Percent Composition of Hydrates

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.

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 and leave 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.

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,
- if the compound is useful as an indicator when it changes from the hydrated to the anhydrous form, and
- the mass of water absorbed by the 25 g of anhydrous compound, which the company proposes to use.

Even if you can guess what the formula for the hydrate should be, carefully perform this lab so that you know how well your company’s supply of CuSO$_4$ absorbs moisture.

**OBJECTIVES**

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

**Determine** that all the water has been driven from a hydrate by heating your sample to a constant mass.

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

**Perform** calculations by using the molar mass.

**Analyze** the results and determine the empirical formula of the hydrate and its percentage by mass of water.
Percent Composition of Hydrates continued

MATERIALS

- balance
- Bunsen burner
- crucible and cover
- crucible tongs
- CuSO$_4$, hydrated crystals
- distilled water
- dropper or micropipet
- ring and pipe-stem triangle
- ring stand
- spatula
- stirring rod, glass
- weighing paper

Always wear safety goggles and a lab apron to protect your eyes and clothing. If you get a chemical in your eyes, immediately flush the chemical out at the eyewash station while calling to your teacher. Know the location of the emergency lab shower and eyewash station and the procedures for using them.

Do not touch any chemicals. If you get a chemical on your skin or clothing, wash the chemical off at the sink while calling to your teacher. Make sure you carefully read the labels and follow the precautions on all containers of chemicals that you use. If there are no precautions stated on the label, ask your teacher what precautions to follow. Do not taste any chemicals or items used in the laboratory. Never return leftovers to their original container; take only small amounts to avoid wasting supplies.

Call your teacher in the event of a spill. Spills should be cleaned up promptly, according to your teacher’s directions.

Acids and bases are corrosive. If an acid or base spills onto your skin or clothing, wash the area immediately with running water. Call your teacher in the event of an acid spill. Acid or base spills should be cleaned up promptly.

Do not heat glassware that is broken, chipped, or cracked. Use tongs or a hot mitt to handle heated glassware and other equipment because hot glassware does not always look hot.

When using a Bunsen burner, confine long hair and loose clothing. If your clothing catches on fire, WALK to the emergency lab shower and use it to put out the fire.

When heating a substance in a test tube, the mouth of the test tube should point away from where you and others are standing. Watch the test tube at all times to prevent the contents from boiling over.

Never put broken glass in a regular waste container. Broken glass should be disposed of separately according to your teacher’s instructions.
Percent Composition of Hydrates continued

Procedure
1. Put on safety goggles and lab apron.
2. Make sure that your equipment is very clean so that you will get the best possible results. Once you have heated the crucible and cover, do not touch them with your bare hands. Remember that you will need to cool the crucible before massing. (The crucible can be cooled on the lab table.) Never put a hot crucible on a balance; it will damage the balance.
3. 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. Use the tongs to transfer the crucible and cover to the lab table, and allow them to cool for 5 min. Determine the mass of the crucible and cover to the nearest 0.01 g, and record the mass in your data table.
4. Using a spatula, add approximately 5 g of copper (II)sulfate hydrate crystals to the crucible. You can obtain your crystals while your crucible is cooling. Check with your instructor to see if you should use different amount of copper (II) sulfate. Break up any large crystals before placing them in the crucible. Determine the mass of the covered crucible and crystals to the nearest 0.01 g, and record the mass 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. Remove the crucible from the flame and allow it and its contents (make sure the crucible is covered) to cool for 5 min and then measure the mass. Record the mass in your data table.
6. Heat the crucible and contents with the cover positioned as in step 5 and contents to redness again for 5 min. Allow the crucible, cover, and contents to cool, and then determine their mass and record it in the data table. If the two mass measurements differ by no more than 0.02 g, you may assume that all of the water has been driven off. Otherwise, repeat the process until the mass no longer changes, which indicates that all of the water has evaporated. Record this constant mass in your data table.
7. After recording the constant mass, remove the cover from your crucible and add a few drops of water with a beral pipet. Record your observations for this step.
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 thoroughly. Place the rehydrated and anhydrous chemicals in the disposal containers designated by your teacher.

