

# Determining the Formula of a Hydrate

Name \_\_\_\_\_

## 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 ( $\text{CaCl}_2 \cdot x\text{H}_2\text{O}$ )	<u>4.72 g</u>
Mass of anhydrate ( $\text{CaCl}_2$ )	<u>3.56 g</u>
Mass of water	<u>1.18 g</u>

**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:  
$$\text{mass of hydrate} - \text{mass of anhydrate} = \text{mass of water}$$
$$4.72 \text{ g} - 3.56 \text{ g} = 1.18 \text{ g}$$
- 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:  
$$\frac{1.18 \text{ g H}_2\text{O}}{1} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = 0.0655 \text{ mol H}_2\text{O}$$
- find the mole  $\text{H}_2\text{O}$  to mole  $\text{CaCl}_2$  ratio:  
$$\frac{0.0655 \text{ mol H}_2\text{O}}{0.0321 \text{ mol CaCl}_2} = \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol CaCl}_2}$$

Since the compound contains 2 moles of water for every 1 mole of anhydrate the formula is  $\text{CaCl}_2 \cdot \underline{2} \text{H}_2\text{O}$

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

1. A hydrate of magnesium sulfate has a mass of 13.52 g. This sample is heated until no water remains. The  $\text{MgSO}_4$  anhydrate has a mass of 6.60 g. Find the formula and name of the hydrate.
2. A sample of copper (II) sulfate hydrate has a mass of 3.97 g. After heating, the  $\text{CuSO}_4$  that remains has a mass of 2.54 g. Determine the correct formula and name of the hydrate.
3. When 5.00 g of  $\text{FeCl}_3 \cdot x\text{H}_2\text{O}$  are heated, 2.00 g of  $\text{H}_2\text{O}$  are driven off. Find the chemical formula and the name of the hydrate.
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.
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.
6. When 8.00 g of  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot x\text{H}_2\text{O}$  are heated, 1.14 g of  $\text{H}_2\text{O}$  are driven off. Find the chemical formula and the name of the hydrate.
7. A hydrate is determined to be 45.43% water and 54.57%  $\text{CoCl}_2$ . Find the chemical formula and name for this hydrate. (\*Hint – assume that there is 100 g total of hydrate compound.)

$$1. \text{MgSO}_4 \cdot x \text{H}_2\text{O} = 13.52 \text{g}$$

$$\text{MgSO}_4 = 6.60 \text{g}$$

$$13.52 - 6.60 \text{g} = 6.92 \text{g H}_2\text{O}$$

$$6.60 \text{g MgSO}_4 \times \frac{1 \text{ mol}}{120.4 \text{ g}} = \frac{.0548 \text{ mol}}{.0548} = 1$$

$$6.92 \text{g H}_2\text{O} \times \frac{1 \text{ mol}}{18 \text{ g}} = \frac{.384 \text{ mol}}{.0548} = 7$$



magnesium sulfate heptahydrate

$$2. \text{CuSO}_4 \cdot x \text{H}_2\text{O} = 3.97 \text{g}$$

$$\text{CuSO}_4 = 2.54 \text{g}$$

$$3.97 - 2.54 = 1.43 \text{g H}_2\text{O}$$

$$2.54 \text{g CuSO}_4 \times \frac{1 \text{ mol}}{159.6 \text{ g}} = \frac{.0159}{.0159} = 1$$

$$1.43 \text{g H}_2\text{O} \times \frac{1 \text{ mol}}{18} = \frac{.0794}{.0159} = 5$$



copper II sulfate pentahydrate

$$3. \text{FeCl}_3 \cdot x \text{H}_2\text{O} = 5.00 \text{g}$$

$$\text{H}_2\text{O} = 2.00 \text{g}$$

$$5.00 - 2.00 = 3.00 \text{g FeCl}_3$$

$$3.00 \text{g FeCl}_3 \times \frac{1 \text{ mol}}{162.3} = \frac{.0185}{.0185} = 1$$

$$2.00 \text{g H}_2\text{O} \times \frac{1 \text{ mol}}{18 \text{ g}} = \frac{.111}{.0185} = 6$$



iron III chloride hexahydrate

$$4. \text{Na}_2\text{CO}_3 \cdot x \text{H}_2\text{O} = 8.85 \text{g}$$

$$\text{H}_2\text{O} = 1.28 \text{g}$$

$$8.85 - 1.28 = 7.57 \text{g Na}_2\text{CO}_3$$

$$7.57 \text{g Na}_2\text{CO}_3 \times \frac{1 \text{ mol}}{106 \text{ g}} = \frac{.0714}{.0714} = 1$$

$$1.28 \text{g H}_2\text{O} \times \frac{1 \text{ mol}}{18 \text{ g}} = \frac{.0711}{.0714} = 1$$



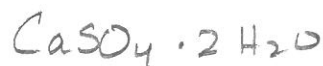
$$5. \text{CaSO}_4 \cdot x \text{H}_2\text{O} = 16.4 \text{g}$$

$$\text{CaSO}_4 = 13.0 \text{g}$$

$$16.4 - 13.0 = 3.4 \text{g H}_2\text{O}$$

$$13 \text{g CaSO}_4 \times \frac{1 \text{ mol}}{136.2 \text{ g}} = \frac{.0954}{.0954} = 1$$

$$3.4 \text{g H}_2\text{O} \times \frac{1 \text{ mol}}{18 \text{ g}} = \frac{.189}{.0954} = 2$$



calcium sulfate dihydrate

$$6. \text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot x \text{H}_2\text{O} = 8.00 \text{g}$$

$$\text{H}_2\text{O} = 1.14 \text{g}$$

$$8.00 - 1.14 = 6.86 \text{g Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$$

$$6.86 \text{g Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \times \frac{1 \text{ mol}}{325.2 \text{ g}} = \frac{.0211}{.0211} = 1$$

$$1.14 \text{g H}_2\text{O} \times \frac{1 \text{ mol}}{18 \text{ g}} = \frac{.0633}{.0211} = 3$$



lead II acetate trihydrate

$$7. 45.43\% \text{H}_2\text{O} \quad 54.57\% \text{CoCl}_2$$

$$54.57 \text{g CoCl}_2 \times \frac{1 \text{ mol}}{129.9 \text{ g}} = \frac{.4201}{.4201} = 1$$

$$45.43 \text{g H}_2\text{O} \times \frac{1 \text{ mol}}{18 \text{ g}} = \frac{2.523}{.4201} = 6$$



cobalt II chloride hexahydrate