Properties of Hydrates
Prelab

Name______________________________________ **Total** ______**/10**

1. What is the purpose of this experiment?

2. What is the definition of a hydrated compound?

3. Give the chemical formula for barium chloride octahydrate.

4. You start your experiment with an empty test tube having a mass of 10.3362g. After adding your hydrated compound, the mass of the test tube and hydrate is 14.5003g. After heating the compound, you weigh the test tube again and the mass is 12.9882g. What is the mass of the water in the hydrated compound? What is the mass of the anhydrous salt?

Properties of Hydrates

In this experiment, you will study and observe the properties of hydrated compounds. You will then be able to determine the number of water molecules associated with an unknown hydrated compound.

Introduction

When ionic compounds are prepared in water solution and then isolated as solids, the crystals often have molecules of water trapped in the structure. Compounds where molecules of water are associated with the ions of the compound are called hydrated compounds. Since these compounds are ionic, they are also called hydrated salts. Many of these compounds have beautiful colors and are very clear crystals. These are the compounds you will be using in the first part of this experiment.

The chemical formula for a hydrated compound is written with a dot between the ionic compound and the moles of water associated with the compound. For an example we will show the formula for nickel(II) chloride hexahydrate. The name nickel(II) tells us the nickel cation has a +2 charge and chloride tells us the nickel is attached to the chloride ion. Therefore, the formula for the ionic compound is $NiCl_2$. As for the number of waters associated with the compound, "hexa" tells us there are 6 moles of water associated with every one mole of nickel(II) chloride in the compound. The formula for nickel(II) chloride hexahydrate is therefore $NiCl_2 \bullet 6\ H_2O$. The molecular weight of this compound is the sum of the nickel(II) chloride (129.6g/mole) and the six molecules of water (108.1g/mole) for a total of 237.7g/mole.

Hydrated compounds (or hydrates) are much more common than you think. Plaster of Paris, ($CaSO_4 \bullet 1/2\ H_2O$) is not only popular with artists, but is also used for casts for broken arms or legs. When water is added to this hydrate, it becomes thick slurry and can be poured or spread over the broken part of the body. As it takes on more water, the material increases in volume and then forms a hard inflexible solid.

Since there is no simple way to predict how many water molecules are associated with a hydrated compound, it must be determined experimentally. The experimental method used involves heating the hydrated compound so that all of the water is released from the solid and evaporated. The compound remaining after evaporating all of the water is called the **anhydrous** compound, a substance that is "without water." The mass of the original hydrated compound must equal the sum of the mass of water driven away and the mass of the anhydrous compound left behind.

For an example calculation we will determine the number of water molecules associated with a hydrated cobalt(II) sulfate molecule, $CoSO_4 \bullet x\ H_2O$, x being the unknown number of water molecules. In the laboratory you weigh out 1.0230g of the hydrate and after heating in a test tube until all of the water has evaporated you are left with 0.6030g of the anhydrous compound which is just $CoSO_4$ without any water molecules attached. There is a lot of information here. The first step we want to take is to determine the mass of the water evaporated from the hydrated compound. Simply take the mass of the hydrated compound (1.0230g) and subtract the mass of the anhydrous compound left behind (0.6030g). The mass of the water evaporated is 0.4200g. We want to know how many moles of water there are to one mole of the anhydrous material ($CoSO_4$). The next step is to convert these masses to moles.

1.0230g of hydrated compound – 0.6030g of anhydrous salt = 0.4200g of water

$$0.4200\text{g} \times \frac{1 \text{mole} H_2O}{18.02\text{g of } H_2O} = 0.02331 \text{ moles of } H_2O$$

$$0.6030\text{g} \times \frac{1 \text{ mole of } CoSO_4}{155.0\text{g of } CoSO_4} = 0.003890 \text{ moles of } CoSO_4$$

The value of *x* can then be determined from the mole ratio.

$$\frac{\text{moles of } H_2O}{\text{moles of } CoSO_4} = \frac{0.02331 \text{ moles of } H_2O}{0.003890 \text{ moles of } CoSO_4} = 5.992 \text{ moles of } H_2O \text{ /moles of } CoSO_4$$

This tells us the is a 6:1 water-to-$CoSO_4$ ratio and so the formula for the cobalt(II) sulfate hydrate is $CoSO_4 \bullet 6 H_2O$ and its name is cobalt(II) sulfate hexahydrate.