**TABLE 1 HYDRATE DATA**

<table>
<thead>
<tr>
<th>Mass of empty crucible and cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial mass of sample, crucible, and cover</td>
</tr>
<tr>
<td>Mass of sample, crucible, and cover after first heating</td>
</tr>
<tr>
<td>Mass of sample, crucible, and cover after second heating</td>
</tr>
<tr>
<td>Constant mass of sample, crucible, and cover</td>
</tr>
</tbody>
</table>

Be sure to record observations, specifying the step in the lab that was performed.

**Analysis**

1. **Explaining events** 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. **Explaining events** 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. **Examining data** 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 CuSO₄. Use the molar mass for CuSO₄, determined from the periodic table, to calculate the number of moles present.

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

**Conclusions**

5. **Interpreting information** Explain why the mass of the sample decreased after it was heated, despite the law of conservation of mass.

6. **Drawing conclusions** Using your answers from items 3 and 4, determine the empirical formula for the copper sulfate hydrate.

7. **Analyzing results** Calculate the percent water in your sample.

8. **Applying conclusions** Calculate the percent water in a mole of copper(II)sulfate pentahydrate using the formula.

9. **Applying conclusions** Calculate the percent error using your answer to number 7 as experimental and to number 8 as accepted.
10. **Drawing conclusions** Three pairs of students obtained the results in the table below 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.

**TABLE 2 STUDENT DATA TABLE**

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Mass before heating (g)</th>
<th>Constant mass after heating (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.92</td>
<td>1.26</td>
</tr>
<tr>
<td>2</td>
<td>2.14</td>
<td>1.40</td>
</tr>
<tr>
<td>3</td>
<td>2.68</td>
<td>1.78</td>
</tr>
</tbody>
</table>

a. This solid is a hydrate. Demonstrate this by calculating the percent water in each sample.

b. If the solid has a molar mass of 208 g/mol after being heated, how many formula units of water are there in one formula unit of the unheated compound?
Prelab Questions. Answer these questions on this paper to be handed in before performing the lab. 27 pts

1. What is a hydrate? 1 pt

2. Why must the crucible be cooled before finding its mass? (Actually there are two reasons.) 2 pts

3. Why must the mass of the anhydrous salt be measured immediately upon cooling? 1 pt

4. Why is it necessary to handle the crucible only with clean tongs after heating? 1 pt

5. Below you will find experimental data for a magnesium sulfate salt. Use the data to answer the questions. Show all work!

| Mass of empty crucible and cover          | 44.36 g |
| Mass of crucible, cover and hydrate       | 46.79 g |
| Mass of crucible, cover and anhydrate     | 45.56 g |
| Mass of crucible, cover and anhydride after step 5 | 45.56 g |
| Mass of crucible, cover, and anhydride after 2\textsuperscript{nd} or 3\textsuperscript{rd} heating (after step 6) | 45.56 g |

a. Calculate the mass of anhydrous magnesium sulfate. 2 pts

b. Calculate the moles of anhydrous magnesium sulfate using the molar mass of magnesium sulfate. 2 pt

c. Calculate the mass of water driven off from the hydrate. 2 pt

d. Calculate the number of moles of water driven off from the hydrate using the molar mass of water. 2 pt
The equation for the reaction that occurred in order to obtain the data above is:

\[ \text{MgSO}_4 \cdot n \text{H}_2\text{O} (s) \rightarrow \text{MgSO}_4 (s) + n \text{H}_2\text{O} \ (g) \]

e. Using your answers to calculations b and d and the above chemical equation, determine the mole ration of \text{MgSO}_4 to \text{H}_2\text{O} to the nearest whole number. Express your answer as ____ moles of water to ____ moles of \text{MgSO}_4. \text{ \textit{Hint: You want 1 mole of MgSO}_4 in this expression.} 5pt

f. Use your answer to e to write the correct formula for the magnesium sulfate hydrate. 1 pt

g. Calculate the percent water in this hydrate. \textit{In order to do this you need to determine the mass of water driven off and the mass of the hydrate from the data table.} 5 pts

h. Calculate the percent error if the percent water in this hydrate is actually 51.1\%. 3 pt
Percent Composition of Hydrates

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, CuSO₄, which can absorb water to become a hydrate that shows a distinctive color change.

