Determining the Formula of an Unknown Hydrate

In this lab you will determine both the identity of the anhydrous salt and the number of waters of hydration in an unknown hydrate.

Stockroom

You will need your unknown.

Equipment

You will need your crucible, crucible cover, crucible tongs, a 150 mL beaker, a metal spatula, a hot plate, a Bunsen burner, and a test tube.

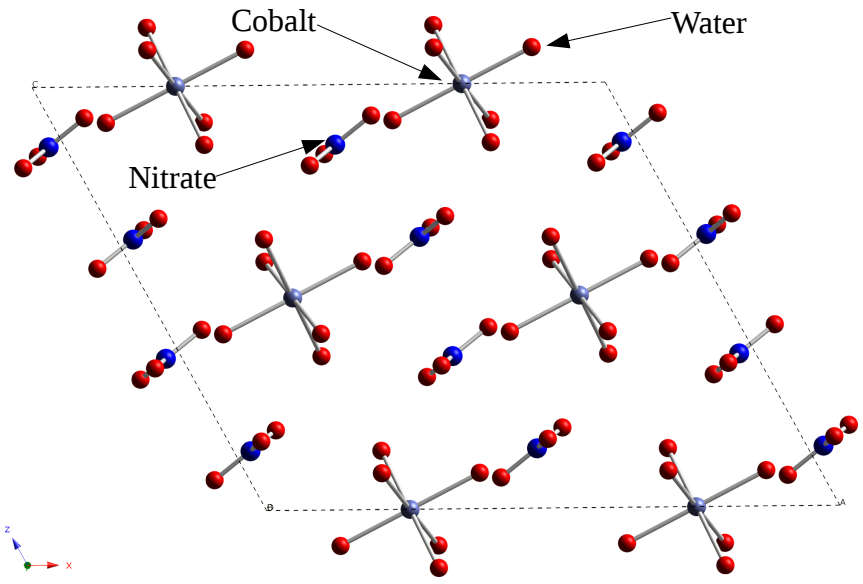
Chemicals

You will need a small strip of unoxidized magnesium metal and about 20 mL of 6M HCl.

Introduction

In this experiment you will discover the formula of an unknown hydrate. Remember that a hydrate is an ionic compound which has a certain number of molecules in the spaces of the salt crystal between the ions.

An example of a hydrate is cobalt(II) nitrate hexahydrate, $Co(NO_3)_2 \cdot 6H_2O$. Here is a picture of what it looks like.



The ionic compound is called the anhydrous salt. The number of water molecules is called the waters of hydration. For example cobalt(II) nitrate hexahydrate has 6 waters of hydration and the anhydrous salt is cobalt (II) nitrate, $Co(NO_3)_2$.

When a hydrate is heated the water molecules vaporize, leaving behind the anhydrous salt.

You will discover the identity of the anhydrous salt by first performing a flame test. You will heat a small sample of your unknown hydrate in a flame. The color of the resulting flame will help you narrow down which salt you have.

The possible salts are $SrCl_2$, $MgSO_4$, K_2CO_3, or $ZnSO_4$. Strontium, when heated in a flame, produces a bright, vivid red color. Potassium gives a violet flame. If you get a red flame when you perform the flame test you know you have strontium chloride. If you get a violet flame you know you have potassium carbonate.

If you do not get either a red flame or a violet flame you know you have either magnesium sulfate or zinc sulfate. To distinguish between the two (you only do this if you don't get a red or violet flame in the flame test) you will determine whether or not a single replacement reaction occurs between your salt and magnesium metal.

If you have zinc sulfate the following reaction will occur.

$$Mg(s)+ZnSO_4(aq)\rightarrow Zn(s)+MgSO_4(aq)$$

You will know this reaction happens if you see a dark coating start to form on the piece of magnesium.

If no reaction happens then you know you have magnesium sulfate as your anhydrous salt.

To find out how many waters of hydration are in your hydrate, you will heat it up until all of the water molecules have evaporated. The difference in mass between the hydrate (before you heated it) and the anhydrous salt (after you heated it is the mass of water that was in your hydrate.

Knowing the mass of water in your hydrate will let you calculate the

moles of water in your hydrate. Knowing the mass of the anhydrous salt (after heating) will let you calculate the moles of your anhydrous salt.

The ratio of moles of water to moles of anhydrous salt gives you the waters of hydration.

Procedure

1.) Weigh your crucible with the crucible cover on it. Record the mass in the data section **(A1).**

2.) Remove the crucible cover and tare the crucible. Add about 4 grams of your unknown to the crucible and record this mass to 3 places past the decimal in the data section **(A2).**

3.) Place the crucible and cover with your unknown in it on a hot plate. Leave the crucible cover slightly ajar to let the steam escape. Heat gently for 5 minutes.

LISTEN AND WATCH CAREFULLY FOR THE HYDRATE TO POP OUT OF THE CRUCIBLE! IF IT DOES, USING YOUR CRUCIBLE TONGS REMOVE THE CRUCIBLE FROM THE HOT PLATE FOR A FEW SECONDS THEN PUT IT BACK ON. CONTINUE THIS UNTIL IT NO LONGER POPS.

4.) After the 5 minutes are up, turn the hot plate up all the way and continue heating for another 15 minutes. Continue to monitor the hydrate to make sure it does not pop out of the crucible.

