EXPLORATION 5A

Technique Builder

Percent Composition of Hydrates

Objectives

Demonstrate **proficiency in using the balance and the Bunsen burner.**

Measure **the mass of a substance before and after its water of crystallization has been removed.**

Relate **results to the law of conservation of mass and the law of multiple proportions.**

Perform **calculations using the molar mass.**

Determine **the empirical formula and percentage by mass of water in the hydrate.**

Situation

You are a research chemist working for a company that is developing a new chemical moisture absorber and indicator. The company plans to seal the moisture absorber into a transparent porous pouch attached to a cellophane window on the inside of packages for compact disc players. This way, moisture within the packages will be absorbed, and any package that has too much moisture can be quickly detected and dried out. Your company's efforts have focused on copper(II) sulfate, $CuSO_4$, which can absorb water to become a hydrate that shows a distinctive color change.

Background

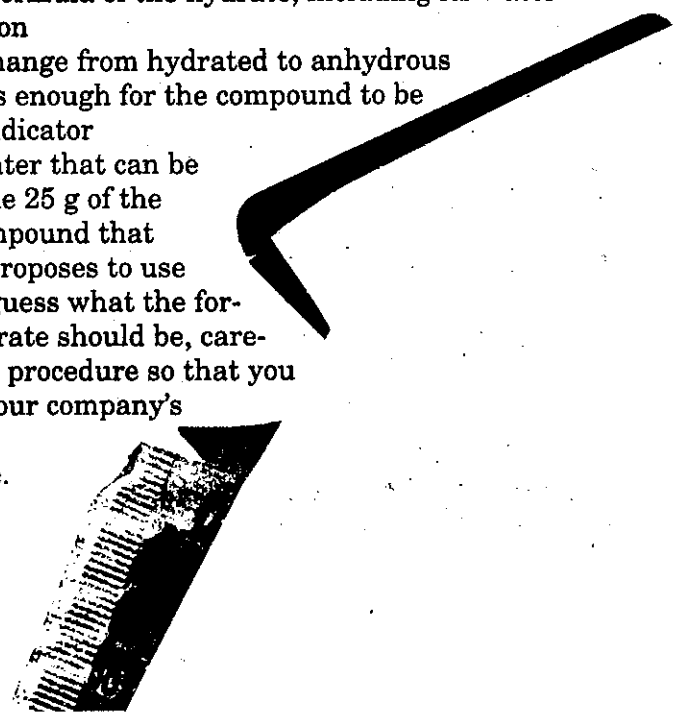
As discussed in Chapter 5, when many ionic compounds are crystallized from a water solution, they include individual water molecules as part of their crystalline structure. If the substances are heated, this water of crystallization may be driven off, leaving behind the pure anhydrous form of the compound. Because the law of multiple proportions also applies to crystalline hydrates, the number of moles of water driven off per mole of the anhydrous compound should be a simple whole number ratio. You can use this information to help you determine the formula of the hydrate.

Problem

To help your company decide whether $CuSO_4$ is the right substance for the moisture absorber and indicator, you will need to examine the hydrated and anhydrous forms of the compound and determine the following.

- the empirical formula of the hydrate, including its water of crystallization
- whether the change from hydrated to anhydrous form is obvious enough for the compound to be useful as an indicator
- the mass of water that can be absorbed by the 25 g of the anhydrous compound that the company proposes to use

Even if you can guess what the formula for the hydrate should be, carefully perform the procedure so that you know how well your company's supply of $CuSO_4$ absorbs moisture.



Safety

Always wear goggles and an apron to provide protection for your eyes and clothing. If you get a chemical in your eyes, immediately flush it out at the eyewash station while calling to your teacher. Know the locations of the emergency lab shower and eyewash and how to use them.

Do not touch any chemicals. If you get a chemical on your skin or clothing, wash it off at the sink while calling to your teacher. Make sure you carefully read the labels and follow the directions on all containers of chemicals that you use. Do not taste any chemicals or items used in the laboratory. Never return leftovers to their original containers; take only small amounts to avoid wasting supplies.

Open flames are dangerous, and you should tie back loose clothing and hair for safety reasons. Use proper methods to hold equipment being heated. The crucible and cover are very hot after each heating. Remember to handle the crucible and cover only with tongs designed to hold a crucible.