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 and leave 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.

To help your company decide whether CuSO₄ 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,
- if the compound is useful as an indicator when it changes from the hydrated to the anhydrous form, and
- the mass of water absorbed by the 25 g of anhydrous compound, which the company proposes to use.

Even if you can guess what the formula for the hydrate should be, carefully perform this lab so that you know how well your company’s supply of CuSO₄ absorbs moisture.

OBJECTIVES

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

**Determine** that all the water has been driven from a hydrate by heating your sample to a constant mass.

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

**Perform** calculations by using the molar mass.

**Analyze** the results and determine the empirical formula of the hydrate and its percentage by mass of water.
Percent Composition of Hydrates continued

**MATERIALS**

- balance
- Bunsen burner
- crucible and cover
- crucible tongs
- CuSO₄, hydrated crystals
- desiccator
- distilled water
- dropper or micropipet
- ring and pipe-stem triangle
- ring stand
- spatula
- stirring rod, glass
- weighing paper

⚠️ **Always wear safety goggles and a lab apron to protect your eyes and clothing.** If you get a chemical in your eyes, immediately flush the chemical out at the eyewash station while calling to your teacher. Know the location of the emergency lab shower and eyewash station and the procedures for using them.

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⚠️ **Call your teacher in the event of a spill.** Spills should be cleaned up promptly, according to your teacher’s directions.

**Acids and bases are corrosive.** If an acid or base spills onto your skin or clothing, wash the area immediately with running water. Call your teacher in the event of an acid spill. Acid or base spills should be cleaned up promptly.

⚠️ **Do not heat glassware that is broken, chipped, or cracked.** Use tongs or a hot mitt to handle heated glassware and other equipment because hot glassware does not always look hot.

**When using a Bunsen burner, confine long hair and loose clothing.** If your clothing catches on fire, WALK to the emergency lab shower and use it to put out the fire.
When heating a substance in a test tube, the mouth of the test tube should point away from where you and others are standing. Watch the test tube at all times to prevent the contents from boiling over.

Never put broken glass in a regular waste container. Broken glass should be disposed of separately according to your teacher’s instructions.
Percent Composition of Hydrates \textit{continued}

\textbf{Procedure}

1. Put on safety goggles and lab apron.

2. Make sure that your equipment is very clean so that you will get the best possible results. Once you have heated the crucible and cover, do not touch them with your bare hands. Remember that you will need to cool the heated crucible in the desiccator before you measure its mass. Never put a hot crucible on a balance; it will damage the balance.

3. 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. Use the tongs to 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 the mass in your data table.

4. Using a spatula, add approximately 5 g of copper sulfate hydrate crystals to the crucible. Break up any large crystals before placing them in the crucible. Determine the mass of the covered crucible and crystals to the nearest 0.01 g, and record the mass 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 their mass. Record 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 and record 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, which indicates that all of the water has evaporated. Record this constant mass in your data table.

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

\textbf{Observation: }_____

\vfill

\hspace{144pt}TEACHER RESOURCE PAGE

\hspace{144pt}Name _______________________ Class _________________ Date __________

\hspace{144pt}Name_________________________  Roster____________

\hspace{144pt}Percent Composition of Hydrates \textit{continued}

\hspace{144pt}Revised 11/13/2012
Percent Composition of Hydrates continued

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 thoroughly. Place the rehydrated and anhydrous chemicals in the disposal containers designated by your teacher.

### TABLE 1 HYDRATE DATA 5 pts

<table>
<thead>
<tr>
<th>Description</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of empty crucible and cover</td>
<td>32.18 g</td>
</tr>
<tr>
<td>Initial mass of sample, crucible, and cover</td>
<td>37.18 g</td>
</tr>
<tr>
<td>Mass of sample, crucible, and cover after first heating</td>
<td>36.08 g</td>
</tr>
<tr>
<td>Mass of sample, crucible, and cover after second heating</td>
<td>35.43 g</td>
</tr>
<tr>
<td>Constant mass of sample, crucible, and cover</td>
<td>35.42 g</td>
</tr>
</tbody>
</table>

**Observations**

Before heating, crystals were shiny blue.
During heating, steam escaped from cover.
After heating, the crystals turned dull gray.

