Composition of Hydrates Lab

**Hydrates** are ionic compounds (salts) that have a definite amount of water (water of hydration) as part of their structure. The water is chemically combined with the salt in a definite ratio. Ratios vary in different hydrates but are specific for any given hydrate.

The formula of a hydrate is represented in a special manner. The hydrate of copper sulfate in this experiment has the formula CuSO₄ * xH₂O. The unit formula for the salt appears first, and the water formula is last. The raised dot means that the water is loosely bonded to the salt. The coefficient x stands for the number of molecules of water bonded to one unit of salt. This special formula, like all other formulas, illustrates the **law of definite composition**.

When hydrates are heated, the “water of hydration” is released as vapor. The remaining solid is known as the anhydrous salt. The general reaction for heating a hydrate is: **hydrate + heat → anhydrous salt + water**

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. The percentage of water in the original hydrate can easily be calculated:

\[
\text{percent H}_2\text{O} = \frac{\text{mass water}}{\text{mass hydrate}} \times 100
\]

In this experiment a hydrate of copper sulfate will be studied (CuSO₄ * xH₂O). The change from hydrate to anhydrous salt is accompanied by a change in color:

\[
\text{CuSO}_4 \times \text{H}_2\text{O} \rightarrow \text{CuSO}_4 + \text{xH}_2\text{O}
\]

**blue** → **white**

**Objective:** To determine the percentage of water in a hydrate.

**Equipment**
- evaporating dish
- iron ring
- wire gauze
- spatula
- laboratory balance
- test tube
- test tube holder

**Chemicals:** copper sulfate hydrate, CuSO₄ * xH₂O

**Safety**
- Do not touch a hot evaporating dish with your hands.
- Tie back long hair and secure loose clothing when working around an open flame.
- Lab aprons and goggles must be worn during the lab.

**Procedure**

**Part A: Reaction of Copper(II) Sulfate**

1. Heat the evaporating dish with the hottest part of the flame for three minutes.
2. Once it is cool enough to handle, remove the evaporating dish from the apparatus.
3. Use the balance to find the mass of the evaporating dish to the 0.01 g. Record the mass.
4. With the evaporating dish on the balance, measure **approximately** 2.00 grams of copper sulfate hydrate. Record the mass of the evaporating dish and the hydrate.
5. Place the evaporating dish & hydrate on the wire gauze. Gently heat the dish by moving the burner back and forth around the base. Increase the heat gradually. **Avoid any popping and spattering.**
6. Heat strongly for five minutes or until the blue color has disappeared. During heating, a spatula should 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 spatula. If the edges of the solid appear to be turning brown, remove the heat momentarily and resume heating at a gentler rate.
7. Allow the evaporating dish to cool enough so that it can be handled. Immediately find the mass of the dish & anhydrous salt and record your data (first heating).
8. Place the evaporating dish & hydrate back on the wire gauze. Heat the dish strongly for three minutes.
9. Allow the evaporating dish to cool enough so that it can be handled. Immediately find the mass of the dish & anhydrous salt and record your data (second heating). If the mass of the first heating and the second heating differ by 0.10 or more, do a third heating.
10. Once your evaporating dish has cooled to room temperature, add a few drops of water and note the color change.
11. Discard the copper(II) sulfate in the waste container. Record the mass of dry copper sulfate on the waste data sheet.
12. Clean and put away all equipment.

Part B: Reactions of Other Hydrates
1. Obtain a small sample of nickel(II) sulfate hexahydrate, cobalt(II) chloride hexahydrate or manganese(II) chloride tetrahydrate
2. Add the sample to your test tube.
3. Make observations of your hydrate.
4. Heat the sample in a low Bunsen burner flame.
5. Make observations of what happens to the hydrate during heating.
6. **Allow the test tube to cool completely to room temperature.**
7. Add a few drops of water to the test tube and note any changes.
8. Clean your test tube.

