CHEM 30A EXPERIMENT 4: HYDRATE

Learning Outcomes

Upon completion of this lab, the student will be able to:

1) Describe the differences between an anhydrous and hydrate compound.
2) Calculate the number of moles of water in a hydrated compound based on experimental data.

Introduction

Several inorganic compounds have water molecules bonded to the metal ion. The nature of the bonding between the metal ion and water molecules will be discussed in detail in a later topic. The inorganic compound with bound water molecules is called a *hydrate*. The number of water molecules bound to the metal ion varies from compound to compound. Some examples of hydrated salts are given below:

KNOWN Hydrate
$CuSO_4 \cdot 5H_2O$ Copper (II) sulfate pentahydrate

Unknown Hydrate will be one of these
$CaSO_4 \cdot 2H_2O$ Calcium sulfate dihydrate
$MgSO_4 \cdot 7H_2O$ Magnesium sulfate heptahydrate
$ZnSO_4 \cdot 7H_2O$ Zinc sulfate heptahydrate

Hydrated Compound: A hydrated compound is defined as one that contains a fixed number of water molecules chemically combined with the metal ion.

Anhydrous Compound: An anhydrous compound is defined as one in which the molecule(s) of water of hydration has been removed.

The anhydrous and hydrated forms of a particular compound may exhibit different properties. For instance, anhydrous copper (II) sulfate is white in color whereas the hydrated form, copper (II) sulfate pentahydrate, is blue in color.

Several compounds, such as sodium hydroxide, zinc chloride, sodium chloride, etc., can absorb water from the atmosphere. Such compounds are said to be *hygroscopic*. Hydrated compounds can also be hygroscopic, but only those waters chemically combined with the metal ion are considered part of the hydrate; a substance is not necessarily a hydrate simply because it contains water.

Some hygroscopic substances such as sodium hydroxide are able to absorb enough water so as to completely be solubilized by the absorbed water. This property is known as **deliquescence**.

A **desiccant** is a chemical substance that is hygroscopic; and due to its ability to absorb water it is used to maintain a dry environment or absorb moisture. Packets of desiccants, such as those made with silica, are often used to absorb moisture from clothing and pill bottles. Desiccants are also used in desiccators in a laboratory to keep chemicals “dry”.

Experimental Design

In this experiment, you will work first work with copper (II) sulfate pentahydrate (the KNOWN hydrate) and confirm that there are indeed five moles of water associated with each mole of copper (II) sulfate. Following this, you will be provided with **ONE** of three hydrated compounds: $CaSO_4 \bullet xH_2O$, $MgSO_4 \bullet yH_2O$, $ZnSO_4 \bullet zH_2O$. Your instructor will identify which one of the three you have chosen for your unknown. The goal of the experiment is to determine the number of moles of water per mole of the anhydrous compound in the given unknown.

The experimental design is based on the fact that heating the hydrated compound can eliminate the waters of hydration. The difference in the mass between the hydrated and anhydrous compound will be the mass of the water. Once the mass of the anhydrous compound and the water are known, the moles of the anhydrous compound and water can be calculated to obtain the formula of the hydrated compound.

Reagents and Supplies

From the Lab: Known Hydrate = $CuSO_4 \bullet 5H_2O$ and

Unknown Hydrate is one of $CaSO_4 \bullet xH_2O$, $MgSO_4 \bullet yH_2O$, or $ZnSO_4 \bullet zH_2O$

(See posted Material Safety Data Sheets)

From the Stockroom: One Large Test Tube, One 250 mL Beaker to hold test tube during weighing, spatula, Test Tube clamp

From the Lab: Bunsen Burner

Procedure

PART 1: ANALYSIS OF COPPER (II) SULFATE PENTAHYDRATE ($CuSO_4 \cdot 5H_2O$)

1. Weigh an empty dry test tube in a clean dry beaker. **(Use same beaker and balance throughout each trial.)**

2. Add some copper (II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) to the test tube (scoop a small amount with a spatula, approximately 0.1000 grams). Measure the mass of the test tube with the solid in the same beaker. Record this mass.

3. Heat the test tube with the hydrate over a Bunsen burner. When the water of hydration has been evaporated, the color of the solid should change from blue to grayish-white. Be sure any condensed water vapor in the test tube has been chased out of the test tube by heating.

4. Place the heated test tube in the beaker. Cool the test tube to room temperature and measure the mass of the test tube with the anhydrous compound in the beaker.

