lab.*

1. Calculate the minimum volume of 6 M hydrochloric acid that would be required to completely react with 0.2000 g of pure aluminum. (3pts)

2. At 25 °C, the vapor pressure of water is 23.8 mmHg. When the barometric pressure in the laboratory is 758.3 mmHg, calculate the volume of water that would be displaced by when 0.0100 moles of hydrogen gas is formed over water. (3pts)

3. A bored TA decides to make the lab more interesting by giving some students alloys of zinc and gold (the aluminum, Al, is replaced by gold, Au). Gold does not evolve hydrogen gas when HCl is added. Only the zinc part of the alloy would react to evolve hydrogen. Rewrite equation (6b) from the Background section
What is the percent mass of gold in a 0.1276 g sample of alloy that generates 6.8×10^{-4} moles of hydrogen gas? (4 pts)

Experiment 6

Name____________________ **Partner(s)__________________________**

Procedure

SAFETY:
Safety Goggles must be worn at all times in the Laboratory.

- HCl (hydrochloric acid) is corrosive, can cause painful chemical burns, and will eat holes in your clothes. Rinse hands with water if you get any on you. See your TA for help cleaning up a spill.
- H_2 (hydrogen) gas forms in the first step, and is flammable; keep away from any sources of flame.

A. Preparation of alloy sample

1. Weigh an empty gelatin capsule on the analytical balance and record the mass to the nearest 0.0001 g.
2. Obtain an unknown alloy sample and record it number.
3. Weigh about 0.3500 g of your alloy sample on a piece of weighing paper. Add half of this to the pre-weighed gelatin capsule. Keep the other half for the second trial. If necessary, break up the alloy turnings into smaller pieces by simply tearing them.
4. Cover the capsule and weigh it again and record the mass of the capsule and alloy together. **The mass of sample must be between 0.1000 and 0.2000 grams.** Use care in both weighings, since the sample is small; a small weighing error will produce a large experimental error.

B. Preparation of apparatus

1. Obtain a suction flask, large test tube, stopper assemblies and a sample of Al-Zn alloy.
2. Assemble the apparatus as shown in Fig 1.
3. Fill the suction flask about 2/3 full of water.
4. Also, fill the 400-mL beaker about 2/3 full of water.
5. Moisten the stopper on the suction flask and insert it firmly into the flask.
6. Open the pinch clamp and apply suction to the tubing attached to the side arm of the suction flask.

Data and Observations

	Trial 1	Trial 2
Mass of empty capsule		
Mass of capsule and alloy		

Observations:

Experiment 6

Name___________________ **Partner(s)**_________________________

7. Pull water into the flask from the beaker until the water level in the flask is about 1 or 2 cm below the side arm. To apply suction, connect a short piece of rubber tubing attached temporarily to the tube that goes through the test tube stopper to an aspirator with the water running slowly.
8. Close the pinch clamp to prevent siphoning.
9. The tubing from the beaker to the flask should be full of water, with no air bubbles.
10. Carefully remove the tubing from the beaker and put the end on the lab bench. As you do this, no water should leak out of the end of the tubing.
11. Pour out the water remaining in the beaker and let the beaker drain for a second or two.
12. Without drying it, weigh the empty beaker on a top-loading balance and record the mass to the nearest 0.1g.
13. Put the tubing back in this beaker.
14. With the pinch clamp still in place, connect the short tubing between the suction flask and the test tube rubber stopper/glass tubing.
15. Measure 10 ml of 6 M HCl, hydrochloric acid, in a graduated cylinder and pour it into the large test tube.

