**Hydrates Analysis**

NAME:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ PERIOD:\_\_\_\_\_\_\_\_\_

**Prelab**

1. A 6.00g sample of calcium sulfate hydrate (CaSO4.x H2O) is heated until all the water is driven off. The anhydrous compound has a mass of 4.77 g. Calculate the value of x in the formula.

2. For the data in problem number 1 above, what is the mass percent water in the hydrate?

3. Calculate the number of grams of water that could be obtained by heating 2.00 g of sodium

sulfate decahydrate (Na2SO4.10 H2O).

**Hydrates Analysis**

Objective: The formula for an unknown hydrate is quantitatively determined by heating the unknown hydrate to constant mass and calculating the ratio of the moles of water to the moles of anhydrous material. Observations will be made of any color changes during heating and re-hydration of the compound as well as heat effects during the re-hydration.

A hydrate is a compound that is associated with a definite number of water molecules. The water is present as individual water molecules and usually no chemical bonds are involved in holding the ions of the compound and the water molecules together. The forces of attraction are electrostatic forces resulting from the charged nature of the anhydrous ionic compound and the polar water molecules. Particle size and space limitations dictate the number of water molecules an ionic compound will accommodate and well as the conditions under which the hydrate is formed. Many ionic compounds form multiple hydrates and to remove all of the bound water for some of these can be difficult in ordinary laboratory conditions and time constraints.

Hydrates are classified as hygroscopic, deliquescent, and effluorescent. These labels specify the properties associated with the ionic compound to which the water is bound. The type of hydrate most suitable for a quantitative hydrate formula determination is the hygroscopic hydrate, which absorbs a definite number of water molecules. In addition to this type's utility for this lab exercise, the useful absorption qualities associated with this class of hydrates makes it extremely useful as a drying agent. The compound is heated to drive off the water and then used to keep other materials dry by absorbing water before the other material. They are sometimes packed with food, film, or shoes to prevent moisture damage. One very commonly used desiccant is calcium sulfate pentahydrate, commercially available as Drierite. You may see it used in desiccators, like the one you may be using today to cool your anhydrous material after heating to drive off the water of hydration. It provides a dry atmosphere to prevent the anhydrous compound from reabsorbing water from the air.

The deliquescent compounds, such as calcium chloride and sodium hydroxide, absorbs water until it dissolves forming a concentrated solution. The efflorescent hydrate, such as sodium sulfate decahydrate (Na2SO4.10 H2O), spontaneously loses some or all of its water of hydration when exposed to dry atmosphere.

If a hydrated substance is heated directly or placed in a warm atmosphere such as in an oven, the water of hydration is lost to the surroundings; and the residue is a water-free or anhydrous compound.

CoCl2. x H2O (s) ⇔ CoCl2 (s) + x H2O (g)

hydrate anhydrous

As the water is lost there may be a color change, which is characteristic of the particular anhydrous compound. Since heat must be added to the hydrate to drive off the water this is an endothermic change. When the anhydrous material or residue is placed in a cool, moist environment, or water is added to it directly, the reverse change occurs. Water is picked up, the hydrate is regenerated, and heat is evolved. The heat absorbed and evolved varies depending upon the compound involved.

The moles of water in a hydrate can be determined quantitatively by heating a known mass of the hydrate for a sufficient length of time to establish constant mass, and then determining the mass of the anhydrous material or residue. The difference between the mass before and after heating the hydrate is the mass of water driven off. This mass of water divided by the molar mass of water gives the number of moles of water initially present. The number of moles of anhydrous compound can be determined by using the mass of the anhydrous compound (residue) and dividing it by the molar mass of the anhydrous compound. The number of moles of water divided by the number of moles of anhydrous compound gives you the coefficient **x** in the accepted form for the chemical formula of a hydrate: anhydrous compound**.**x H2O. The Greek prefixes are used to specify the number of moles of water present in the name of the hydrate. The hydrate, MgSO4. 7 H2O, is named magnesium sulfate heptahydrate.

