WATER OF HYDRATION
EXPERIMENT 7

OBJECTIVE

The objective of this experiment is to determine the percentage of water in a hydrated salt of both known and unknown formulas. The experimental results will be compared with calculated theoretical values.

EQUIPMENT AND CHEMICALS

Magnesium sulfate heptahydrate ($MgSO_4 \bullet 7\ H_2O$)
Copper (II) sulfate ($CuSO_4 \bullet 5\ H_2O$)
Crucible (25 ml)
Ring stand with clay triangle
Bunsen burner
Evaporating dish
Tripling beam balance
Unknown hydrates

DISCUSSION

Hydrates are crystalline salts that are bonded to water molecules in definite proportions. The weakly bound water is known as either the water of hydration or water of crystallization. The fixed numbers of water molecules that are weakly bonded to the salt are represented as follows:

salt • number of waters

magnesium sulfate heptahydrate

($MgSO_4 \bullet 7\ H_2O$)

The dot represents the weak salt • water bond in the chemical formula. The bond is so weak that simply heating the hydrated salt to liberate the water molecules as vapour can normally break it. If water is added to the now anhydrous salt, the reverse will take place with the waters reattaching themselves to the salt. This is known as a reversible action.

$$\underset{\text{(hydrate)}}{MgSO_4 \bullet 7\ H_2O} \longleftrightarrow \underset{\text{(anhydrate)}}{MgSO_4} + \underset{\text{(water)}}{7\ H_2O}$$

There are three closely related substances that act similar to hydrates but have distinct individual characteristics. These are hydroscopic, deliquescent, and efflorescent substances.

Hydroscopic substances -	readily absorb moisture from the air and are used as drying agents (desiccants).
Deliquescent substances -	continue to absorb water from the air until they form a solution.
Efflorescent substances -	are hydrates that lose water when simply exposed to the atmosphere.

As previously mentioned, each hydrated salt has water molecules bonded to them in definite proportions. The percent water in the hydrated salt can be calculated, theoretically, using the chemical formula of the hydrate.

$$\% \ H_2O = \frac{\text{(number of } H_2O \text{ molecules) (molecular mass of } H_2O)}{\text{molecular mass of hydrate}} \times 100$$

Example 1: Calcium chloride hexahydrate has the chemical formula $CaCl_2 \bullet 6\ H_2O$. What is the theoretical percentage of water?

The formula weight of $CaCl_2 \bullet 6\ H_2O$ is:

Ca: 1 x 40.1 = 40.1 amu
Cl: 2 x 35.5 = 71.0 amu
H: 12 x 1.0 = 12.0 amu
O: 6 x 16.0 = 96.0 amu

Formula weight of $CaCl_2 \bullet 6\ H_2O$ = 219.1 amu

Formula weight of H_2O = 18 amu

$$\% \ H_2O = \frac{\text{(6 waters) (18 amu)}}{\text{219.9 amu}} \times 100 = 49.3\%$$

For an unknown hydrate, the number of waters of hydration can be calculated given the % water and the molecular weight of the hydrated salt.

Example 2: The % water of hydration is 49.3% and the molecular weight of $CaCl_2$ is 111.1 amu. Determine the formula.

If 49.3% of the weight is water, this means that the remaining 50.1% (100% - 49.3%) is the weight of the $CaCl_2$. Therefore, if we base the calculations on 100 grams, the $CaCl_2$ would weigh 50.7 grams.

A. Calculate the moles of water and $CaCl_2$. in 100 grams.

$$\text{moles } H_2O = 49.3 \text{ grams } H_2O \times \frac{1 \text{ mole } H_2O}{18 \text{ grams } H_2O} = 2.74 \text{ moles}$$

$$\text{moles } CaCl_2 = 50.7 \text{ grams } CaCl_2 \times \frac{1 \text{ mole } CaCl_2}{111.1 \text{ grams } CaCl_2} = 0.46 \text{ moles}$$

B. Convert the moles of H_2O and $CaCl_2$ to whole numbers by dividing the smallest number of moles (0.46 moles $CaCl_2$) into each component.

$$\text{For } H_2O: \quad \frac{2.70 \text{ moles}}{0.46 \text{ moles}} = 5.87 \text{ (approx 6)}$$

$$\text{For } CaCl_2: \quad \frac{0.46 \text{ moles}}{0.46 \text{ moles}} = 1.00$$

C. The formula can be written where there is one molecule of $CaCl_2$ for every six molecules of water.

$CaCl_2 \bullet 6\ H_2O$ (answer)

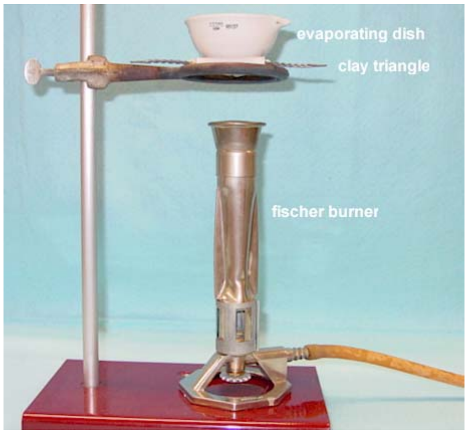
PROCEDURES

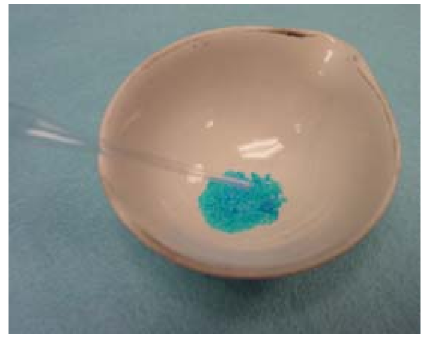
PART A - REVERSIBILITY OF HYDRATION

The waters of hydration can be removed or added by simply heating a hydrated salt or wetting an anhydrous salt. This is called a reversible reaction.

