EXPERIMENT 4D

Formula of a Hydrate

Many salts that have been crystallized from a water solution appear to be dry, but when they are heated, large amounts of water are given off. The crystals often change color when the water is released. This suggests that water is a part of their crystal structure. These compounds are called *hydrates*, meaning that they contain water. When these compounds are heated strongly in a crucible, the water is driven off, leaving an *anhydrous* compound (without water). Usually, the amount of water present in a compound is in a whole-number mole ratio. One common example of a hydrate is copper(II) sulfate. The formula of the hydrate is $CuSO_4 \cdot 5H_2O$. The formula of the anhydrous form of the compound is simply $CuSO_4$. The formula of the hydrate indicates that five moles of water are combined with one mole of the copper(II) sulfate.

Granules of calcium chloride ($CaCl_2$) are often used to take moisture out of the air of damp rooms. They do this by forming the hydrate $CaCl_2 \cdot 6H_2O$. Chemical drying agents such as calcium chloride are called *dessicants*.

In this experiment, you will be given an unknown hydrate and asked to find the percent of water in the hydrate. This calculation will help you to determine the formula of the hydrate.

OBJECTIVES

1. to determine the percent of water in an unknown hydrate
2. to determine the moles of water present in each mole of the unknown substance
3. to use the molecular mass to find the empirical formula of the hydrate

MATERIALS

Apparatus

lab burner
crucible and cover
crucible tongs
pipestem triangle
ring stand and ring
centigram balance
desiccator
medicine dropper
safety goggles
lab apron

Reagents

5 g of a hydrate
distilled water

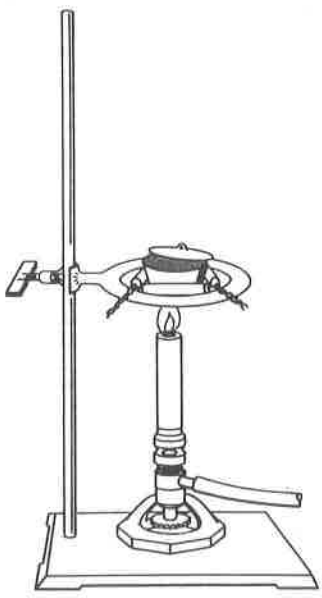

Figure 4D-1

PROCEDURE

1. Put on your safety goggles and lab apron. You will be using the lab burners during this experiment. Use them cautiously.
2. Place a clean, dry crucible with a cover in a pipestem triangle mounted on an iron ring. Leave the cover slightly off so that the heating will drive off any water that remains in the crucible. (See Figure 4D-1.) Heat with the burner for two to three minutes to make sure that the crucible is dry.
3. From this point on, you should not touch the crucible with your hands. Use only the crucible tongs. Allow the crucible to cool for about three minutes, then find the mass of the empty crucible and the cover. Record the mass in your copy of Table 1.
4. Place enough of the hydrate that you are assigned into the crucible so that it is one-fourth to one-third full. Find and record the mass of the crucible, cover, and hydrate.

5. Place the crucible, with the cover slightly off, on the pipestem triangle and begin heating. Gradually increase the heat until the bottom of the crucible is a dull red. Maintain this temperature for five minutes.
6. Turn off the burner and bring the crucible, with the cover, to a desiccator for cooling. Allow the crucible to cool for about five minutes, then find and record the mass of the crucible, cover, and contents.
7. Reheat the crucible for another five minutes to make sure that all of the water is driven off. Again, cool it in the desiccator, then find and record the mass. If the masses that you determine in Steps 6 and 7 do not agree within 0.03 g, check with your instructor to see if you need to continue the heating/mass-determination process.
8. Once your masses agree and the crucible is cool, add a few drops of distilled water to the crucible. Note any changes in the substance in Table 1.
9. If enough time remains, repeat the experiment with another hydrate.

REAGENT DISPOSAL

Place all solids in the designated waste containers.

POST LAB DISCUSSION

Your instructor will give you the mass of one mole of the anhydrous salt. This should help you in determining the empirical formula of the hydrate. In order to find the mass of water in your sample of hydrate, you will simply subtract the mass of the anhydrous compound from the mass of the hydrate. Using this value, you can then find the mass of water that would be present in one mole of the hydrate. Once you know the mass of water present in one mole of the hydrate, you can calculate the number of moles of water in one mole of anhydrous salt by dividing by the molar mass of water.

Adding water at the end of the experiment rehydrates the compound. In some compounds, there is a noticeable change in texture or color when the water is added. The hydrate should appear as it did before you heated it.

DATA AND OBSERVATIONS

Table 1

	TRIAL ONE	TRIAL TWO
Mass of empty crucible and cover		
Mass of crucible, cover and hydrate		
Mass after first heating		
Mass after second heating		
Mass of one mole of the anhydrous salt (from your teacher)		

COMPLETE IN YOUR NOTEBOOK

For both trials, describe any changes that you observed when adding water to the crucible.

QUESTIONS AND CALCULATIONS

1. For both trials, calculate the number of moles of the anhydrous salt that you prepared. (Your teacher will give you the molar mass of the anhydrous salt.)
2. For both trials, calculate the number of moles of water removed by heat from your sample of hydrate.
3. For both trials, calculate the moles of water per mole of the anhydrous salt.
4. For both trials, calculate the percent of water in the hydrate.
5. What is the empirical formula of the hydrate in each trial?

FOLLOW-UP QUESTIONS

1. Can you suggest reasons why the procedure used in this experiment might not be appropriate for all hydrates?
2. A substance was found to have the following percentages:

   Zinc 23%
   Sulfur 11%
   Oxygen 22%
   Water 44%
   What is the empirical formula of this compound?
3. If a sample of 2.56 g of this substance were heated in a crucible as in this experiment, calculate the mass of anhydrous compound that would remain in the crucible.

CONCLUSION

State the results of Objective 3.