

# Formula of a Hydrate

## Goals

- Determine the percent water in a hydrated salt.
- Calculate the number of moles of water in a hydrated salt.
- Determine the formula of a hydrated salt.

## Lab Questions

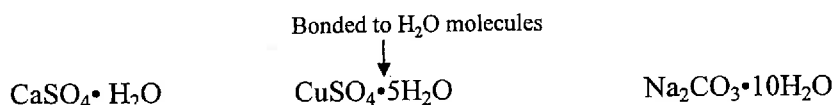
1. What is a hydrate? Anhydrate?
2. What happens when a hydrate is heated?
3. How would you determine the percent of water in a hydrate?

## Concepts to Review

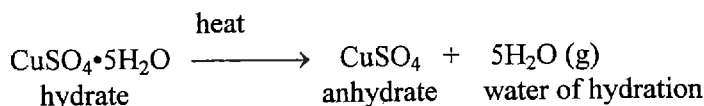
Molar mass  
Moles  
Formula  
Hydrates  
Dehydration

## Discussion

Many solid forms of salts contain a specific number of water molecules. These compounds are called *hydrates*. The molecules of water contained in the hydrate are referred to as *water of hydration*. Since the number of water molecules is specific for each kind of hydrate, water is included in the formula of the compound. A hydrate formula is the formula of the salt followed by a dot and the number of water molecules, as shown by the following:



Because the water molecules in a hydrate are held by weak attractive forces, the water can be removed by heating the hydrate. The form of the salt without water is called an *anhydrate*.



In this lab, the mass of the hydrate before heating and the mass of the anhydrate after heating gives the amount of water lost. The percent water in the hydrate can then be determined.

$$\text{g salt hydrate} - \text{g salt anhydrate} = \text{g water}$$

$$\frac{\text{g water}}{\text{g hydrate}} \times 100 = \% \text{ water in hydrate}$$

The formula of the hydrate is determined by calculating the moles of remaining compound (anhydrate) and the moles of water.

$$\text{g H}_2\text{O} \times \frac{1 \text{ mole H}_2\text{O}}{18.0 \text{ g H}_2\text{O}} = \text{moles H}_2\text{O}$$

$$\text{g salt (anhydrate)} \times \frac{1 \text{ mole salt}}{\text{Molar mass salt}} = \text{moles salt (anhydrate)}$$

## Laboratory Activities

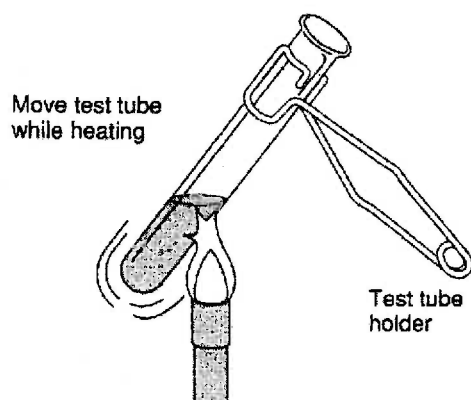
***Safety goggles are required for laboratory experiments!***



### A. Copper (II) Sulfate•5H<sub>2</sub>O , A Hydrate

**Materials needed:** CuSO<sub>4</sub>•5H<sub>2</sub>O, test tube, test tube holder, test tube rack, Bunsen burner, dropper, small beaker

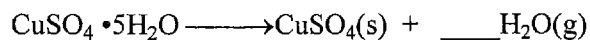
- A.1 Place a small amount of the solid crystals of CuSO<sub>4</sub>•5H<sub>2</sub>O in a test tube. Describe the CuSO<sub>4</sub>•5H<sub>2</sub>O crystals. Place a test tube holder on the test tube. Gently heat the lower portion of the test tube by continuously moving the test tube through the flame. The proper way to heat a substance in a test tube is shown in Figure 15.1.



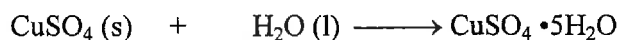
***DO NOT HEAT A TEST TUBE IN ONE SPOT. KEEP THE TEST TUBE MOVING.***

**Figure 15.1** Heating a sample in a test tube.

- A.2 Describe the appearance of the  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  crystals after heating. Also observe the upper part of the test tube and describe what you see. Return the test tube to your test tube rack and let it cool. Balance the equation for the reaction. In the hydrate formula the 5 molecules of water attached follow the raised dot( $\cdot$ ).



