

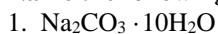
Hydrates

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: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. 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**

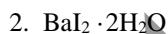
The prefixes used for naming hydrates are as follows:

Prefix	Moles of Water	Name	Formula
mono-	1	monohydrate	$\text{XY} \cdot \text{H}_2\text{O}$
di-	2	dihydrate	$\text{XY} \cdot 2\text{H}_2\text{O}$
tri-	3	trihydrate	$\text{XY} \cdot 3\text{H}_2\text{O}$
tetra-	4	tetrahydrate	$\text{XY} \cdot 4\text{H}_2\text{O}$
penta-	5	pentahydrate	$\text{XY} \cdot 5\text{H}_2\text{O}$
hexa-	6	hexahydrate	$\text{XY} \cdot 6\text{H}_2\text{O}$
hepta-	7	heptahydrate	$\text{XY} \cdot 7\text{H}_2\text{O}$
octa-	8	octahydrate	$\text{XY} \cdot 8\text{H}_2\text{O}$
nona-	9	nonahydrate	$\text{XY} \cdot 9\text{H}_2\text{O}$
deca-	10	decahydrate	$\text{XY} \cdot 10\text{H}_2\text{O}$

Name the following hydrates:



sodium carbonate decahydrate



barium iodide dihydrate

Write the formula for the following hydrates:

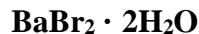
1. sodium tetraborate decahydrate



2. nickel(II) sulfite hexahydrate



3. barium bromide dihydrate

**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. $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$
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: $2 \times 23.0 = 46.0$ C: $1 \times 12.0 = 12.0$ O: $3 \times 16.0 = 48.0$ 106.0 H: $20 \times 1.0 = 20.0$ O: $10 \times 16.0 = 160.0$ 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. $\text{Na}_2\text{CO}_3: 106.0 \div 286.0 = 0.371$ $10\text{H}_2\text{O}: 180.0 \div 286.0 = 0.629$
5. Multiply each result by 100 in order to get a percentage.	5. $\text{Na}_2\text{CO}_3: 0.371 \times 100 = 37.1\%$ $10\text{H}_2\text{O}: 0.629 \times 100 = 62.9\%$

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. $\text{BaI}_2 \cdot 2\text{H}_2\text{O}$
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: $1 \times 137.3 = 137.3$ I: $2 \times 126.9 = \underline{253.8}$ 391.1 H: $4 \times 1.0 = 4.0$ O: $2 \times 16.0 = \underline{32.0}$ 36.0
3. Add the totals for each part together to find the molecular formula mass.	3. $391.1 + 36.0 = \mathbf{427.1}$
4. Divide each part's total by the molecular formula mass.	4. $\text{BaI}_2: 391.1 \div 427.1 = \mathbf{0.916}$ $\text{H}_2\text{O}: 36.0 \div 427.1 = 0.084$
5. Multiply each result by 100 in order to get a percentage.	5. $0.916 \times 100 = \mathbf{91.6\%}$ $0.084 \times 100 = \mathbf{8.4\%}$

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 MgSO₃ and 0.763 g of H₂O.

Description of Action	Action
1. Calculate the molar mass of each compound.	1. MgSO ₃ Mg: $1 \times 24.3 = 24.3$ S: $1 \times 32.1 = 32.1$ O: $3 \times 16.0 = \underline{48.0}$ 104.4 H ₂ O: H: $2 \times 1.0 = 2.0$ O: $1 \times 16 = \underline{16.0}$ 18.0
2. Divide each molecule's percentage or mass by the total molecular mass. Remember to use significant figures.	2. MgSO ₃ : $0.737 \div 104.4 = \mathbf{0.00706}$ H ₂ O: $0.763 \div 18.0 = \mathbf{0.0424}$
3. Divide each result by the smallest result.	3. MgSO ₃ : $0.00706 \div 0.00706 = \mathbf{1.00}$ H ₂ O: $0.0424 \div 0.00706 = \mathbf{6.01}$
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. $\text{MgSO}_3 \cdot 6\text{H}_2\text{O}$
5. Name the compound.	5. magnesium sulfite hexahydrate

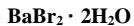
OK, your turn. Find the formula of a hydrate that is 76.9% CaSO₃ and 23.1% H₂O.

