ALUM FROM WASTE ALUMINUM CANS INTRODUCTION

Modern beverage containers are usually composed of either aluminum, in the form of aluminum cans, or polyethylene terephthalate (PETE), the clear plastic beverage bottles. Approximately 300 million aluminum beverage cans are produced each day in the U.S. Aluminum is one of the most indestructible materials used in metal containers. The average "life" of an aluminum can is about one hundred years. Although aluminum is the third most abundant element in the earth's crust, the expense of extracting it from common soils is too expensive and the major source is the ore *bauxite*, the hydrated form of aluminum oxide, $Al_2O_3 \cdot 2H_2O$. Although there is concern regarding the depletion of aluminum ores, the major concern is the amount of electrical energy needed to extract the aluminum from its ores. To produce a single can, the energy needed is about the same as that required to keep a 100-watt bulb lit for 6 hours. That energy can be reduced by up to 95 percent by recycling used aluminum cans. Recycling also has the benefit of reducing litter from discarded cans and a number of states have passed laws requiring a deposit on aluminum cans to encourage recycling.

In this experiment, instead of recycling aluminum into new metal cans, a chemical process will be used that transforms scrap aluminum into a useful chemical compound, potassium aluminum sulfate dodecahydrate, $KAl(S0_4)_2 \cdot 12H_20$, commonly called "alum". Alum is widely used in the dyeing of fabrics, in the manufacture of pickles, in canning some foods, as a coagulant in water purification and waste-water treatment plants, and in the paper industry.

The class of chemical compounds known as "alums" are ionic compounds that crystallize from solutions containing sulfate anion, SO_4^{2+}, a trivalent cation, such as $A1^{3+}$, Cr^{3+}, or Fe^{3+}, and a monovalent cation, such as K^+, Na^+, or NH_4^+. Most alums crystallize readily as octahedra or cubes which, under the appropriate conditions, may grow to considerable size. Six of the 12 water molecules per formula unit are bound tightly to the trivalent cation. The remaining six are loosely bound to the sulfate anion and monovalent cation.

BACKGROUND INFORMATION

Although aluminum is a "reactive" metal, it reacts only slowly with dilute acids because its surface is normally protected by a very thin, impenetrable coating of aluminum oxide. (Such metals are referred to as self-protecting metals.) Alkaline solutions, or bases, (containing OH^-) dissolve the oxide layer and then attack the metal. Thus, in aqueous alkaline medium, aluminum is oxidized to the tetrahydroxoaluminate(III) anion which is stable only in basic solution.

Reaction A: $$2\ A1_{(s)} + 6\ H_2O_{(l)} + 2\ KOH_{(aq)} \rightarrow 2\ K[Al\ (OH)_4]_{(aq)} + 3\ H_{2(g)}$$

When sulfuric acid is slowly added to an alkaline solution of this complex anion, initially, one hydroxide ion is removed from each tetrahydroxoaluminate anion causing the precipitation of white, gelatinous aluminum hydroxide, $Al(OH)_3$,

Reaction B: $$2K[Al(OH)_4]_{(aq)} + H_2SO_{4(aq)} \rightarrow 2\ Al(OH)_{3(s)} + K_2SO_{4(aq)} + 2\ H_2O_{(l)}$$

The excess potassium hydroxide is neutralized by some of the sulfuric acid to form potassium sulfate.

Reaction C: $$2\ KOH_{(aq)} + H_2SO_{4(aq)} \rightarrow K_2SO_{4(aq)} + 2\ H_2O_{(l)}$$

On addition of more sulfuric acid, the aluminum hydroxide dissolves forming the hydrated aluminum cation

Reaction D: $$2\ A1(OH)_{3(s)} + 3\ H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 6\ H_2O_{(l)}$$

Addition of alkali to the $Al(OH)_3$ precipitate will also bring about dissolution by reforming $[Al(OH)_4]^-$. A hydroxide, such as aluminum hydroxide, that can be dissolved by either acid or base is said to be *amphoteric.* When the acidified aluminum sulfate solution is cooled, potassium aluminum sulfate dodecahydrate ("Alum") precipitates.