1. Place approximately one gram of hydrated $CuSO_4 \bullet 5\ H_2O$ in an evaporating dish. Observe the colour and record your observations.

2. Set the evaporating dish on a ring stand and gently heat the $CuSO_4 \bullet 5\ H_2O$. Observe any colour change and record your observations.

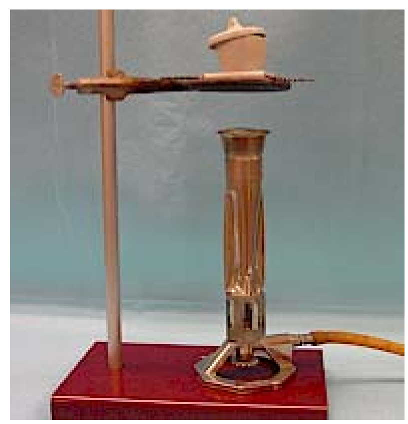




3. Add a few drops of water to the evaporating dish. Observe the colour and record your observations.

PART B - PERCENTAGE OF WATER IN MAGNESIUM SULFATE HEPTAHYDRATE)

The percentage of water can be determined in a hydrated salt by heating it to remove the water and determining the weight loss. All weights must be +/-0.1 grams.



1. Weigh a clean dried 25 ml crucible and lid. Record this weight.

2. Add approximately 3-4 grams of $MgSO_4 \bullet 7\ H_2O$ to the crucible. Record the weight of the crucible and the hydrate.

3. Heat the crucible to a dull red glow for approximately 15 minutes. Make sure that the crucible lid is slightly offset to allow the escape of water vapour.

4. Allow the crucible to cool near room temperature. This is the temperature at which you can comfortably pick up the crucible without burning yourself.

5. Weigh the crucible, crucible lid and anhydrous $MgSO_4$. Record the weight on the Report Sheet.

6. Calculate the % water in $MgSO_4 \bullet 7\ H_2O$ from your experimental results.

7. Calculate the theoretical % H_2O.

Calculations $$\%\ H_2O = \frac{\text{mass of water given off}}{\text{mass of hydrate}} \times 100$$

PART C - PERCENTAGE OF WATER IN AN UNKNOWN HYDRATE

The percentage of water in an unknown hydrated salt is determined as in Part B and the number of waters of hydration can then be calculated using the formula weight of the anhydrous salt.

1. Obtain an unknown hydrated salt from your instructor along with the formula weight of the anhydrous salt. Record this information.

2. Using the unknown hydrate, repeat the procedures outlined in Part B.

3. Calculate the % water in the unknown.

4. Calculate the water of hydration of the unknown using the formula weight of the anhydrous salt.

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NAME ___________________
DATE ____________________
SECTION _________________

WATER OF HYDRATION
REPORT SHEET
EXPERIMENT 7

REVERSIBILITY OF HYDRATION

1. Colour of wet $CuSO_4$ ________________________

2. Colour of dry $CuSO_4$ ________________________

3. Colour of re-wetted $CuSO_4$ ________________________

From your experimental observations, what can you conclude about the $CuSO_4 \bullet 5\ H_2O$?

PERCENTAGE OF WATER IN MAGNESIUM SULFATE HEPTAHYDRATE

1. Mass of crucible, lid, and hydrate ________________________

2. Mass of crucible and lid ________________________

3. Mass of hydrate (1-2) ________________________

4. Mass of crucible, lid, and hydrate after heating ________________________

5. Mass of water given off (1-4) ________________________

Calculation of % water $MgSO_4 \bullet 7\ H_2O$ from the experimental results:

% water ________________________

Calculation of theoretical % water in $MgSO_4 \bullet 7\ H_2O$

% water ______________________

How does your experimental and theoretical results compare? Why would they be different?

PERCENTAGE OF WATER IN AN UNKNOWN HYDRATE

Unknown No. __________

1. Mass of crucible, lid, and hydrate ____________________________
2. Mass of crucible and lid ____________________________
3. Mass of hydrate (1-2) ____________________________
4. Mass of crucible, lid, and hydrate after heating ____________________________
5. Mass of water given off (1-4) ____________________________
6. Mass of anhydrous unknown (4-2) ____________________________

Calculation of % water in the unknown from the experimental results.

% water _________________

Calculate the water of hydration on the unknown hydrate, given the formula weight of the anhydrous salt.

Formula weight = ______________________ (Obtain from instructor)