5. Discard the contents of the test tube in the appropriate waste disposal container.

6. Repeat the steps 1-5 for a second sample. This will be Trial 2. Repeat Steps 1-6 if time allows for Trial 3.

PART 2: ANALYSIS OF UNKNOWN HYDRATE ($CaSO_4 \cdot xH_2O$, $MgSO_4 \cdot yH_2O$, or $ZnSO_4 \cdot zH_2O$)

1. Weigh an empty dry test tube in a clean dry beaker. **(Use same beaker and balance throughout each trial.)**

2. Add some unknown hydrate (one of the ones above and be sure to record which sample you used) to the test tube (scoop a small amount with a spatula, approximately 0.1000 grams). Measure the mass of the test tube with the solid in the same beaker. Record this mass.

3. Heat the test tube with the hydrate over a Bunsen burner. When the water of hydration has been evaporated, the color of the solid should change from blue to grayish-white. **Be sure any condensed water vapor in the test tube has been chased out of the test tube by heating**.

4. Place the heated test tube in the beaker. Cool the test tube to room temperature and measure the mass of the test tube with the anhydrous compound in the beaker.

5. Discard the contents of the test tube in the appropriate waste disposal container.

6. Repeat the steps 1-5 for a second sample. This will be Trial 2. Repeat Steps 1-6 if time allows for Trial 3.

Data Table

PART 1: ANALYSIS OF THE KNOWN COPPER (II) SULFATE PENTAHYDRATE ($CuSO_4 \cdot 5H_2O$)

	Trial 1	**Trial 2**	**Trial 3**
Mass of empty test tube + beaker (grams)			
Mass of test tube + $CuSO_4 \cdot 5H_2O$ + beaker (grams)			
Mass of test tube + anhydrous $CuSO_4$ + beaker (following heating) (grams)			

PART 2: ANALYSIS OF UNKNOWN HYDRATE: (CIRCLE ONE) $CaSO_4 \cdot xH_2O$, $MgSO_4 \cdot yH_2O$, or $ZnSO_4 \cdot zH_2O$

	Trial 1	**Trial 2**	**Trial 3**
Mass of empty test tube + beaker (grams)			
Mass of test tube + hydrate + beaker (grams)			
Mass of test tube + anhydrous compound + beaker (following heating) (grams)			

Calculations

PART 1: ANALYSIS OF THE KNOWN COPPER (II) SULFATE PENTAHYDRATE ($CuSO_4 \cdot 5H_2O$)

	Trial 1	**Trial 2**	**Trial 3**
1. Mass of empty test tube + beaker (grams)			
2. Mass of test tube + hydrate ($CuSO_4 \cdot 5H_2O$) + beaker (grams)			
3. Mass of hydrate (grams) = (#2-#1)			
4. Mass of test tube + anhydrous compound ($CuSO_4$) (following heating) + beaker (grams)			
5. Mass of anhydrous compound (grams) = (#4-#1)			
6. Mass of water (grams) = (#2-#4)			
7. Moles of anhydrous compound = #5/(159.609 g/mole)			
8. Moles of water = #6/(18.02 g/mole)			
9. Formula of hydrated compound = #8/#7			

PART 2: ANALYSIS OF UNKNOWN HYDRATE

Identity of Unknown Hydrate: (CIRCLE ONE) $CaSO_4 \bullet xH_2O$, $MgSO_4 \bullet yH_2O$, or $ZnSO_4 \bullet zH_2O$

	Trial 1	**Trial 2**	**Trial 3**
1. Mass of empty test tube + beaker (grams)			
2. Mass of test tube + hydrate + beaker (grams)			
3. Mass of hydrate (grams) = (#2-#1)			
4. Mass of test tube + anhydrous compound (following heating) + beaker (grams)			
5. Mass of anhydrous compound (grams) = (#4-#1)			
6. Mass of water (grams) = (#2-#4)			
7. Moles of anhydrous compound = #5/(molar mass of anhydrous unknown)			
8. Moles of water = #6/(18.02 g/mole)			
9. Formula of hydrated compound = #8/#7			

Molar Mass:

$CuSO_4$ = 159.609 g/mole

$MgSO_4$ = 120.366 g/mole

$CaSO_4$ = 136.14 g/mole

$ZnSO_4$ = 161.47 g/mole

Moles of Water = g water/18.02 g/mole = _____

Moles of Anhydrate = g anhydrate/molar mass of anhydrate = _____

Number of waters in hydrate = moles of water/moles of anhydrate = _____

Formula of Hydrate: ($CaSO_4 \bullet xH_2O$, $MgSO_4 \bullet yH_2O$, or $ZnSO_4 \bullet zH_2O$) = _____

Results:

The identity of the unknown provided is: (circle one) $CaSO_4 \bullet xH_2O$, $MgSO_4 \bullet yH_2O$, or $ZnSO_4 \bullet zH_2O$

The formula of the hydrated unknown compound is:

_____