Description of Action	Action
1. Calculate the molar mass of the ionic compound and the water separately.	1. CaSO ₃ Ca: $1 \times 40.1 = 40.1$ S: $1 \times 32.1 = 32.1$ O: $3 \times 16.0 = \underline{48.0}$ 120.2 H ₂ O H: $2 \times 1.0 = 2.0$ O: $1 \times 16.0 = \underline{16.0}$ 18.0
2. Divide each molecule's percentage by the total molecular mass. Remember to use significant figures	2. CaSO ₃ : $76.9 \div 120.2 = \mathbf{0.640}$ H ₂ O: $23.1 \div 18.0 = \mathbf{1.28}$
3. Divide each result by the smallest result. Remember to use significant figures.	3. CaSO ₃ : $0.640 \div 0.640 = \mathbf{1.0}$ H ₂ O: $1.28 \div 0.640 = \mathbf{2.0}$
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. $\text{CaSO}_3 \cdot 2\text{H}_2\text{O}$
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.

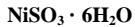
1. Calculate the percent of water in barium bromide dihydrate.



BaBr₂: 89.2%

H₂O: 10.8%

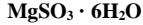
2. Calculate the percent of water in nickel(II) sulfite hexahydrate.



NiSO₃: 56.2%

H₂O: 43.8%

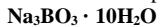
3. Calculate the percent of water in magnesium sulfite hexahydrate.



MgSO₃: 49.2%

H₂O: 50.8%

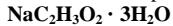
4. Calculate the percent of water in sodium borate decahydrate.



Na₃BO₃: 41.5%

H₂O: 58.5%

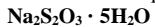
5. Calculate the percent of water in sodium acetate trihydrate.



NaC₂H₃O₂: 60.3%

H₂O: 39.7%

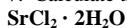
6. Calculate the percentage of water in sodium thiosulfate pentahydrate.



Na₂S₂O₃: 63.7%

H₂O: 36.3%

7. Calculate the percentage of water in strontium chloride dihydrate.

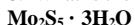


SrCl₂: 81.5%

H₂O: 18.5%

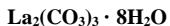
Part II: Determine the formula and name for the following hydrates.

8. What is the formula for a hydrate that is 86.7% Mo₂S₅ and 13.3% H₂O?



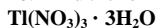
molybdenum(V) sulfide trihydrate

9. What is the formula for a hydrate that is 76.1% La₂(CO₃)₃ and 23.9% H₂O?



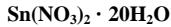
lanthanum carbonate octahydrate

10. Find the formulas for the hydrate with the following analysis: 5.262 g Tl(NO₃)₃ and 0.728 g H₂O.



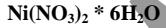
thallium(III) nitrate trihydrate

11. Find the formula for the hydrate composed of compounds with the following masses: 2.94 g Sn(NO₃)₂ and 4.37 g H₂O.



tin(II) nitrate didechydrate

12. Determine the empirical formula for a hydrate that is 62.8% Ni(NO₃)₂ and 37.2% H₂O.



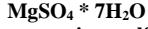
nickel(II) nitrate hexahydrate

13. Calculate the empirical formula for a hydrate that is 63.9% CuSO₄ and 36.1% H₂O.



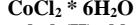
copper(II) sulfate pentahydrate

14. Calculate the empirical formula for a hydrate that is 49.2% MgSO₄ and 50.8% H₂O.



magnesium sulfate heptahydrate

15. Calculate the empirical formula for a compound that is 54.6% CoCl₂ and 45.3% H₂O.



cobalt(II) chloride hexahydrate