Name _____ **Chemistry** ___/___/___

Hydrates

Hydrates are compounds that attract and bond with water molecules when they crystallize. The ratio of these water molecules in the compound is always a whole number. A sample hydrate formula is written as follows: **$CuSO_4 \cdot 5H_2O$**. The way we name the formula is only slightly different from what we have already learned. First, name the ionic compound the way we have learned, $CuSO_4$ is copper(II) sulfate. We then add the correct prefix for the number of water molecules and the word hydrate. The complete name for our ionic compound hydrate is: **copper(II) sulfate pentahydrate**

The prefixes used for naming hydrates are as follows:

Prefix	Moles of Water	Name	Formula
mono-	1	monohydrate	$XY \cdot H_2O$
di-	2	dihydrate	$XY \cdot 2H_2O$
tri-	3	trihydrate	$XY \cdot 3H_2O$
tetra-	4	tetrahydrate	$XY \cdot 4H_2O$
penta-	5	pentahydrate	$XY \cdot 5H_2O$
hexa-	6	hexahydrate	$XY \cdot 6H_2O$
hepta-	7	heptahydrate	$XY \cdot 7H_2O$
octa-	8	octahydrate	$XY \cdot 8H_2O$
nona-	9	nonahydrate	$XY \cdot 9H_2O$
deca-	10	decahydrate	$XY \cdot 10H_2O$

Name the following hydrates:

1. $Na_2CO_3 \cdot 10H_2O$ **sodium carbonate decahydrate**
2. $BaI_2 \cdot 2H_2O$ **barium iodide dihydride**

Write the formula for the following hydrates:

1. sodium tetraborate decahydrate **$Na_2B_4O_7 \cdot 10\ H_2O$**
2. nickel(II) sulfite hexahydrate **$NiSO_3 \cdot 6H_2O$**
3. barium bromide dihydrate **$BaBr_2 \cdot 2H_2O$**

Part I: Calculating Percent Water in a Hydrate

Calculating the amount of water in a hydrate is done exactly like any other percent composition problem. You just have to remember to keep the mass of the water separate. Remember, our goal is to determine the percent of water in the compound.

Example #1: Calculate the percent of water in sodium carbonate decahydrate.

Description of Action	Action
1. Write the formula for the compound.	**1.** $Na_2CO_3 \cdot 10H_2O$
2. Calculate the molar mass of each part of the compound separately. Also, the number in front of the water molecule must be distributed and multiplied by the subscript of both the hydrogen and the oxygen in the water molecule.	**2.** Na: 2 x 23.0 = 46.0 C: 1 x 12.0 = 12.0 O: 3 x 16.0 = 48.0 **106.0** H: 20 x 1.0 = 20.0 O: 10 x 16.0 = 160.0 **180.0**
3. Add the totals for each part together to find the molecular formula mass.	**3.** 106.0 + 180.0 = **286.0**
4. Divide each part's total by the molecular formula mass.	**4.** Na_2CO_3: 106.0 ÷ 286.0 = **0.371** $10H_2O$: 180.0 ÷ 286.0 = **0.629**
5. Multiply each result by 100 in order to get a percentage.	**5.** Na_2CO_3: 0.371 x 100 = **37.1%** $10H_2O$: 0.629 x 100 = **62.9%**

Now you try one. Calculate the percent of water in barium iodide dihydrate.

Description of Action	Action
1. Write the formula for the compound.	**1.** $BaI_2 \cdot 2H_2O$
2. Calculate the molar mass of each part of the compound separately. Also, the number in front of the water molecule must be distributed and multiplied by the subscript of both the hydrogen and the oxygen in the water molecule.	**2.** Ba: 1 x 137.3 = 137.3 I: 2 x 126.9 = 253.8 **391.1** H: 4 x 1.0 = 4.0 O: 2 x 16.0 = 32.0 **36.0**
3. Add the totals for each part together to find the molecular formula mass.	**3.** 391.1 + 36.0 = **427.1**
4. Divide each part's total by the molecular formula mass.	**4.** **BaI_2:** 391.1 ÷ 427.1 = **0.916** **H_2O:** 36.0 ÷ 427.1 = 0.084
5. Multiply each result by 100 in order to get a percentage.	**5.** 0.916 x 100 **= 91.6%** 0.084 x 100 = **8.4%**

Part II: Determining the Empirical Formula of a Hydrate from its Percent Composition

In this section you will be given a percent composition or mass composition and have to work backwards to a formula.

Example #1: Given the following masses, determine the formula of the hydrate: 0.737g $MgSO_3$ and 0.763 g of H_2O.