5.) While waiting for the hydrate to heat, perform the flame test on a sample of your hydrate.

a.) Get a small amount of 6M HCl in your 150 mL beaker.

b.) Take a metal spatula and dip it first in the HCL and then put it into a flame from a Bunsen burner. If you see any colors, especially yellow, in the flame, repeat until you do not see any colors coming from the spatula.

c.) Place a small amount of your unknown hydrate on the tip of the cleaned spatula and hold it in the hottest part of the flame for a minute. Record your observations in the data section.

d.) If you see a red flame your anhydrous salt is strontium chloride, if you see a violet flame your anhydrous salt is potassium carbonate and you do not have to do the next step.

e.) Only if you did you not get either a red or violet flame in the flame test, dissolve a small amount of your unknown hydrate in a couple of milliliters of D.I. water in a test tube.

f.) Drop a small piece of magnesium metal into the solution in the test tube.

g.) Wait at least 5 minutes. If you see a dark colored coating form on the magnesium metal your anhydrous salt is zinc sulfate. If you do not see a dark coating form you have magnesium sulfate as your anhydrous salt. Record your observations in the data section.

6.) After the crucible has been heating for 20 minutes on the hot plate (5 minutes gentle heating and 15 minutes strong heating) remove the crucible and cover from the hot plate with crucible tongs. Place the crucible on a piece of wire gauze on the lab bench.

7.) When the crucible is cool to the touch, weigh the crucible and cover on the balance. Record the mass to three places past the decimal in the data section **(A3).**

8.) Place the crucible and cover back on the hot plate (at it's highest setting) and heat for another 10 minutes.

9.) Using crucible tongs, remove the crucible and cover from the hot plate and set on a piece of wire gauze to cool.

10.) When the crucible is cool to the touch weigh the crucible and cover. Record the mass in the data section **(A4).**

11.) On your calculator find **(A3) – (A4).** If the difference is greater than 0.01 g proceed to step 12. If the difference is 0.01 g or less stop, you are finished with the procedure.

12.) If the difference between (A3) and (A4) was bigger than 0.01 g place the crucible and cover back on the hot plate (at it's highest setting) and heat for another 10 minutes.

13.) Using crucible tongs, remove the crucible and cover from the hot plate and set on a piece of wire gauze to cool.

14.) When the crucible is cool to the touch weigh the crucible and cover. Record the mass in the data section **(A5).**

Data and Analysis

DATA

Mass of crucible and cover_____(A1)

Mass of hydrate before heating_____(A2)

Flame test observations_____

_____

_____

Magnesium strip observations (if necessary)_____

_____

_____

Mass of crucible and cover after first heating_____(A3)

Mass of crucible and cover after second heating_____(A4)

Mass of crucible and cover after third heating_____*(A5)

***Only if necessary**

Analysis

1.) Record the identity of your anhydrous salt ($SrCl_2$, $MgSO_4$, K_2CO_3, or $ZnSO_4$) based on the results of your flame test and magnesium strip test on the line below (A6).

_____**(A6)**

2.) Calculate the mass of your anhydrous salt, **(A4) – (A1)** or **(A5) – (A1)** if you had to do a third heating. Show all of your work including units and significant figures in the space below. Write your answer rounded to the correct number of significant figures on the line provided **(A7).**

_____**(A7)**

3.) Calculate the molar mass of your anhydrous salt using the molar masses on the periodic table from my website. Show all of your work including units and significant figures in the space below. Write your answer rounded to the correct number of significant figures on the line provided **(A8).**

_____**(A8)**

4.) Calculate the moles of your anhydrous salt in your unknown. You can find this by dividing the mass of your anhydrous salt, **(A7)**, by it's molar mass, **(A8)**. Show all of your work including units and significant figures in the space below. Write your answer rounded to the correct number of significant figures on the line provided **(A9)**.

_____**(A9)**

5.) Calculate the mass of water in your unknown. You can find this by subtracting the mass of the anhydrous salt (after you drove off all of the water) from the original mass of the hydrate (when it still had the water). That is, **(A2) – A(7)**. Show all of your work including units and significant figures in the space below. Write your answer rounded to the correct number of significant figures on the line provided **(A10)**.

_____**(A10)**

6.) Calculate the moles of water in your unknown. You can do this by dividing the mass of water in your unknown, **(A10)**, by the molar mass of water. Make sure to use the molar masses from the periodic table on my website. Show all of your work including units and significant figures in the space below. Write your answer rounded to the correct number of significant figures on the line provided **(A11)**.

_____**(A11)**

7.) Calculate the number of waters of hydration in your unknown. That is, find ***x*** in the formula ***anhydrous salt*·*x*H_2O** where "***anhydrous salt***" is the formula of your anhydrous salt. You do this by dividing the moles of water by the moles of the anhydrous. Round to the nearest whole number.

$$\frac{\textbf{(A11)}}{\textbf{(A9)}} = x$$

Show all of your work including units in the space below. Write your answer on the line provided **(A12).**

_____**(A12)**

8.) Write the complete formula for your hydrate on the line below. That is, write it in the form ***anhydrous salt*·*x*H_2O** where for ***anhydrous salt*** you put the formula for your anhydrous salt ($SrCl_2$, $MgSO_4$, K_2CO_3, or $ZnSO_4$) and for ***x*** you put what you got for **(A12).**

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