Reaction E: $$A1_2(SO_4)_{3(aq)} + K_2SO_{4(aq)} + 24\ H_2O_{(l)} \rightarrow 2\ K[Al(SO_4)_2] \bullet 12H_2O_{(s)}$$

The overall reaction that takes place is the sum of the previous reactions.

$$2\ Al_{(s)} + 2\ KOH_{(aq)} + 4\ H_2SO_{4(aq)} + 22\ H_2O_{(l)} \rightarrow 2\ KA1(SO_4)_2 \bullet 12H_2O_{(s)} + 3\ H_{2(g)}$$

SAFETY

Goggles or safety glasses must be worn at all times in the laboratory

Potassium hydroxide solutions are caustic. In the event of contact with your skin or eyes, wash the affected area immediately with lots of water. If necessary, seek qualified medical assistance.

Sulfuric acid is corrosive. In the event of contact with your skin or eyes, wash the affected area immediately with lots of water. If necessary, seek qualified medical assistance.

Ethanol is a flammable liquid. Avoid flames. Prolonged skin exposure can cause drying and cracking of the skin.

The aluminum metal may have shape edges. Exercise care in handling the metal.

DISPOSAL

Dispose of all materials in the proper waste containers as provided in the laboratory.

MATERIALS NEEDED

Aluminum beverage can
Potassium hydroxide, KOH, 1.4 M solution
Sulfuric acid, H_2SO_4, 3 M solution
Ethanol
Sandpaper
Scissors or metal snips
Watch glass
Graduated cylinder
Ruler
Beakers, 50-mL or 100-mL, 250-mL, 600-mL
Bunsen burner or hotplate
Funnel and filter paper
Stirring rod
Spatula

PROCEDURE

1. Read the procedure. Circle any place that says record and underline what you are supposed to record. Use what you have circled to create a data table. Label blanks so that information can be recorded efficiently in lab.

2. Look over the reactions in the background section. Find the places in the procedure where you will be doing each reaction. In the procedure, label the procedure with A,B,C,D,E when these reactions will be occurring.

3. Using scissors or metal snips, cut a piece of aluminum approximately 5 cm x 7.5 cm from the can.

4. Using a piece of sandpaper, scrape off any paint and/or plastic coating from both sides, as completely as possible. Weigh the cleaned piece of aluminum. You need approximately 1.0 g of aluminum (if the mass is between 0.9 and 1.2 g, that is acceptable).

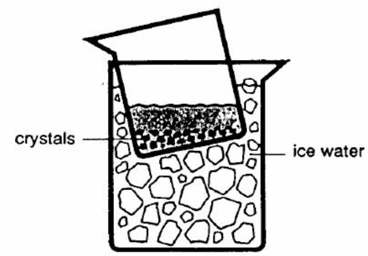
5. Weigh a 250-mL beaker. Cut your aluminum sample into small squares of about 0.2 cm length (small pieces will react at a faster rate) and place them in the 250-mL beaker. Weigh the beaker and final sample to the nearest 0.01 g and record the mass. Determine the mass of the aluminum and record on your data table.

6. Add 50 mL of 1.4 M potassium hydroxide to the 250-mL beaker containing the aluminum pieces. Place the beaker on a hotplate, and heat it so it is hot, but not boiling. <u>If the liquid level in the beaker drops to less than half of its original volume, add distilled water to maintain the volume at approximately 25 mL. The reaction is complete when the hydrogen evolution ceases and there are no visible pieces of aluminum metal.</u> The final volume of the liquid should be about 25 mL. Record observations of the reaction.

7. While the solution is cooling, set up a filter stand, funnel with filter paper and a 250 mL beaker underneath the funnel to catch the filtrate. The filter paper should be moistened before you begin. Filter the warm solution to

remove any solid residue. The filtrate should be clear with any dark residue left on the filter paper. Rinse the beaker twice with 5-mL portions of distilled water, pouring each rinse through the filter residue.

8. If the filtrate is not yet cool, place the beaker in a cooling bath of cold water. You can make a cooling bath by nesting your 250 mL beaker into a larger beaker Slowly *and carefully, with stirring,* add 35 mL of 3.0 M H_2SO_4 to the cooled solution. The solution will get hot from the neutralization reaction occurring. Record observation of the reaction. You may notice the appearance of a white precipitate of aluminum hydroxide. Addition of the last few milliliters of the sulfuric acid will usually dissolve the $Al(OH)_3$. If necessary, warm the solution gently, while stirring, to completely dissolve any $Al(OH)_3$ that might have formed. The final solution will contain potassium ions (from the KOH used), aluminum ions, and sulfate ions. If, after a few minutes of heating, any solid residue remains, filter the mixture and work with the clear filtrate.



