Name _____ Date _____ Period ____

Chem 07-33 Solving Problems in Chemistry (SPIC)

Chapter 5:8, 11 Hydrates

5:8 Hydrates

Some crystals form hydrates as they crystallize from water solutions. These compounds have water molecules adhering to their crystal structure. There is a fixed ratio of water molecules per formula unit. Hydrates are named using the Greek prefixes to name the quantity of water molecules.

calcium sulfate dihydrate	$CaSO_4 \cdot 2\ H_2O$
sodium sulfate decahydrate	$Na_2SO_4 \cdot 10\ H_2O$
Magnesium sulfate septhydrate	$MgSO_4 \cdot 7\ H_2O$

The raised dot indicates that the water molecules are not held tightly and can be driven off by heating the hydrate.

Example 9

In an experiment, a student gently heated a hydrated copper compound to remove the water of hydration. The following data was recorded.

Mass of the crucible, cover, and contents before heating	21.54 g before
Mass of empty crucible and cover	19.82 g container
Mass of crucible, cover, and contents after heating to constant mass	20.94 g after

A. Calculate the experimental percent of water in the compound
B. Calculate the percent error assuming that the compound is copper II sulfate pentahydrate.

Solving Process:

The mass of the original compound is found by subtracting the mass of the container from the total mass before.

$$\%\ H_2O = \frac{\text{g } H_2O \text{ removed}}{\text{g original compound}} \times 100\ \%$$

$$= \frac{0.60 \text{ g } H_2O}{1.72 \text{ g cmpd}} \times 100\% = 34.9\%\ H_2O/\text{cmpd}$$

To calculate the percent error, compare the experimentally determined value for the percent water with the value calculated from the formula for copper (II) sulfate pentahydrate, $CuSO_4 \cdot 5\ H_2O$. The calculated percent of water in the compound is 36.0% H_2O/compound.

$$\%\ \text{error} = \frac{|\text{expected} - \text{achieved}|}{\text{expected}} \times 100\%$$

$$= \frac{|36.0\%\ H_2O/\text{cmpd} - 34.9\%\ H_2O/\text{cmpd}|}{36.0\%\ H_2O/\text{cmpd}} \times 100\%$$

$$= 3.1\%\ \text{error}$$

Practice Problems

13. Calculate the percentage of each of the following in the compound sodium sulfate decahydrate, $Na_2SO_4 \cdot 10\ H_2O$.
    a. Na b. S c. O d. H_2O

14. Calcium chloride can exist as the anhydrous compound $CaCl_2$ or in three different hydrated forms that are mono-, di-, and hexahydrates. Calculate the following.
    a. The percent calcium in each compound
    b. The percent water in each of the three hydrates

15. In a laboratory experiment, barium chloride dihydrate was heated to completely remove its water of hydration. Calculate:

a. The experimental percent of water
b. The percent of $BaCl_2$
c. The percent error

The data below was obtained in the experiment.

Empty crucible and cover	20.286 g container
Crucible, cover and contents before heating	21.673 g before
Crucible, cover, and contents after heating	21.461 g after

5:11 Empirical Formulas of Hydrates

The method used to calculate the formulas of hydrates is basically the same that is used to calculate other empirical formulas except that it is necessary to determine the number of moles of water involved. Hydrated compounds can be made anhydrous by heating to drive the water out of the crystals. After heating, the water is released into the atmosphere and all that remains is the anhydrous residue.

Example 13

A hydrated compound has an analysis of 18.29% calcium, 32.3% chlorine, and 49.34% water. What is its formula?

Solving Process

First, find the number of moles.

$$\frac{18.29 \text{ g Ca}}{} \left| \frac{1 \text{ mole Ca}}{40.08 \text{ g Ca}} \right. = 0.4563 \text{ moles Ca}$$

$$\frac{32.3 \text{ g Cl}}{} \left| \frac{1 \text{ mole Cl}}{35.45 \text{g Cl}} \right. = 0.9131 \text{ moles Cl}$$

$$\frac{49.34 \text{ g } H_2O}{} \left| \frac{1 \text{ mole } H_2O}{18.02 \text{ g } H_2O} \right. = 2.738 \text{ moles } H_2O$$

Determine the ratio of moles

$$\frac{0.4563 \text{ moles Ca}}{0.4563} = 1.000 \text{ mole Ca} \qquad \frac{0.9131 \text{ moles Cl}}{0.4563} = 2.001 \text{ moles Cl} \qquad \frac{2.738 \text{ moles } H_2O}{0.4563} = 6.000 \text{ moles } H_2O$$

The empirical formula is $CaCl_2 \cdot 6\ H_2O$. The raised dot between the $CaCl_2$ and the 6 H_2O means that this substance is a hydrated compound.

Practice Problems

21. The masses of the hydrates listed below were measured, heated to drive off the water of hydration, and cooled. Then the masses of the residues were measured. Find the formulas of the following hydrates.

a. 1.62 g of $CoCl_2 \cdot x\ H_2O$ gave a residue of 0.88 grams.
b. 1.21 g of $Pb(C_2H_3O_2)_2 \cdot x\ H_2O$ gave a residue of 1.03 grams.
c. 1.04 g of $NiSO_4 \cdot x\ H_2O$ gave a residue of 0.61 grams.
d. 1.26 g of $CaSO_4 \cdot x\ H_2O$ gave a residue of 0.99 grams.

22. A hydrated magnesium compound has a formula mass of 174 g/mole cmpd and contains 31.0% water of hydration. From the following analysis, calculate the molecular formula: Mg 13.90%, P 17.74%, H 4.01%, O 64.30%.