Data Table:
Part A: Reaction of Copper(II) Sulfate

<table>
<thead>
<tr>
<th>Mass of evaporating dish</th>
<th>__________________ grams.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of evaporating dish &amp; hydrate</td>
<td>__________________ grams.</td>
</tr>
<tr>
<td>Mass of evaporating dish &amp; anhydrous salt (first heating)</td>
<td>__________________ grams.</td>
</tr>
<tr>
<td>Mass of evaporating dish &amp; anhydrous salt (second heating)</td>
<td>__________________ grams.</td>
</tr>
</tbody>
</table>

Observations:

Color of hydrate before heating: __________________________________________________________

Color of anhydrous salt: ____________________________________________________________

Color of re-hydrated salt: _____________________________________________________________

Calculations:

Find the total mass of the hydrate used: __________________________________________________

Find the mass of the water in the hydrate: ____________________________________________

Find the mass of the anhydrous salt: ________________________________________________

Find the percentage of water in the hydrate: __________________________________________

Find the percentage of anhydrous salt in the hydrate: _________________________________

Determine the formula of the hydrate using the percentages from above: ______________________

Part B: Reactions of Other Hydrates

Chemical Chosen: __________________________

Observations before heating: _______________________________________________________

Observations after heating: _______________________________________________________

Observations after adding water: ___________________________________________________
Post- Lab Questions:
1. What is a hydrate?

2. Why was the empty evaporating dish heated for three minutes at the start of the lab?

3. Why must you measure the mass of the anhydrous salt immediately upon cooling?

4. What does the term “anhydrous” mean?

5. How would the predicted formula be different (more water or less water) if the evaporating dish was not heated to dryness? Why?

6. How would the predicted formula be different (more water or less water) if some of the hydrate got stuck on your spatula? Why?

7. Use the information from below to make calculations and determine the formula of the hydrate.

   Situation 1:
   **Hydrate Used:** Na₂CO₃ ·xH₂O
   **Data:**
   b. Mass of evaporating dish & hydrate: 54.87 grams.
   **Calculations:**
   a. Find the total mass of the hydrate used.
   b. Find the mass of the water.
   c. Find the mass of the anhydrous salt.
   d. Find the percentage of water in the hydrate.
   e. Find the percentage of anhydrous salt in the hydrate.
   f. Determine the formula of the hydrate using the percentages from above.
8. Use the information from below to make calculations and determine the formula of the hydrate.

**Situation II:**
**Hydrate Used:** CaSO₃ · xH₂O

**Data:**
- a. Mass of evaporating dish: 42.98 grams.
- b. Mass of evaporating dish & hydrate: 47.28 grams.

**Calculations:**
- a. Find the total mass of the hydrate used.
- b. Find the mass of the water.
- c. Find the mass of the anhydrous salt.
- d. Find the percentage of water in the hydrate.
- e. Find the percentage of anhydrous salt in the hydrate.
- f. Determine the formula of the hydrate using the percentages from above.

9. When heated to 220.°C, BeC₂O₄ * 3H₂O(s) dehydrates completely as represented below.
   \[ \text{BeC}_2\text{O}_4 \cdot 3\text{H}_2\text{O}(s) \rightarrow \text{BeC}_2\text{O}_4(s) + 3\text{H}_2\text{O}(g) \]

If 3.21 g of BeC₂O₄ * 3H₂O(s) is heated to 220.°C, calculate the mass of BeC₂O₄(s) formed.

10. A student is assigned the task of determining the number of moles of water in one mole of MgCl₂ * nH₂O. The student collects the data shown in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of empty container</td>
<td>22.347 g</td>
</tr>
<tr>
<td>Initial mass of sample and container</td>
<td>25.825 g</td>
</tr>
<tr>
<td>Mass of sample and container after first heating</td>
<td>23.982 g</td>
</tr>
<tr>
<td>Mass of sample and container after second heating</td>
<td>23.976 g</td>
</tr>
<tr>
<td>Mass of sample and container after third heating</td>
<td>23.977 g</td>
</tr>
</tbody>
</table>

(a) Explain why the student can correctly conclude that the hydrate was heated a sufficient number of times in the experiment.

(b) Use the data above to determine the formula of the hydrated compound.