Making Scrap Aluminum into a Useful Chemical

Name _____

Introduction

As we have seen in other parts of the course, pure aluminum is produced in a relatively expensive and complicated process involving the reduction of Al^{3+} directly by electrons when a eutectic mixture of salts is electrolyzed at about 950ºC. Because the energy content of the metal is so high (compared to its oxide, chloride, and other salts), the most economical recycling of metal cans, sheet metal, rods, foil, and wire usually involves simply re-melting the pure material and casting or rolling it into new forms. However, one can also make the metal into relatively valuable pure chemical, alum. Alum, $KAl(SO_4)_2 \cdot 12H_2O$, is an active ingredient in many deodorants and antiperspirants. The "$\cdot 12H_2O$ indicates that, for each molecule of the potassium aluminum sulfate, there are twelve molecules of water that are associated. These "waters of hydration" can usually be removed by heating the substance, but they are considered to be part of the molecular structure and are included when the molar weight is calculated.

In this laboratory, you will imagine that you and your laboratory partner have been contracted to investigate the feasibility of recycling aluminum cans into alum. Your task is to devise a cost-effective route to the desired product. You will need to investigate the costs of the chemicals that you use to change the aluminum into alum, and you should do some Web research to get prices before you begin the experiment. One of the important variables affecting the cost of production will be the yield, the amount of alum you can obtain from a specified amount of aluminum. Of course, you should try to obtain the highest possible yield, which will minimize the cost of alum production.

Goals

You will:

1. Devise and optimize a method for the synthesis of alum from aluminum cans.
2. Determine the cost-effectiveness of the method.
3. Report your findings and recommendations about the economics of this scheme.

Materials

Aluminum can scrap	Scissors
KOH pellets	Sandpaper
9 **M** H_2SO_4	Buchner funnel or filter funnel and filter paper
Ethanol	Other supplies by request

Getting Started

Before you come to laboratory, you should investigate the cost of the reagents that you will be using. Of course, you may not know in advance how much of the chemicals you will use, but the total cost can be computed after you have optimized the procedure.

You will be supplied with aluminum cans such as are used for soft drinks. Often, these containers have paint on the outside but they always have an inert liner on the inside. It is far easier to remove these materials from the experiment beforehand, by sanding them off of the cans, than it is to filter them out of the solution after the can has been dissolved. You should perform your experiments on small samples, on the order of 1.0 to 1.5 grams of aluminum. In order to keep the costs of the chemical process as low as possible, do not use any more reagents than necessary. You will need to do some preliminary calculations to determine the approximate minimum amount of the reagents that you will need. Check these estimates with your laboratory TA before beginning.

The preparation of alum from aluminum metal is done in several steps, beginning with the dissolution of aluminum. When most people think about what would be necessary to dissolve a metal, they first consider acids; in this case a base is more effective. The balanced equation is:

$$2\ Al(s) + KOH(aq) + 6\ H_2O(l) = 2\ K^+(aq) + 2\ Al(OH)_4^-(aq) + 3\ H_2(g) \qquad (1)$$

Caution: Potassium hydroxide is corrosive – it readily dissolves human tissue. Treat it with respect. It is particularly important that you use safety goggles at all times while you or those around you are performing these experiments.

Addition of sulfuric acid to the product mixture of reaction (1) is the second step of the series:

$$2\ Al(OH)_4^-(aq) + H_2SO_4(aq) = 2\ Al(OH)_3(s) + SO_4^{2-}(aq) + 6\ H_2O(l) \qquad (2)$$

Caution: Concentrated sulfuric acid is also corrosive. You will be using a 9 M solution, which is quite concentrated.

Addition of excess sulfuric acid dissolves the aluminum hydroxide:

$$2\ Al(OH)_3(s) + 3\ H_2SO_4(aq) = 2\ Al^{3+}(aq) + 3\ SO_4^{2-}(aq) + 6\ H_2O \qquad (3)$$

Upon cooling the product mixture from reaction (3), alum will form according to the equation:

$$Al^{3+}(aq) + K^+(aq) + 2\ SO_4^{2-}(aq) + 12\ H_2O(l) = KAl(SO_4)_2 \cdot 12H_2O(s) \qquad (4)$$

The product should form nice, readily observable crystals. You may have to "scratch" the inside of the glass container with a stirring rod in order to initiate the crystallization process. If too much excess sulfuric acid was added, crystals of alum may not form. Your alum product can be dried using a suction filtration apparatus, or by gentle heating on a hot plate. It is sometimes desirable to wash the solid products of a chemical reaction to remove remaining unreacted chemicals. If this is done, you should use a solvent that will not dissolve away your product. In this case, a 1:1 mixture of ethanol and water will remove excess chemicals without dissolving much of the alum.

After your product is dry, calculate and report the percent yield.

Laboratory Report:
Your laboratory report should also include a complete description of the process that you used, from the aluminum scrap to the final product, and the results you obtained. You should estimate the cost of doing this procedure on a commercial scale, including the cost of raw materials, chemical reagents, filtering supplies, and waste disposal. Don't forget to include a bill for your group's services! What happens to the costs when the process is scaled up to production of 100 kg of alum?

Indicate the percent contribution each team member made in this investigation, listing your name first.

Name:	Percent contribution
_____	_____
_____	_____
_____	_____