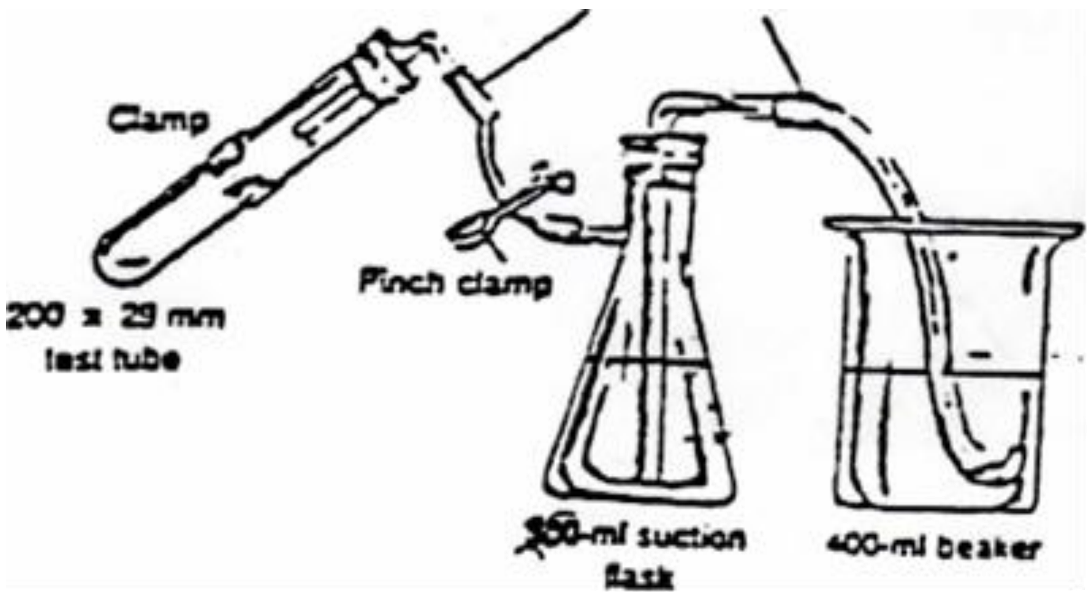
C. Reaction procedure
1. Carefully, drop the gelatin capsule into the HCl solution in the test tube. If it sticks to the side of the tube, poke it down into the acid with a stirring rod.
2. Insert the rubber stopper firmly into the test tube
3. Open the pinch clamp. If a little water goes into the beaker at that point, pour that water out letting the beaker drain for a second or two and then return the rubber tubing.
4. Within 3 or 4 minutes the acid will eat through the gelatin capsule and begin to react with the alloy. The hydrogen gas that is formed will go into the suction flask and displace water from the flask into the beaker. The volume of water that is displaced will equal the volume of gas that is produced.
5. As the reaction proceeds you will probably observe a dark foam,

STOP and THINK

How precisely do you need to measure the hydrochloric acid?

	Trial 1	Trial 2
Mass of empty beaker		
Mass of beaker and water		

Figure 1 Reference: Masterton, W L., J. Chem Educ., 1961, 38, 558.



which contains particles of unreacted alloy. The foam may carry some of the alloy up the tube. If this happens, wiggle the tube gently to make sure that all of the alloy goes into the acid solution. The reaction should be over within five to ten minutes. At that time the liquid solution will again be clear, the foam will be mostly dissipate, the capsule will be completely dissolved, and there should be no unreacted alloy.

D. Weighing the displaced water
1. When the reaction is over, close the pinch clamp
2. Take the tubing out of the beaker.
3. Weigh the beaker and the displaced water and record the mass to the nearest 0.1g. (Table on previous page)
4. Pour the acid solution into the sink.
5. Reassemble the apparatus and repeat the experiment with the second portion of your sample.

E. Laboratory Conditions
1. Record the temperature of the water
2. Record the barometric pressure.

Observations:

Temperature of the water	
Barometric Pressure	

Experiment 6

Name___________________ **Partner(s)**_________________________

Calculations

	Trial 1	Trial 2
Mass of alloy only		
Mass of displaced water		
Volume of displaced water = volume of gas		
Partial Pressure of water vapor $P(H_2O)$		
Partial Pressure of hydrogen gas $P(H_2)$		
Mass of Al in the alloy sample		
Mass of Zn in the alloy sample		
Mass percent Al in the alloy sample		
Average Mass percent Al		
Mass percent Zn in the alloy sample		
Average Mass percent Zn		

Sample Calculations

For each type of calculation, show one sample calculation with words, then substitute in numbers:

Experiment 6: Analysis of Al-Zn Alloy

Post-Lab Questions (10pts)

1. What is the total mass of anhydrous $AlCl_3$ plus $ZnCl_2$ which could be recovered from the reaction of your sample of alloy with HCl in Trial 1.

2. Indicate if the following experimental errors will increase, decrease or cause no change in your calculated percent aluminum in the alloy. Explain clearly your reasoning:
a. The temperature of the water was significantly lower than room temperature
b. The mass of alloy used in the experiment was actually less than the mass used in the calculations.
c. The alloy contained a component which did not react with HCl.
d. You assumed that the total pressure was due to H_2 and did not correct for partial pressure of water.