9. Prepare an ice-water bath by filling a 600-mL beaker two-thirds full with ice. Add cold water to just cover the ice. Set the reaction beaker into the ice-water bath to chill thoroughly. Crystals of the alum should begin to form in a few minutes. If crystals do not form, you may have to induce crystallization. To induce crystallization, try stirring the solution rapidly, but do not splash any of the liquid from the beaker, or you may scratch the inside bottom of the beaker containing the solution with your stirring rod. As an alternative, you may add one or two very minute seed crystals. Seed crystals (if desired) can be obtained by placing a drop of solution on the end of a stirring rod and blowing on it until it is dry. As a last resort only, reduce the volume of solution by boiling away some of the water and then cooling the solution in the ice bath.

10. Clean and reassemble filtration apparatus. Get a clean piece of filter paper. Record the mass of your filter paper. Note that this is the 2^{nd} piece of filter paper that is used in this experiment.

11. Get 25 mL of 50% ethanol and water. Remove the chilled solution of alum crystals from the ice bath and chill the ethanol mixture.

12. Filter the alum crystals from the chilled solution, transferring as much of the crystalline product as possible to the funnel. Use half of the chilled ethanol solution to rinse the remaining crystals from the beaker into the funnel. Rinse the beaker again with the second half of the solution. (Ethanol in the wash solution reduces the solubility of the alum.)

13. While the crystals are drying, weigh a clean, dry watch glass. Record this mass. Transfer the filter paper and crystals to a watch glass and allow to dry overnight.

14. The next day: Record the mass your crystals, filter paper and watch glass. Record observations of your crystals. Determine the mass of Alum crystals obtained and record the mass of the Alum in the data table.

CALCULATIONS

Theoretical Yield (Put this definition into your notes)

The theoretical yield, sometimes called the expected yield, is the amount of alum you would obtain from your starting mass of aluminum if all the reactions work perfectly and you are able to obtain all the intermediate compounds and products. The theoretical yield can be calculated from the overall reaction that takes place:

$$2\ Al_{(s)} + 2\ KOH_{(aq)} + 4\ H_2SO_{4(aq)} + 22\ H_2O_{(l)} \rightarrow 2\ KA1(SO_4)_2{\bullet}12H_2O_{(s)} + 3\ H_{2(g)}$$

1. According to the reactio, _____________moles of aluminum will react to form __________moles of alum.

2. To calculate the theoretical yield of the alum, use the mass of aluminum you used in your reaction and determine the mass of alum that could potentially be produced in this reaction.

Percent Yield (Put this definition and equation into your notes)

The percent yield is the percent of the theoretical yield you actually obtained. To calculate the percent yield, use the equation:

$$\text{Percent yield} = \frac{\text{Mass of alum obtained}}{\text{Theoretical yield of alum}} \times 100\%$$

QUESTIONS: (answer these questions on your report sheet)

1. What is the author's purpose in the introduction?

2. Why is the inside of an aluminum can lined with a plastic coating?

3. Why is the percent yield of alum usually less than 100%? (What happened to the missing material?)

4. Is this process an effective method for the recycling of aluminum?

ALUM FROM WASTE ALUMINUM CANS—Lab Report

Name ____ Course/Section __________________

Partner's Name (if applicable) _____________________________ Date __________________

DATA:

Use the information you circled and underlined to create a data table.

CALCULATIONS:

1. According to the reaction, _____________moles of aluminum will react to form __________moles of alum.

2. To calculate the theoretical yield of the alum, use the mass of aluminum you used in your reaction and determine the mass of alum that could potentially be produced in this reaction.

3. The percent yield is the percent of the theoretical yield you actually obtained.

QUESTIONS:

5. What is the author's purpose in the introduction?

6. What evidence does the author use to support their position?

7. Why is the inside of an aluminum can lined with a plastic coating?

8. Why is the percent yield of alum usually less than 100%? (What happened to the missing material?)

9. Is this process an effective method for the recycling of aluminum?