Experiment on the chemical reactions in synthesis of alum

Introduction

A topic of interest to many scientists is the recycling of Aluminium to stimulate the formation of alum. Alum was synthesized using vacuum filtration in a four-step process in which observation data was collected for each step. Observation data led to the determination of each step's chemical reaction type and the development of the step's net ionic equation. Alum's percent yield was also reported and calculated.

Experimental Summary

To begin the experiment, 0. 9 to 1. 2 grams of aluminum can piece were weighed on an analytical balance. Mass was recorded in a lab notebook. Next, aluminum can pieces were transferred to a 250-milliliter beaker. Fifty milliliters of potassium hydroxide with a molar concentration of 1. 4 were also added to the 250-milliliter beaker. The 250-milliliter beaker was put on a hot plate to increase the speed of the reaction. Once the reaction came to an end, observations were recorded in a lab notebook. These observations were written in relation to reaction one. An aspirator was set up in the meantime the reaction above was proceeding. Filter paper was added to the Buchner funnel. Once the reaction ended, the vacuum source was turned on, the filter paper was rinsed with distilled water, and the hot mixture was poured into the funnel in that same order. The reaction beaker was rinsed with increments of five milliliters until all the reaction mixture was transferred and poured into the Buchner funnel. The filter residue on the filter paper contained the dark residue and the filter flask was a clear liquid. After the above observations were complete, a clean 250 milliliter beaker was rinsed

with ten milliliters of distilled water and combined with the filtrate. The reaction beaker was then cooled with the help of an ice bath and water was added until a slush texture was formed. Once the slush texture in the reaction was created, twenty milliliters of sulfuric acid with a molar concentration of 6. 0 was added to the reaction mixture. If solid formed in the reaction beaker, the reaction beaker was put on a hot plot for a few minutes to dissolve as much solid possible. Any insoluble solid still present after heating was filtered in the same set up described above in terms of the aspirator, filter paper, Buchner funnel, filter flask, and vacuum source. Observations were recorded in a lab notebook. These observations of the insoluble solid were written in relation to reaction two. Observations were recorded in a lab notebook after heating the reaction beaker and dissolving as much solid as possible. These observations were written in relation to reaction three. After finishing the process above, an ice bath was prepared once again in order to cool the reaction beaker once put in the bath. This led to crystallization. These observations were written in relation to reaction four. The formation of alum crystals was induced by scratching the side of the reaction beaker. A stirring rod was used for this part. An aspirator was set up in the meantime the reaction above was proceeding. Once the reaction ended, the crystals or also called precipitates, were transferred onto the filter paper. Next, the reaction beaker was rinsed with ten milliliters of fifty percent ethanol two times and poured onto the filter paper to collect the remaining crystals. Air continued to be pulled in order to dry the alum crystals. While the alum crystals dried, a watch glass was weighed on an analytical balance and recorded in grams. After the alum crystals dried, the alum crystals were put onto the watch glass and weighed together on the

analytical balance. This was also recorded in grams on the lab notebook. Concluding the experiment, all chemicals were disposed in their proper waste containers and glassware was cleaned and return to its proper bins as well. 1

Results and Calculations

The mass of aluminum reacted was 0. 9822 grams. The molecular weight of aluminum is 26. 9815 grams. The moles of aluminum reacted was 0. 03640 moles. This was calculated by dividing the mass of aluminum by the molecular weight of aluminum.

Table 1: Mass, molecular weight, and moles of Al

Mass of aluminum	0. 9822 grams
Molecular weight of aluminum	26. 9815 grams
Moles of aluminum	0. 03640

(mass/weight)	moles

The mass of the watch glass and alum combined was 67. 6859 grams (M1). The mass of the watch glass was 58. 4933 grams (M2). The mass of alum recovered was 9. 1926 grams (M1 – M2).

Table 2: Calculating actual yield of alum

Mass of watch glass (M1)	58. 4933 grams
Mass of watch glass and alum (M2)	67. 6859 grams
Mass of alum (actual yield) (M2 - M1)	9. 1926 grams

Moles of aluminum was then converted to moles of alum by performing stoichiometry based on the balanced chemical equation of the overall reaction. The moles of alum formed was 0. 03640 moles. The formula weight of alum is 474. 39 grams. With this set of information, the theoretical yield of alum was determined to be 17. 2678 grams. The percent yield was calculated by dividing the mass of alum recovered by the theoretical yield of alum. Therefore, the percent yield was determined to be 53. 24 percent.