After adding water to the anhydrate, the crystals

**Analysis**

1. **Explaining events** 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 pts

   The crucible was heated to be certain it was completely dry. The tongs had to be clean so that they did not transfer any dirt or debris to the crucible. The presence of any water, dirt, or debris causes error in the mass measurements.

2. **Explaining events** 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. 2 pts

   The cover was used to keep debris out of the crystals. It also helped prevent water from condensing on the crystals as they cooled. Without the cover, each mass measurement would have been slightly larger because the crystals would have absorbed water.
3. **Examining data** 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 CuSO₄. Use the molar mass for CuSO₄, determined from the periodic table, to calculate the number of moles present.  

\[
35.42 \text{ g} - 32.18 \text{ g} = 3.24 \text{ g CuSO}_4 \\
3.24 \text{ g/(159.62 g/mol)} = 2.03 \times 10^{-2} \text{ mol CuSO}_4
\]

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

\[
37.18 \text{ g} - 35.42 \text{ g} = 1.76 \text{ g H}_2\text{O} \\
1.76 \text{ g/(18.02 g/mol)} = 0.0977 \text{ mol H}_2\text{O}
\]

**Conclusions**

5. **Interpreting information** Explain why the mass of the sample decreased after it was heated, despite the law of conservation of mass.  

As the sample was heated, water evaporated from the crystal to become water vapor. The mass of the water vapor and the crystals was the same as the mass of the hydrated crystals, so the law of conservation of mass was not violated.

6. **Drawing conclusions** Using your answers from items 3 and 4, determine the empirical formula for the copper sulfate hydrate.  

**empirical formula: CuSO₄·5H₂O**

\[
0.0977 \text{ mol H}_2\text{O}/2.03 \times 10^{-2} \text{ mol CuSO}_4 = 4.81 \text{ mol H}_2\text{O}/1.00 \text{ mol CuSO}_4 \\
1.00 : 4.81 \text{ is close to } 1:5
\]

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

\[
1.76 \text{ g/5.00 g} \times 100\% \approx 35.2\%
\]

8. **Applying conclusions** How much water could 25 g of anhydrous CuSO₄ absorb?  

\[
25.0 \text{ g CuSO}_4 \times 1.76 \text{ g H}_2\text{O}/3.24 \text{ g CuSO}_4 = 13.6 \text{ g H}_2\text{O}
\]
9. Applying 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. 2 pts

Anhydrous copper sulfate is a white powder. When water is added, copper sulfate turns blue. This dramatic color change makes it a good indicator of moisture.

10. 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 $\text{CoCl}_2 \cdot 2\text{H}_2\text{O}$ to pink $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$. When this hydrated mixture becomes totally pink, it can be restored to the dihydrate form by being heated in the oven. Write equations for the reactions that occur when this mixture is heated. 1 pt

$\text{CoCl}_2 \cdot 6\text{H}_2\text{O} \rightarrow \text{CoCl}_2 \cdot 2\text{H}_2\text{O} + 4\text{H}_2\text{O}$

11. Drawing conclusions Three pairs of students obtained the results in the table below 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.

<table>
<thead>
<tr>
<th>TABLE 2 STUDENT DATA TABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample number</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

a. Could the solid be a hydrate? Explain how you could find out. 2 pt

The solid could be a hydrate, because it has less mass after heating. If the ratio of the amount of the water apparently lost to the amount of the apparently anhydrous compound is a small, whole-number ratio that remains constant with different samples, the solid is a hydrate.
b. If the solid has a molar mass of 208 g/mol after being heated, how many formula units of water are there in one formula unit of the unheated compound? 8 pt

Sample 1: $1.26 \text{ g XY} \times \frac{1 \text{ mol}}{208 \text{ g}} = 6.06 \times 10^{-3} \text{ mol XY}$

$0.66 \text{ g H}_2\text{O} \times \frac{1 \text{ mol}}{18.02 \text{ g H}_2\text{O}} = 3.7 \times 10^{-2} \text{ mol H}_2\text{O}$

