Water in a Hydrate (91 points)

AP Chemistry. A. Collins 2013/14

INTRODUCTION:

Many compounds are formed as a result of reactions that occur in aqueous solutions. When water is evaporated from a solution, the water molecules often find themselves trapped in the crystalline structure of the salt. These compounds appear to be dry, but when they are heated, large amounts of water are released. The water molecules are part of the crystalline structure and are weakly bonded to the ions or molecules that make up the compound. Such compounds are known as **hydrates**, in reference to the water they contain. The solid that remains when the water is removed is referred to as the anhydrous salt, or **anhydrate.**

$$\text{Hydrate} \xrightarrow{\Delta} \text{Anhydrate} + H_2O$$

Usually, the amount of water present in a hydrate is in a whole number molar ratio to the moles of anhydrate. An example of a hydrate is magnesium sulfate. Its formula is $MgSO_4{\cdot}7H_2O$, indicating that seven moles of water are combined with one mole of magnesium sulfate in the crystalline form.

In this investigation, you will be given an unknown hydrate and asked to determine the percent of water in the compound. From this information the identity of the hydrate will be determined by comparing the water percentage to that of the unknown choices. Upon identification, the molar ratio of water to anhydrous salt will be calculated.

PURPOSE: (5 PTS)

PRE-LAB QUESTIONS/INQUIRY IDEAS: (19 points)

1. What is a hydrate? What is an anhydrate? (4 pts)
2. Why do you think it's necessary to heat the evaporating dish before finding its mass? (3 pts)
3. Why must the mass of the anhydrous salt be measured somewhat quickly after cooling? (3 pts)
4. What is the molar mass of the hydrate of magnesium sulfate described in the introduction? (2 pts)
5. What is the molar mass of the anhydrous salt, magnesium sulfate? (2 pts)
6. What is the percent of water in $MgSO_4{\cdot}7H_2O$? (2 pts)
7. What is the density of the hydrate and the anhydrate ($MgSO_4{\cdot}7H_2O$)? Cite source. (3 pts)

PROCEDURE: (10 pts)

Safety: The evaporating dish gets extremely hot. Handle carefully with laboratory tongs. Be sure to wear your apron and safety glasses at all times. Also, since we are working with a flame, tie back long hair and loose clothing. Your unknown hydrate may be a skin irritant. Avoid contact.

1. Put on your safety glasses and apron and gather the following materials: clay triangle, Bunsen burner, evaporating dish, an unknown hydrate sample, spatula or stirring rod, and laboratory tongs.
2. Properly assemble your equipment with the evaporating dish approximately 30 cm above the base of the ring stand.
3. Light a Bunsen burner and heat a clean, dry evaporating dish in the hottest part of the flame for one minute. Handle the evaporating dish with tongs. It will be extremely hot.
4. Remove the evaporating dish from heat and allow to cool on the lab bench top for at least three minutes.
5. Once it is no longer hot (warm is okay) measure and record the mass of the cool evaporating dish to the nearest 0.001g.
6. Record the number of your unknown hydrate sample in your notebook. Transfer approximately 3-5 grams of your unknown sample to the evaporating dish. Measure and record the mass of the evaporating dish and the hydrate to the nearest 0.001g.
7. Place the evaporating dish and hydrate on a clay triangle. Begin heating gently while stirring. Gradually increasing the heat until there is no more popping or splattering. You will need to hold the dish with tongs to avoid knocking it off the stand while stirring.

8. Examine the material in the evaporating dish. Record some observations in your lab notebook. If the edges of the solid appear to be turning brown, reduce the heat momentarily and then begin heating again at a slower rate. Heat for five more minutes.
9. VERY CAREFULLY remove the evaporating dish from the flame and allow it to cool for at least three minutes. Measure and record the mass of the evaporating dish and the anhydrous salt.
10. Reheat the evaporating dish and contents for a few minutes, cool and measure the mass again. The value should be within 0.010 g of the last recorded mass. If it is not, reheat and measure again until the mass of the last two measurements is within the 0.010 g range. Record the final mass.
11. Dispose of the final products in the appropriate waste beakers. Clean up your work area and wash your hands before leaving.

CHEMICAL SAFETY/PHYSICAL DATA: (10 pts)

DATA: (7 pts)

Carefully re-read the procedure for this lab. Create a data table that will contain only spaces for the relevant measurements required to complete the lab. You will only perform one trial in this lab session.

OBSERAVATIONS: (5 pts)

CALCULATIONS: (10 pts)

Be sure to show all calculations used to decipher masses and molar ratios. Determine the smallest whole number ratio of moles of anhydrous salt to (most likely a non whole integer) moles of water. Ex: You will probably get something like this → 1.00 $CuSO_4$: 5.13 H_2O

CONCLUSION: (2 pts)

After consulting the list of possible unknowns, determine the empirical formula for your hydrate. [What you got *and* what you were supposed to get. "I got 1.00 $CuSO_4$: 5.13 H_2O, but I can determine that my hydrate was $CuSO_4 – 5H_2O$."

ERROR ANALYSIS: (10 pts)

You calculated the experimental percentage of water in your hydrate. Now, look at the actual empirical formula for your compound and calculate the mass of water that should have been in your hydrate. This will serve as your accepted value. Calculate a percent error for this investigation. In your discussion, try to account for what experimental errors may have occurred (follow your lab guidelines).

POST LAB QUESTIONS: (13 pts)

1. Explain what effect the following errors would have on the value for the percent water in the hydrate.
    a. The hydrate was not heated long enough to drive off all the water. (3 pts)
    b. A damp crucible was used, and it was not dried before adding the hydrate. (3 pts)
    c. The crucible and contents were allowed to cool overnight before finding their mass. (3 pts)

2. The method used in this investigation is not suitable for all hydrates. Give two reasons for this. (4 pts)