Determining the Formula of a Hydrate

Name KEY

Chem Worksheet 11-6

A **hydrate** is an ionic compound that contains water molecules in its structure. To determine the formula of a hydrate experimentally, we must calculate the mole: mole ratio of the water portion compared to the anhydrate portion. An **anhydrate** is the substance that remains after the water is removed from a hydrate. When a hydrate is heated the water molecules are driven off as steam, leaving behind the water-free anhydrate.

The first step to finding the formula for a hydrate is to record the mass of the hydrate. After heating the hydrate, the mass is determined for the anhydrate that remains. The mass of the water that was present is calculated by finding the difference between the mass of the hydrate and the mass of the anhydrate. The mass of the water and the mass of the anhydrate are each converted to moles using their respective molar masses. From this a whole number ratio can be determined (see example).

Data Table

Mass of hydrate ($CaCl_2 \cdot xH_2O$)	4.72 g
Mass of anhydrate ($CaCl_2$)	3.56 g
Mass of water	1.18 g

Example

A calcium chloride hydrate has a mass of 4.72 g. After heating for several minutes the mass of the anhydrate is found to be 3.56 g. Use this information to determine the formula for the hydrate.

- find the mass of the water driven off: mass of hydrate – mass of anhydrate = mass of water
  $4.72\text{ g} - 3.56\text{ g} = 1.18\text{ g}$

- convert the mass of anhydrate to moles: $\frac{3.56\text{ g } CaCl_2}{1} \times \frac{1\text{ mol } CaCl_2}{110.98\text{ g } CaCl_2} = 0.0321\text{ mol } CaCl_2$

- convert the mass of water to moles: $\frac{1.18\text{ g } H_2O}{1} \times \frac{1\text{ mol } H_2O}{18.02\text{ g } H_2O} = 0.0655\text{ mol } H_2O$

- find the mole H_2O to mole $CaCl_2$ ratio: $\frac{0.0655\text{ mol } H_2O}{0.0321\text{ mol } CaCl_2} = \frac{2\text{ mol } H_2O}{1\text{ mol } CaCl_2}$

Since the compound contains 2 moles of water for every 1 mole of anhydrate the formula is **$CaCl_2 \cdot \underline{2}\ H_2O$**

Solve the following problems. Show work to support your answer.

$6.60\text{g} \left| \frac{1\text{mol}}{120.4\text{g}} \right. = 0.0548\text{mol } MgSO_4$ $\quad \frac{6.92}{18\text{g}} = .384\text{mol}$

$MgSO_4 \cdot 7H_2O$

1. A hydrate of magnesium sulfate has a mass of 13.52 g. This sample is heated until no water remains. The $MgSO_4$ anhydrate has a mass of 6.60 g. Find the formula and name of the hydrate.

$24.3 + 32.1 + 16\times4$

$CuSO_4 \cdot 5H_2O$

2. A sample of copper (II) sulfate hydrate has a mass of 3.97 g. After heating, the $CuSO_4$ that remains has a mass of 2.54 g. Determine the correct formula and name of the hydrate. $\frac{2.54\text{g}}{159.6\text{g}} \left| \frac{1\text{mol}}{} \right. = 0.0158\text{mol } CuSO_4$

$63.5 + 32.1 + 16\times4$ $\quad \frac{1.43}{18\text{g}} \left| \frac{1\text{mol}}{} \right. = 0.079$

$FeCl_3 \cdot 6H_2O$

3. When 5.00 g of $FeCl_3 \cdot xH_2O$ are heated, 2.00 g of H_2O are driven off. Find the chemical formula and the name of the hydrate. $\frac{3\text{g}}{162.3\text{g}} \left| \frac{1\text{mol}}{} \right. = 0.0185\text{mol } FeCl_3$ $\quad \frac{2\text{g}}{18\text{g}} \left| \frac{1\text{mol}}{} \right. = .111\text{mol}$

$55.8 + 35.5\times3$

$NaCl \cdot H_2O$

4. A sample of the hydrate of sodium carbonate has a mass of 8.85 g. It loses 1.28 g when heated. Find the formula and the name of the hydrate. $\frac{7.57\text{g}}{106\text{g}} \left| \frac{1\text{mol}}{} \right. = 0.0714\text{mol}$ $\quad \frac{1.28\text{g}}{18\text{g}} \left| \frac{1\text{mol}}{} \right. = 0.071$