- A.3 When the test tube and contents have cooled, add a few drops of water to the test tube. Record your observations. Balance the equation for the reaction.

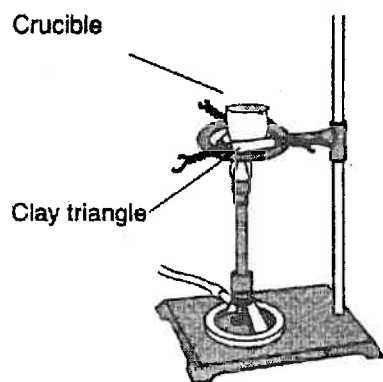


## B. Formula of a Hydrate

**Materials needed:** Unknown hydrates of  $\text{MgSO}_4$  or  $\text{BaCl}_2$ , crucible, clay triangle, crucible tongs, Iron ring and stand, Bunsen burner, heat resistant pad, laboratory balance

**Each time you weigh an item or a substance, report the complete mass. Do not round off any mass!**

- B.1 Obtain a clean, dry crucible, heat for 2-3 minutes and let it cool. Weigh carefully.
- B.2 Fill the crucible 1/3 to 1/2 full with one of the hydrates available: magnesium sulfate ( $\text{MgSO}_4$ ) hydrate or barium chloride ( $\text{BaCl}_2$ ) hydrate. Weigh and record the total mass of the crucible and the hydrate.
- B.3 Set the crucible and hydrate on a clay triangle that is set on an iron ring. See Figure 15.2.



**Figure 15.2** Heating a crucible set in a clay triangle on an iron ring.

Heat gently for 5 minutes. Then increase the intensity of the flames and heat strongly for 10 minutes more. The bottom of the crucible will turn a dull red. Turn off the burner. Using crucible tongs, move the crucible to a heat resistant surface. After the crucible cools to room temperature, weigh the crucible and its contents. Record the mass.

***Always allow heated items to cool to room temperature. Hot containers must not be placed on a balance pan.***

**Optional** To determine that you have completely driven off the water of hydration, you may wish to heat the crucible and its contents for another 5 minutes and cool again. Weigh. If the mass in the second heating is within 0.05 g of the mass obtained after the first heating, you have completely dehydrated the salt. If not, heat again until you have agreement between final weighings. Use the *final weighing* for your calculations.

### Calculations

B.4 Calculate the mass of the salt hydrate before heating (B.2-B.1).

B.5 Calculate the mass of the salt anhydrate after heating (B.3-B.1).

B.6 The difference in the mass of the hydrate and the anhydrate is the mass of water lost during the heating. Calculate the grams of water lost (B.4 - B.5).

B.7 Calculate the percent water in the hydrate.

$$\frac{\text{g water (B.6)}}{\text{g hydrate (B.4)}} \times 100 = \% \text{ water in hydrate}$$

B.8 Calculate the moles of H<sub>2</sub>O lost by the hydrate.

$$\text{g water (B.6)} \times \frac{1 \text{ mole}}{18.0 \text{ g water}} = \text{moles water}$$

B.9 Calculate the moles of anhydrate (MgSO<sub>4</sub> or BaCl<sub>2</sub>) in the sample using the molar mass of your anhydrate. The molar mass of MgSO<sub>4</sub> anhydrate is 120.4 g/mole. The molar mass of BaCl<sub>2</sub> anhydrate is 208.3 g/mole.

$$\text{g anhydrate (B.5)} \times \frac{1 \text{ mole}}{\text{molar mass of anhydrate}} = \text{moles anhydrate}$$

B.10 Determine the ratio of moles of water for 1 mole of the anhydrate. Round off the value for moles H<sub>2</sub>O to the nearest whole number.

$$\frac{\boxed{\phantom{00}} \text{ moles water (B.8)}}{\boxed{\phantom{00}} \text{ moles anhydrate (B.9)}} = \frac{\boxed{\phantom{00}} \text{ moles H}_2\text{O}}{1 \text{ mole anhydrate}} = \frac{\boxed{\phantom{00}} \text{ moles H}_2\text{O (rounded)}}{1 \text{ mole anhydrate}}$$

B.11 Use the whole number values in B.10 to write the formula of your hydrate.