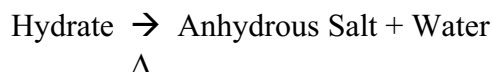Regents Chemistry

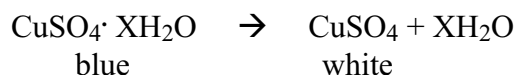# Composition of Hydrates

Introduction:

Hydrates are ionic compounds (salts) that have a definite amount of water as part of their structure. This "water of hydration" is released as vapor when the hydrate is heated. The remaining solid is known as the **anhydrous salt**. The general reaction for heating a hydrate is:

$$\text{Hydrate} \rightarrow \text{Anhydrous Salt} + \text{Water}$$
$$\Delta$$

The percent of water in a hydrate can be found experimentally by accurately determining the mass of the hydrate and the mass of the anhydrous salt. The difference in mass is due to the water lost by the hydrate. Procedures involving meaurements of masses to determine quantitative information is termed **gravimetric analysis**. The percent of water in the original hydrate can easily be calculated:

$$\%H_2O = \frac{massH2O}{masshydrate} \times 100$$

In this experiment, a hydrate of copper sulfate will be studied ($CuSO4 \cdot XH_2O$). The change from copper hydrate to anhydrous salt is accompanied by a color change:

$$CuSO_4 \cdot XH_2O \quad \rightarrow \quad CuSO_4 + XH_2O$$
$$\text{blue} \qquad\qquad \text{white}$$

This investigation should aid in the understanding of the composition of hydrates, single decomposition reactions, and the Law of Definite Composition.
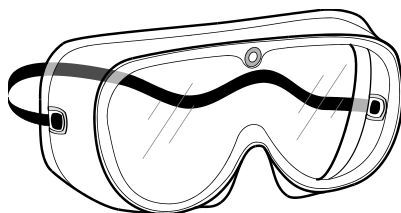
Purpose:

- determine the percent of water of hydration in a hydrate via gravimetric analysis

- perform statistical analysis of class data

Equipment:

evaporating dish	stirring rod
crucible tongs	hot plate
microspatula	safety goggles
laboratory balance	

Materials: copper sulfate hydrate, $CuSO_4 \cdot XH_2O$

Procedure: **NOTE: You MUST WEAR GOGGLES!**

1. Obtain an evaporation dish, wash and thoroughly dry with a paper towel.

2. Find the mass of the evaporating dish to the nearest 0.01 g. Record this mass in your data table.

3. With the evaporating dish on the balance, measure into it as best you can 2.00 g of copper sulfate hydrate. Be careful not to spill any on the balance. Use the spatula to transfer the salt. Record the mass of dish and hydrate.

4. Place the evaporating dish with the hydrate on the hot plate. Heat the dish using a medium setting for the first three minutes and then increase the setting for the next five minutes. Gradual heating should avoid any popping and spattering. **YOU MUST WEAR GOGGLES**.

5. Heat strongly for 5 minutes or until the blue color has disappeared. During heating, a microspatula may be used to "spread" the solid and break up any "caked" portions of the hydrate. Be careful not to pick up any of the solid on the microspatula. If the edges of the solid appear to be turning brown, remove the heat momentarily and resume heating at a gentler rate.

6. Using crucible tongs, remove the evaporating dish from the hot plate and place on the lab bench. **Allow the evaporating dish to COOL**.   Weighing a hot dish will transfer the heat through the metal pan of the balance and ruin the electronic balances circuitry. You can tell when the dish is cool enough to mass by placing your hand next to the dish. If you don't feel any heat it is safe to mass the dish. Immediately after cooling find the mass of the dish and anhydrous salt, and record the mass. It is important not to allow the anhydrous

salt to cool too long because water vapor in the air will begin to rehydrate the anhydrous salt.

7. Repeat steps 5 & 6. The mass after the second heating should be within 0.05 g of the first heating. This is called **heating to constant mass**. Heating to constant mass ensures that all of the water of hydration has been driven off and we are massing only the anhydrous salt.

8. After the dish has colled and been weighed, get a beral dropper and a small amount of water in a beaker. Slowly add drops of water to the anhydrous salt and record your observations. Empty the contents of the dish into the waste container it the front of the room and wash and dry the dish. Put away all equipment (allow time for the hot plate to cool).

Data:

1.   Mass of evaporating dish................ _____ g $\pm$ _____ g

2.   Mass of evaporating dish + hydrate...._____ g $\pm$ _____g

3.   Mass of dish + anhydrous salt........... _____ g $\pm$ _____ g
(after first heating)

4.   Mass of dish + anhydrous salt........... _____ g $\pm$ _____ g
(after second heating)

Calculations (show all work):

1. Determine the mass of the hydrate including the uncertainty.

2. Determine the mass of the water lost including the uncertainty.

3. Determine the percent of the water in the hydrate including the uncertainty.

4. Dermine the mass of anhydrous salt.

5. Determine the empirical formula of your hydrate.

Questions:

1. The true value for the percent of water in this hydrate is 36.0%. Calculate your experimental (percent) error.

2. Your percentage of hydrate may be different from the accepted value. Explain why your percentage might be

    a) greater than 36.0%
    b) less than 36.0%

3. Why must the evaporating dish be allowed to cool before measuring its mass?

4. What is meant by :heating to constant mass and why is it important in this experiment?

5. Explain how this experiment illustrates the Law of Definite Composition.

6. Why must the mass of the anhydrous salt be measured immediately upon cooling?

7. A substance consists of 23% zinc, 11% sulfur, 22% oxygen and 44% water. Determine the empirical formula of this hydrate.

8. If a sample of 2.56 g of the above substance were heated in a crucible, calculate the mass of anhydrous salt that would remain.

9. Describe what happened when you adeed water to the anhydrous copper sulfate. Would you predict this to be an endothermic or exothermic reaction? Was your prediction verified by observation?

10. For the class data:

    a) Calculate the average percent water with the uncertainty.
    b) Calculate the standard deviation
    c) Can any of the measurements be discarded? Why or why not?

Teacher notes:

Question 2:

$$\% \ H_2O = \frac{\text{mass } H_2O}{\text{mass hydrate}}$$

If greater than 36%, some hydrate may have stuck to the microspatula while stirring or some hydrate may have spilled; this would give a lower denominator and thus bigger % water.

If less than 36%, hydrate may not have been heated long enough (larger denominator), or you waited too long after cooling and the anhydrous compound absorbed some water (higher denominator)

Questions 7 & 8.

$$\frac{126}{287.5} = 43.7\% \ H_2O$$
$$= 56.2 \ \% \ ZnSO_4$$

Therefore .562(2.56) = 1.44 g anhydrous salt