Never put broken glass or ceramics in a regular waste container. Broken glass or ceramics should be disposed of separately.

Always clean up the lab and all equipment after use, and dispose of substances according to proper disposal methods. Wash your hands thoroughly before you leave the lab after all lab work is finished.

Materials

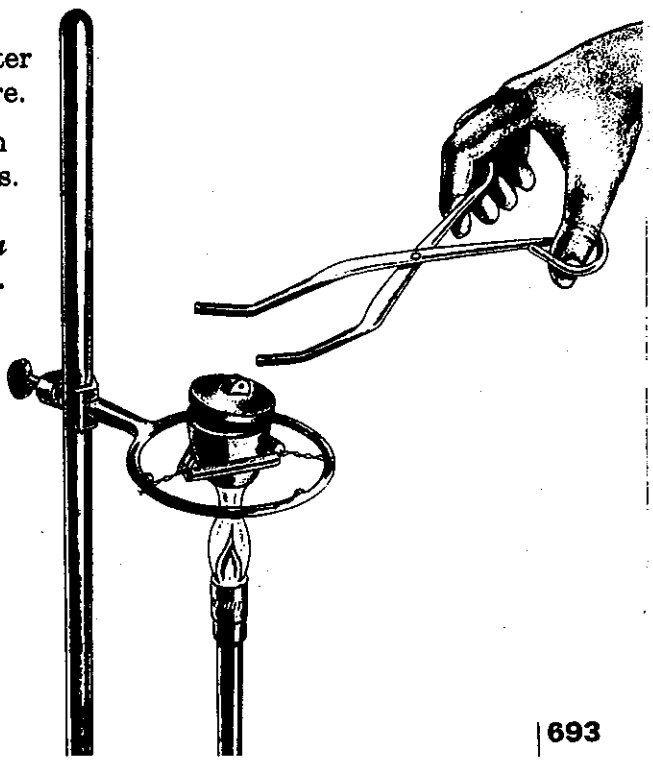
- **$CuSO_4$, hydrated crystals**
- **Distilled water**
- **Balance**
- **Bunsen burner**
- **Crucible and cover**
- **Crucible tongs**
- **Desiccator**
- **Dropper or micropipet**
- **Glass stirring rod**
- **Ring and pipe-stem triangle**
- **Ring stand**
- **Spatula**
- **Weighing paper**

Preparation

1. ***Organizing Data***
   Prepare a data table in your lab notebook with spaces for the mass of the empty crucible with cover and for the initial mass of the sample, crucible, and cover; and several spaces for the mass of the sample, crucible, and cover after heating. Leave room for observations about the procedure.
2. Make sure that your equipment and tongs are very clean for this work so that you will get the best possible results. Remember that you will need to cool the heated crucible in the desiccator before measuring its mass. ***Never put a hot crucible on a balance; it will damage the balance.***

Technique

3. To prepare the crucible and cover, place the crucible and cover on the triangle with the lid slightly tipped. The small opening will allow gases to escape. Heat the crucible and cover until the crucible glows slightly red. Using the tongs, transfer the crucible and cover to the desiccator, and allow them to cool for 5 min. Determine the mass of the crucible and cover to the nearest 0.01 g, and record it in your data table.



4. Using a spatula, add approximately 5 g of copper sulfate hydrate crystals to the crucible. Break the crystal up before placing it in the crucible. Put on the crucible's cover, determine the mass of the covered crucible and crystals to the nearest 0.01 g, and record it in your data table.

5. Place the crucible with the copper sulfate hydrate on the triangle, and again position the cover so there is only a small opening. If the opening is too large, the crystals may spatter as they are heated. Heat the crucible very gently on a low flame to avoid spattering. Increase the temperature gradually for 2 or 3 min, and then heat until the crucible glows red for at least 5 min. Be very careful not to raise the temperature of the crucible and its contents too suddenly. You will observe a color change, which is normal, but if the substance remains yellow after cooling, it was overheated and has begun to decompose. Allow the crucible, cover, and contents to cool for 5 min in the desiccator, and then measure its mass. Enter the mass in your data table.