$3.7 \times 10^{-2} \text{ mol H}_2\text{O}/6.06 \times 10^{-3} \text{ mol XY} = 6.1 \text{ mol H}_2\text{O}/1.0 \text{ mol XY}$

Sample 2: $4.1 \times 10^{-2} \text{ mol H}_2\text{O}/6.73 \times 10^{-3} \text{ mol XY} = 6.1 \text{ mol H}_2\text{O}/1.0 \text{ mol XY}$

Sample 3: $5.0 \times 10^{-2} \text{ mol H}_2\text{O}/8.56 \times 10^{-3} \text{ mol XY} = 5.8 \text{ mol H}_2\text{O}/1.0 \text{ mol X}$
Prelab Questions. Answer these questions on this paper to be handed in before performing the lab. These questions will be due ________________ (FILL IN THE DATE/TIME). 27 pts

1. What is a hydrate? 1 pt

A hydrate is a solid compound with water bound to its crystal structure.

2. Why must the crucible be cooled before finding its mass? (Actually there are two reasons.) 2 pts

1. The hot crucible can damage the balance. 2. The hot air currents rise, causing the crucible to weight light.

3. Why must the mass of the anhydrous salt be measured immediately upon cooling? 1 pt

It may pick up water from the air.

4. Why is it necessary to handle the crucible only with clean tongs after heating? 1 pt

Your hands can transfer oils to crucible. Dirty tongs can cause add mass to the crucible.

5. Below you will find experimental data for a magnesium sulfate salt. Use the data to answer the questions. Show all work!

<table>
<thead>
<tr>
<th>Description</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of empty crucible and cover</td>
<td>44.36 g</td>
</tr>
<tr>
<td>Mass of crucible, cover and hydrate</td>
<td>46.79 g</td>
</tr>
<tr>
<td>Mass of crucible, cover and anhydrate (after step 5)</td>
<td>45.56 g</td>
</tr>
<tr>
<td>Mass of crucible, cover, and anhydrate after 2\textsuperscript{nd} or 3\textsuperscript{rd} heating (after step 6)</td>
<td>45.56 g</td>
</tr>
</tbody>
</table>

a. Calculate the mass of anhydrous magnesium sulfate. 2 pts

45.56 g – 44.36 g = 1.20 g

b. Calculate the moles of anhydrous magnesium sulfate using the molar mass of magnesium sulfate. 2 pt

120 g MgSO\textsubscript{4} (1 mol/120.4 g) = 9.97 x 10\textsuperscript{-3} mol

c. Calculate the mass of water driven off from the hydrate. 2 pt

46.79 g – 45.56 g = 1.23 g

d. Calculate the number of moles of water driven off from the hydrate using the molar mass of water. 2 pt

1.23 g (1 mol/18.02 g) = 6.83 x 10\textsuperscript{-2}
The equation for the reaction that occurred in order to obtain the data above is:

$$\text{MgSO}_4 \cdot n \text{H}_2\text{O} (s) \rightarrow \text{MgSO}_4 (s) + n \text{H}_2\text{O} (g)$$

e. Using your answers to calculations b and d and the above chemical equation, determine the mole ration of MgSO$_4$ to H$_2$O to the nearest whole number. Express your answer as ___ moles of water to ___ moles of MgSO$_4$. *Hint: You want 1 mole of MgSO$_4$ in this expression.*

5pt

$$9.97 \times 10^{-3} \text{ mol MgSO}_4 / 9.97 \times 10^{-3} = 1$$

$$6.83 \times 10^{-2} \text{ mol H}_2\text{O} / 9.97 \times 10^{-3} = 6.9$$

f. Use your answer to e to write the correct formula for the magnesium sulfate hydrate. 1 pt

$$\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$$

g. Calculate the percent water in this hydrate. *In order to do this you need to determine the mass of water driven off and the mass of the hydrate from the data table.* 5 pts

Hydrate mass = 46.79 g - 44.36 g = 2.43 g hydrate

$$1.23 \text{ g}/2.43 \text{ g} \times 100\% = 50.6\% \text{ water}$$

h. Calculate the percent error if the percent water in this hydrate is actually 51.1%. 3 pt

$$\frac{(50.6 - 51.1)}{51.1} \times 100\% = -1\%$$