Na_2CO_3 $\quad 23\times2 + 12 + 16\times3$

$CaSO_4 \cdot 2H_2O$

5. A 16.4 g sample of hydrated calcium sulfate is heated until all the water is driven off. The calcium sulfate that remains has a mass of 13.0 g. Find the formula and the chemical name of the hydrate. $\frac{13\text{g}}{136.2\text{g}} \left| \frac{1\text{mol}}{} \right. = .0954\text{mol}$

$CaSO_4$ $\quad 40.1 + 32.1 + 16\times4$

$Pb(C_2H_3O_2)_2 \cdot 3H_2O$

6. When 8.00 g of $Pb(C_2H_3O_2)_2 \cdot xH_2O$ are heated, 1.14 g of H_2O are driven off. Find the chemical formula and the name of the hydrate. $\frac{6.86\text{g}}{325.2\text{g}} \left| \frac{1\text{mol}}{} \right. = 0.0211\text{mol}$ $\quad \frac{1.14\text{g}}{18\text{g}} \left| \frac{1\text{mol}}{} \right. = 0.0633$ $\quad \frac{3.4}{18\text{g}} = .189\text{mol}$

$207.2 + 12\times4 + 6 + 16\times4$

$Z \cdot 6H_2O$

7. A hydrate is determined to be 45.43% water and 54.57% $CoCl_2$. Find the chemical formula and name for this hydrate. (*Hint – assume that there is 100 g total of hydrate compound.)

$\frac{54.57\text{g}}{129.9} \left| \frac{1\text{mol}}{} \right. = .420\text{mol}$ $\quad 58.9 + 35.5\times2$

$\frac{45.43\text{g}}{18\text{g}} \left| \frac{1\text{mol}}{} \right. = 2.524\text{mol}$

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Name _____

HYDRATES

Many compounds crystallize from a water solution with

H2O molecules adhering to the particles of the crystal.

These compounds are called Hydrates.

They usually contain a specific ratio of Water to Compound (Salt)

It is possible to heat these compounds to drive off the

H2O and then calculate the ratio. What is formed is called the

Anhydrous Salt.

Example: $NiSO_3 \cdot 6\ H_2O$

The formula shows that 6 molecules of water adhere to

1 formula unit.

To calculate the formula mass of the compound, add the

Anhyd Salt + H2O

$NiSO_3$ = 127.8 + $6\ H_2O$ = 108 = 246.8 g/mol

Hydrates

BaI_2 mm → 391.1 g/mol

Problem:

We have a 10.407 g sample of hydrated barium iodide. After heating to drive off the water, the sample weighs 9.520 grams.

1. How many grams of water were driven off? .887g

9.520g 2. Convert grams of anhydrous salt to moles of Barium Iodide .0243

3. Convert grams of water to moles of water .0493

4. determine the ratio: $\frac{\text{moles of water}}{\text{moles of barium iodide (anhydrous)}} = \frac{2}{1}$

5. write the formula

$BaI_2 \cdot 2H_2O$

Find the formulas for the following hydrates if the amounts of anhydrous salts and water are as follows:

0.391 g Li_2SiF_6, 0.0903 g water $\frac{.002508}{.005017} = 2$ $Li_2SiF_6 \cdot 2H_2O$

155.9 g/mol

0.737 g Magnesium Sulfite, 0.763 g water $\frac{.04239}{.007059} = 6$ $MgSO_3 \cdot 6H_2O$

$MgSO_3$ = 104

2.734 g Iron (II) Sulfate, 2.270 g water $\frac{.12611}{.0179} = 7$ $FeSO_3 \cdot 7H_2O$

$FeSO_3$ .126

~~135.9 g/mol~~

151.9 g/mol = .0179

Sample Lab Data for Hydrate Lab

You and your lab partner collect the following data in an experiment where a hydrated compound of calcium sulfite ($CaSO_3$) is heated to dryness.

Data

Mass of evaporating dish, lid, and hydrated sample	52.00 grams
Mass of empty evaporating dish and lid	50.00 grams
Mass of evaporating dish, lid, and dehydrated sample	50.98 grams

Questions

1. What is the mass of the dehydrated sample?

.98g $CaSO_3$

2. What is the mass of the water lost?

1.02g H_2O

3. How many moles of $CaSO_3$ are present?

120.2g/mol

.00815 3mol

4. How many moles of water were in the sample?

.05667

5. What is the formula of the hydrate?

$\frac{.05667}{.00815\,3} \approx 7$ $CaSO_3 \cdot 7H_2O$