6. Heat the covered crucible and contents to redness again for 5 min. Allow the crucible, cover, and contents to cool in the desiccator, and then determine their mass, recording it in the data table. If the two mass measurements differ by no more than 0.01 g, you may assume that all of the water has been driven off. Otherwise, repeat the process until the mass no longer changes, indicating that all of the water has evaporated. Record this constant mass in your data table.

7. After recording the constant mass, set a part of your sample aside on a piece of weighing paper. Using the dropper or pipet, put a few drops of water onto this part to rehydrate the crystals. Record your observations in your data table.

Cleanup and Disposal

8. Clean all apparatus and your lab station. Make sure to completely shut off the gas valve before leaving the laboratory. Remember to wash your hands. Place the rehydrated and anhydrous chemicals in the disposal containers designated by your teacher.

Analysis and Interpretation

1. ***Analyzing Methods***
   Why do you need to heat the clean crucible before using it in this lab? Why do the tongs used throughout this lab need to be especially clean?

2. ***Organizing Data***
   Why do you need to use a cover for the crucible? Could you leave the cover off each time you measure the mass of the crucible and its contents and still get accurate results? Explain your answer.

3. ***Analyzing Information***
   Calculate the mass of anhydrous copper sulfate (the residue that remains after heating to constant mass) by subtracting the mass of the empty crucible and cover from the mass of the crucible, cover, and heated $CuSO_4$. Use the molar mass for $CuSO_4$, determined from the periodic table, to calculate the number of moles present.

4. ***Resolving Discrepancies***
Explain why the mass of the sample got smaller after it was heated, despite the law of conservation of mass.

5. ***Analyzing Information***
Calculate the mass and moles of water originally present in the hydrate using the molar mass determined from the periodic table.

Conclusions

6. ***Analyzing Information***
Using your answers from items **3** and **5**, determine the empirical formula for the copper sulfate hydrate.

7. ***Organizing Data***
What is the percentage by mass of water in the original hydrated compound?

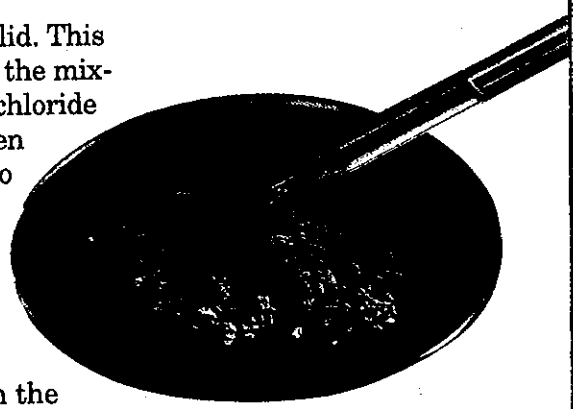
8. ***Organizing Conclusions***
How much water could 25 g of anhydrous $CuSO_4$ absorb?

9. ***Evaluating Conclusions***
When you rehydrated the small amount of anhydrous copper sulfate, what were your observations? Explain whether this substance would make a good indicator of moisture.

Extensions

1. ***Evaluating Methods***
What possible sources of error can you identify in your procedure? If you can think of ways to eliminate them, ask your teacher to approve your suggestions, and run the procedure again.

2. ***Applying Conclusions***
Some cracker tins include a glass vial of drying material in the lid. This is often a mixture of magnesium sulfate and cobalt chloride. As the mixture absorbs moisture to form hydrated compounds, the cobalt chloride changes from blue-violet $CoCl_2 \cdot 2H_2O$ to pink $CoCl_2 \cdot 6H_2O$. When this hydrated mixture becomes totally pink, it can be restored to the dihydrate form by heating it in the oven. Write equations for the reactions that occur when this mixture is heated.



3. ***Applying Ideas***
Three pairs of students obtained the following results when they heated a solid. In each case, the students observed that when they began to heat the solid, drops of a liquid formed on the sides of the test tube.

Sample number	Mass before heating (g)	Constant mass after heating (g)
1	1.92	1.26
2	2.14	1.40
3	2.68	1.78

a. Could the solid be a hydrate? Explain how you could find out.

b. If the solid has a molar mass of 208 g/mol after heating and a formula of XY, how many formula units of water are there in one formula unit of the unheated compound?