Once you know the numerical value of **x**, you can calculate the theoretical mass percent of water in the hydrate. Since **x** will be the moles of water released upon dehydration of one mole of hydrate, **x** multiplied by the molar mass of water gives you the mass of water present in the hydrate. Dividing the mass of water by the molar mass of the anhydrous compound and multiplying by 100 gives the percent water.

The experimental percent water in the hydrate can be calculated from the mass data generated in the experiment. The percent error in the percent water may be calculated using the relationship:

(Note that if your mass of water is less that the theoretical value, which is very likely, your percent error will be a negative value)

**Procedure:**

1. Mass an empty, dry 100mL beaker.

2. Add approximately 2 grams of hydrate to the beaker.

3. Remass the beaker and hydrate. Keep the correct number of significant figures in your masses.

4. Adjust your heat setting on the hot plate such that you can see moisture being removed but not hot enough to cause splattering or decomposition of the compound.

5. After you have heated the hydrate for five minutes most of the water will have been removed and you may then heat more strongly until you see no further color change and no sign of moisture (approximately 2 minutes).

6. Before massing the sample after heating, it is essential that the residue be cooled to room temperature. Since we are working with hygroscopic materials, if they are allowed to cool in the room atmosphere, some moisture will be reabsorbed, causing an error in the mass of the anhydrous compound. To eliminate this source of error, the hot beakers will be cooled in a desiccator, which will provide a dry environment for cooling to room temperature. You instructor will demonstrate the use of a desiccator. If you have any difficulty handling the lid, please ask for assistance. The lid is lubricated to seal the desiccator from the outer atmosphere. It is essential that the lid be removed and replaced using a gentle sliding motion rather than simply placing the lid on the base or attempting to pull the lid off without rotating and sliding to loosen the seal of the vacuum grease. Cooling may take 5 minutes or longer, depending upon how many beakers are in the desiccator, the size of the desiccator, and the temperature of the beakers.

7. Use heat resistant gloves or beaker tongs to remove the beaker from the hotplate and set it on a ceramic pad. Allow the beaker to cool partially to room temperature before placing it in the desiccator. Cool the beaker to room temperature in the desiccator.

8. Mass the cooled beaker and anhydrous compound.

9. Reheat the beaker for 2-3 minutes, cool to room temperature in the desiccator, and remass it until constant mass is achieved. If the two masses agree within 0.1g on a centigram balance, consider this to be constant mass and use the lower of the two masses. You may find that more than two mass measurements are required to establish constant mass for the residue, especially if you rush the heating cycles or do not thoroughly cool the residue between heating and mass measurements.

10. After all the mass data has been collected, add enough water from a wash bottle and observe the evolution of heat in re-hydration and observe color changes.

11. Follow your instructor’s directions for disposing of the compounds.

12. Complete the calculations for the formula of the hydrate. Remember to use correct significant figures in your molar masses and calculated results.

**Hydrates Analysis**

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LAB PARTNER:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ DATE:\_\_\_\_\_\_\_\_\_\_\_

**DATA TABLE**

| Hydrate used |  |  |
| --- | --- | --- |
| Mass of empty beaker and hydrate |  |  |
| Mass of empty beaker |  |  |
| Mass of hydrate |  |  |
| Mass of anhydrous compound after the first heating |  |  |
| Mass of anhydrous compound after the second heating |  |  |
| Mass of anhydrous compound |  |  |
| Mass of water |  |  |
| Molar mass water |  |  |
| Molar mass anhydrous compound |  |  |
| Moles of anhydrous compound |  |  |
| Moles of water |  |  |
| Moles water/mole anhydrous compound |  |  |
| Experimental value **x** |  |  |
| Formula for the hydrate |  |  |
| Theoretical percent water in the hydrate |  |  |
| Experimental percent water in the hydrate |  |  |
| Percent Error in the percent water |  |  |

Calculations:

Discussion:

Comment on your results. Include any difficulties you may have experienced or sources or error, which may have affected your results.