Table 3: Calculating percent yield of alum

Moles of alum	0. 03640 moles
Formula weight of alum	474. 39 grams
Theoretical yield of alum (moles * weight)	17. 2678 grams
Percent yield ((actual yield/	53. 24 percent

theoretic

al) *

100)

Discussion and Analysis:

Observation data collected regarding reaction one included an apparent color change, which in turn led to the continuation of a less clear solution and eventually a dark, gray colored solution, and gas formation. Reaction one can be viewed as the dissolution step. Therefore, some of the substance separated into ions from a molecular level. Reaction one's chemical reaction was classified as a gas formation and redox reaction.

Balanced chemical equation and net ionic equations of reaction 1:

$2Al(s) + 2KOH(aq) + 6H2O(l) \rightarrow 2KAl(OH)4(aq) + 3H2(g)$

$2Al(s) + 2OH- + 6H2O(l) \rightarrow 2Al(OH)4(aq) + 3H2(g)$

Observation data collected regarding reaction two after the addition of sulfuric acid included a white and thick precipitate of aluminum hydroxide. Reaction two can be viewed as the precipitation of aluminum hydroxide step. Ions bound together to from a precipitate from a molecular level. Reaction two's chemical reaction was classified as a precipitation and acid-base reaction.

Balanced chemical equation and net ionic equations of reaction 2:

$2KAl(OH)4(aq) + H2SO4(aq) \rightarrow 2Al(OH)3(s) + 2H2O(l) + K2SO4(aq)$

Al(OH)4-(aq) + H+ (aq) → Al(OH)3(s) + H2O(l)

Observation data collected regarding reaction three after further addition of sulfuric acid included the white precipitate in reaction two dissolving. Reaction three can be viewed as the dissolving of aluminum hydroxide step which leads to smaller and individual molecules from a molecular level. Reaction three's chemical reaction was classified as an acid-base reaction.

Balanced chemical equation and net ionic equations of reaction 3:

2Al(OH)3(s) + [6H+ + 3SO42-] (aq) → [2Al3+ + 3SO42-]+ 6 H2O (l)

Al(OH)3(s) + H+ (aq) → Al3+(aq) + 3H2O (l)

Observation data collected regarding reaction four included the formation of crystals through a crystallization process. Reaction four can be viewed as the precipitation of alum on cooling step. The molecules are forming a crystal lattice structure from a molecular level. Reaction four's chemical reaction was classified as a precipitation and combination reaction.

Balanced chemical equation and net ionic equations of reaction 4:

Al2(SO4)3(aq) + K2SO4(aq) + 24H2O(l) → 2 KAl(SO4)2•12H2O(s)

K+ (aq) + Al3+(aq) + 2 SO42-(aq) + 12H2O(l) → KAl(SO4)2•12H2O(s)

Through the combination of the four chemical reactions or in other words, the four-step process, an overall reaction was determined. The overall reaction was classified as a precipitation, gas formation, acid-base, and redox reaction.

Balanced chemical equation of overall reaction:

2Al(s) + 2 KOH(aq) + 4H2SO4(aq) + 22H2O(l) ---> 2 KAl(SO4)2·12H2O(s) + 3H2(g)

The mass of alum recovered was 9. 1926 grams, which is also known as the actual yield. The theoretical yield of alum was determined to be 17. 2678 grams. The percent yield was calculated by dividing the mass of alum recovered by the theoretical yield of alum. Therefore, the percent yield was determined to be 53. 24 percent. Possible sources of error that could have affected the percent yield could be contamination, impurities, product loss when transferring to different glassware, crystals going through the filter, and crystal loss due to the addition of ethanol.

Conclusions

The accumulated observation data led to a better understanding of the chemical reactions present in the synthesis of alum. Alum’s percent yield was determined to be 52. 34 percent.

References

1. Bethel, Ryan; Lee, Edward. Fundamentals of Chemistry 119/120 Laboratory Manual, 9th Edition; Hayden-McNeil, 2019; 101-106.