There are a few other notes that need to be made before starting this experiment. In part I, you will be asked to determine the percent error between your theoretical and experimental values. The percent error can be determined using the following formula :

$$\text{Percent Error} = \frac{|\text{Experimental value} - \text{Theoretical value}|}{\text{Theoretical value}} \times 100\ \%$$

The lines on either side of Experimental value - Theoretical value indicate that you want the absolute value of that subtraction which will always be positive. In parts I and II when determining the number of water molecules associated with an unknown hydrate, you will be asked to determine the percentage of water in the unknown hydrate. This is determined using the following formula

$$\%\ H_2O = \frac{\text{mass of } H_2O}{\text{mass of hydrated compound}} \times 100\%$$

From our example using cobalt(II) sulfate hexahydrate, the mass of the sample of the hydrated compound was 1.023g and the mass of the water evaporated was 0.4200g. The percentage of water in the hydrated compound is:

$$\%\ H_2O = \frac{\text{mass of } H_2O}{\text{mass of hydrated compound}} \times 100 = \frac{0.4200\text{g}}{1.0230\text{g}} \times 100\% = 41.06\%$$

The theoretical mass percentage of water in cobalt(II) sulfate hexahydrate is based on the chemical formula of the hydrate; $CoSO_4 \bullet 6H_2O$. The molecular weight of cobalt(II) sulfate hexahydrate is 263.12 g/mole. The mass of six waters is 108.12g. The theoretical mass percentage of water in cobalt(II) sulfate hexahydrate is:

$$\%\ H_2O = \frac{\text{mass of } H_2O}{\text{mass of hydrated compound}} \times 100 = \frac{108.12\text{g}}{263.12\text{g}} \times 100\% = 41.09\%$$

In Part I, you will verify the formula of a known hydrated compound and in Part II, you will determine the number of water molecules associated with an unknown hydrated compound.

Procedure

Part I

1. Carefully clean and dry a test tube.

2. Using techniques learned in experiment 1, weigh the empty test tube on the **analytical** balance and record its mass. At your bench pour all of the coloured hydrated compound in the packet into the test tube and reweigh. Record this mass as well.

3. Grip the test tube containing the hydrated salt with the test tube holder and carefully heat over a bunsen burner flame for approximately 5-10 minutes. Start out heating gently and then heat strongly taking care not to char your sample. Charring can be avoided by not heating too long at any one spot. You want to heat evenly.

4. After heating for approximately 5-10 minutes, allow the test tube to cool for 10 minutes. Take this test tube with the salt you weighed out (**Do not remove the salt from the test tube**) and weigh it. Record this mass.

5. Repeat steps 3 and 4 to insure that all of the water has been removed. If there is a difference in mass between the two heatings greater than 0.05g, then you may have to heat the sample a third maybe even a fourth time. If so just repeat steps 3 and 4 again.

6. Record any observations such as color change during heating. After you are all finished with your weighings, pour a few drops of distilled water over the anhydrous salt and record what happens.

Be sure to show ALL calculations for Part I.

Part II

You will repeat the same procedure as in Part I, only this time you will be using an unknown hydrated salt. Make sure you record the molecular weight of the anhydrous salt of your unknown hydrate on your data sheet. This will be very important in your calculations later. You may not have to heat your unknown hydrate as long as you had to for your known hydrate so be careful not to char your sample.

Be sure to show ALL calculations for Part II.

Results
Part I

Formula of known hydrated salt ____________________________

Mass of test tube and hydrated salt ____________

Mass of empty test tube ____________

Mass of hydrated salt ____________

Mass of test tube and salt after first heating ____________

Mass of test tube and salt after second heating ____________

Mass of test tube and salt after third heating ____________

Mass of anhydrous salt ____________

Mass of water lost ____________

Experimental mass % of water in hydrated salt ____________
(calculated from your data)

Theoretical mass % of water in hydrated salt ____________
(calculated from the formula given)

Percent Error ____________

Moles of water ____________

Moles of anhydrous salt ____________

Moles of water / moles of anhydrous salt ____________

Moles of water / moles of anhydrous salt (to nearest integer) ____________

Formula of hydrated salt from **your data** ____________________________

Observations

Calculations

Part II

Molecular weight of unknown **anhydrous** salt ____________

Mass of test tube and hydrated salt ____________

Mass of empty test tube ____________

Mass of hydrated salt ____________

Mass of test tube and salt after first heating ____________

Mass of test tube and salt after second heating ____________

Mass of test tube and salt after third heating ____________

Mass of anhydrous salt ____________

Mass of water lost ____________

Mass percent of water in hydrated salt ____________

Moles of water ____________

Moles of anhydrous salt ____________

Moles of water / moles of anhydrous salt ____________

Moles of water / moles of anhydrous salt (to nearest integer) ____________

Calculations