Description of Action	Action
1. Calculate the molar mass of each compound.	**1.** $MgSO_3$ Mg: 1 x 24.3 = 24.3 S: 1 x 32.1 = 32.1 O: 3 x 16.0 = 48.0 **104.4** H_2O: H: 2 x 1.0 = 2.0 O: 1 x 16 = 16.0 **18.0**
2. Divide each molecule's percentage or mass by the total molecular mass. Remember to use significant figures.	**2.** $MgSO_3$: 0.737 ÷ 104.4 = **0.00706** H_2O: 0.763 ÷ 18.0 = **0.0424**
3. Divide each result by the smallest result.	**3.** $MgSO_3$: 0.00706 ÷ 0.00706 = **1.00** H_2O: 0.0424 ÷ 0.00706 = **6.01**
4. You will always get a whole number result. Write the formula by putting water's value in front of its formula. You will never have to do anything with the first compound	**4.** **$MgSO_3 \cdot 6H_2O$**
5. Name the compound.	**5. magnesium sulfite hexahydrate**

OK, your turn. Find the formula of a hydrate that is 76.9% $CaSO_3$ and 23.1% H_2O.

Description of Action	Action
1. Calculate the molar mass of the ionic compound and the water separately.	**1.** **$CaSO_3$** Ca: 1 x 40.1 = 40.1 S: 1 x 32.1 = 32.1 O: 3 x 16.0 = 48.0 **120.2** **H_2O** H: 2 x 1.0 = 2.0 O: 1 x 16.0 = 16.0 **18.0**
2. Divide each molecule's percentage by the total molecular mass. Remember to use significant figures	**2.** $CaSO_3$: 76.9 ÷ 120.2 = **0.640** H_2O: 23.1 ÷ 18.0 = **1.28**
3. Divide each result by the smallest result. Remember to use significant figures.	**3.** $CaSO_3$: 0.640 ÷ 0.640 = **1.0** H_2O: 1.28 ÷ 0.640 = **2.0**
4. You will always get a whole number result. Write the formula by putting water's value in front of its formula. You will never have to do anything with the first compound.	**4.** **$CaSO_3 \cdot 2H_2O$**
5. Name the compound (when possible).	**5. calcium sulfite dihydrate**

Homework:
Part I: Calculate the percent composition of water in each of the following compounds.
1. Calculate the percent of water in barium bromide dihydrate.
$BaBr_2 \cdot 2H_2O$
$BaBr_2$: 89.2%
H_2O: 10.8%

2. Calculate the percent of water in nickel(II) sulfite hexahydrate.
$NiSO_3 \cdot 6H_2O$
$NiSO_3$: 56.2%
H_2O: 43.8%

3. Calculate the percent of water in magnesium sulfite hexahydrate.
$MgSO_3 \cdot 6H_2O$
$MgSO_3$: 49.2%
H_2O: 50.8%

4. Calculate the percent of water in sodium borate decahydrate.
$Na_3BO_3 \cdot 10H_2O$
Na_3BO_3: 41.5%
H_2O: 58.5%

5. Calculate the percent of water in sodium acetate trihydrate.
$NaC_2H_3O_2 \cdot 3H_2O$
$NaC_2H_3O_2$: 60.3%
H_2O: 39.7%

6. Calculate the percentage of water in sodium thiosulfate pentahydrate.
$Na_2S_2O_3 \cdot 5H_2O$
$Na_2S_2O_3$: 63.7%
H_2O: 36.3%

7. Calculate the percentage of water in strontium chloride dihydrate.
$SrCl_2 \cdot 2H_2O$
$SrCl_2$: 81.5%
H_2O: 18.5%

Part II: Determine the formula and name for the following hydrates.
8. What is the formula for a hydrate that is 86.7% Mo_2S_5 and 13.3% H_2O?
$Mo_2S_5 \cdot 3H_2O$
molybdenum(V) sulfide trihydrate

9. What is the formula for a hydrate that is 76.1% $La_2(CO_3)_3$ and 23.9% H_2O?
$La_2(CO_3)_3 \cdot 8H_2O$
lanthanum carbonate octahydrate

10. Find the formulas for the hydrate with the following analysis: 5.262 g $Tl(NO_3)_3$ and 0.728 g H_2O.
$Tl(NO_3)_3 \cdot 3H_2O$
thallium(III) nitrate trihydrate

11. Find the formula for the hydrate composed of compounds with the following masses: 2.94 g $Sn(NO_3)_2$ and 4.37 g H_2O.
$Sn(NO_3)_2 \cdot 20H_2O$
tin(II) nitrate didecahydrate

12. Determine the empirical formula for a hydrate that is 62.8% $Ni(NO_3)_2$ and 37.2% H_2O.
$Ni(NO_3)_2 * 6H_2O$
nickel(II) nitrate hexahydrate

13. Calculate the empirical formula for a hydrate that is 63.9% $CuSO_4$ and 36.1% H_2O.
$CuSO_4 * 5H_2O$
copper(II) sulfate pentahydrate

14. Calculate the empirical formula for a hydrate that is 49.2% $MgSO_4$ and 50.8% H_2O.
$MgSO_4 * 7H_2O$
magnesium sulfate heptahydrate

15. Calculate the empirical formula for a compound that is 54.6% $CoCl_2$ and 45.3% H_2O.
$CoCl_2 * 6H_2O$
cobalt(II) chloride hexahydrate