EXPERIMENT A3: 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:

$CuSO_4 \cdot 5H_2O$	Copper (II) sulfate pentahydrate
$CaSO_4 \cdot 2H_2O$	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 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: $CaSO_4.xH_2O$, $MgSO_4.yH_2O$, $ZnSO_4.zH_2O$. 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

$CuSO_4 \bullet 5H_2O$ and one of $CaSO_4.xH_2O$, $MgSO_4.yH_2O$, $ZnSO_4.zH_2O$

(See posted Material Safety Data Sheets)

Micro-crucibles

Procedure

PART 1: ANALYSIS OF COPPER (II) SULFATE PENTAHYDRATE

1. Heat an empty crucible and bring it to a constant mass (±0.0010 g). In order to do this, record the mass of the empty crucible. Then heat the crucible for 3-4 minutes. Once the crucible is cool, record its mass again. Repeat the heating-cooling-weighing process until the mass recorded is the same as that for the previous measurement.

2. Add some copper (II) sulfate pentahydrate to the micro-crucible (scoop a small amount with a spatula, approximately 0.1000 grams). Measure the mass of the micro-crucible with the solid.

3. Heat the micro-crucible over a Bunsen burner. When the water of hydration has been evaporated, the color of the solid should change from blue to grayish-white.

4. Cool the micro-crucible to room temperature and measure the mass of the micro-crucible with the anhydrous compound.

5. In order to ensure that all the water of hydration has been evaporated from the solid, the micro-crucible containing the anhydrous solid should be heated over the flame once again.

6. Once again, cool the micro-crucible and measure the mass of the micro-crucible containing the anhydrous compound.

7. The heating-cooling-weighing of the micro-crucible with the anhydrous compound must be repeated a few times (three to four times) until the mass of the micro-crucible containing the anhydrous compound is a constant between the last two measurements (±0.0010 g).

8. Discard the contents of the micro-crucible in the appropriate waste disposal container.

PART 2: ANALYSIS OF UNKNOWN HYDRATE

1. Heat an empty crucible and bring it to a constant mass (±0.0010 g). In order to do this, record the mass of the empty crucible. Then heat the crucible for 3-4 minutes. Once the crucible is cool, record its mass again. Repeat the heating-cooling-weighing process until the mass recorded is the same as that for the previous measurement.

2. Add some unknown hydrate to the micro-crucible (scoop a small amount with a spatula, approximately 0.1000 grams). Measure the mass of the micro-crucible with the solid.

3. Heat the micro-crucible over a Bunsen burner. Continue the heating process for about five minutes.

4. Cool the micro-crucible to room temperature and measure the mass of the micro-crucible with the anhydrous compound.

5. In order to ensure that all the water of hydration has been evaporated from the solid, the micro-crucible containing the anhydrous solid should be heated over the flame once again.

6. Once again, cool the micro-crucible and measure the mass of the test tube containing the anhydrous compound.

7. The heating-cooling-weighing of the micro-crucible with the anhydrous compound must be repeated a few times (three to four times) until the mass of the micro-crucible containing the anhydrous compound is a constant between the last two measurements (±0.0010 g).

8. Discard the contents of the micro-crucible in the appropriate waste disposal container.

Data Table

PART 1: ANALYSIS OF COPPER (II) SULFATE PENTAHYDRATE

	Trial 1	**Trial 2**	**Trial 3**
Constant mass of empty micro-crucible (grams)			
Mass of micro-crucible + hydrate (grams)			
Mass of micro-crucible + anhydrous compound (following first heating) (grams)			
Mass of micro-crucible + anhydrous compound (following second heating) (grams)			
Mass of micro-crucible + anhydrous compound (following third heating) (grams)			
Mass of micro-crucible + anhydrous compound (following fourth heating) (grams)			

PART 2: ANALYSIS OF UNKNOWN HYDRATE

	Trial 1	**Trial 2**	**Trial 3**
Constant mass of empty micro-crucible (grams)			
Mass of micro-crucible + hydrate (grams)			
Mass of micro-crucible + anhydrous compound (following first heating) (grams)			
Mass of micro-crucible + anhydrous compound (following second heating) (grams)			
Mass of micro-crucible + anhydrous compound (following third heating) (grams)			
Mass of micro-crucible + anhydrous compound (following fourth heating) (grams)			

Calculations

PART 1: ANALYSIS OF COPPER (II) SULFATE PENTAHYDRATE

	Trial 1	**Trial 2**	**Trial 3**
Mass of empty micro-crucible (grams)			
Mass of micro-crucible + hydrate (grams)			
Mass of hydrate (grams)			
Constant mass of micro-crucible + anhydrous compound (following final heating) (grams)			
Mass of anhydrous compound (grams)			
Mass of water (grams)			
Moles of anhydrous compound			
Moles of water			
Formula of hydrated compound			

PART 2: ANALYSIS OF UNKNOWN HYDRATE

A. Assume that the anhydrous compound is $CaSO_4$

	Trial 1	**Trial 2**	**Trial 3**
Mass of empty micro-crucible (grams)			
Mass of micro-crucible + hydrate (grams)			
Mass of hydrate (grams)			
Constant mass of micro-crucible + anhydrous compound (following final heating) (grams)			
Mass of anhydrous compound (grams)			
Mass of water (grams)			
Moles of anhydrous compound			
Moles of water			
Formula of hydrated compound			

B. Assume that the anhydrous compound is $MgSO_4$

	Trial 1	**Trial 2**	**Trial 3**
Mass of empty micro-crucible (grams)			
Mass of micro-crucible + hydrate (grams)			
Mass of hydrate (grams)			
Constant mass of micro-crucible + anhydrous compound (following final heating) (grams)			
Mass of anhydrous compound (grams)			
Mass of water (grams)			
Moles of anhydrous compound			
Moles of water			
Formula of hydrated compound			

C. Assume that the anhydrous compound is $ZnSO_4$

	Trial 1	**Trial 2**	**Trial 3**
Mass of empty micro-crucible (grams)			
Mass of micro-crucible + hydrate (grams)			
Mass of hydrate (grams)			
Constant mass of micro-crucible + anhydrous compound (following final heating) (grams)			
Mass of anhydrous compound (grams)			
Mass of water (grams)			
Moles of anhydrous compound			
Moles of water			
Formula of hydrated compound			

Results

The identity of the unknown provided is: _____

The formula of the hydrated unknown compound is: _____