Hydrates and Water of Hydration

1. What is a hydrate? Hydrates are compounds that contain water within the structure of their crystal lattices. The water they contain is known as the **water of hydration**. One well known hydrate is Epsom salt, which is used as a bath salt and is symbolized as $MgSO_4 \bullet 7H_2O$. Its official name would be magnesium sulfate heptahydrate. The dot between $MgSO_4$ and $7H_2O$ means that water is actually a part of the hydrate molecule, and the molecular mass of the hydrate must include the water. When the water of hydration is driven out of the hydrate (usually by heat), the resulting "dry" crystal is called the **anhydrous** form.
[Remember the prefixes? mono, di, tri, tetra, penta, hexa, hepta, octa, nona, deca.]

2. How do you figure out the molecular mass of a hydrate? Add up the numbers from the periodic table like you usually do, only include the water.

Ex: $MgSO_4 \bullet 7H_2O$ [Note: water has a molecular mass of 18.02g/mol]

Mg:	24.31 g/mol
S:	32.07 g/mol
4O:	64.00 g/mol
7 H_2O:	126.14 g/mol
	246.52 g/mol

3. How can you figure out the percent of water in a hydrate?

The basic formula is:

$$\frac{\text{mass of the water in the hydrate}}{\text{mass of the hydrate including the water}} \times 100 = \text{percentage of the mass contributed by water}$$

Ex: $MgSO_4 \bullet 7H_2O$

a. mass of the water: 7×18.02 g/mol H_2O = 126.14 g/mol

b. mass of the hydrate: calculated above in #2 to be 246.52 g/mol

c. Figuring the percent:

$$\frac{\text{mass of } 7\,H_2O}{\text{mass of } MgSO_4 \bullet 7H_2O} = \frac{126.14 \text{ g/mol}}{246.52 \text{ g/mol}} \times 100 = 51.17\%$$

4. How can I figure out how much water is in a certain sample of a hydrate? When heated sufficiently, a hydrate will release all of its water molecules. Upon heating (symbolized by Δ) the hydrate becomes an anhydrous salt.

$MgSO_4 \cdot 7H_2O$ --------> $MgSO_4$ + $7H_2O$
(hydrate) (anhydrous salt plus water)

Upon heating, 1 mole of $MgSO_4 \cdot 7H_2O$ yields 1 mole of $MgSO_4$.
How many moles of H_2O result? Answer: 7.

Ex: Suppose you had 2.76 moles of $MgSO_4 \cdot 7H_2O$. How many moles of water would be released if it was heated?

$$\text{Answer: } 2.76 \text{ moles } MgSO_4 \cdot 7H_2O \times \frac{7 \text{ moles } H_2O}{1 \text{mole } MgSO_4 \cdot 7H_2O} = 19.3 \text{ moles } H_2O$$

Ex: How many grams of water would be in a 512 gram sample of $MgSO_4 \cdot 7H_2O$?
(In # 2 we figured that $MgSO_4 \cdot 7H_2O$ has a molecular mass of 246.52 g/mol. H_2O has a molecular mass of 18.02 g/mol.)

$$512 \text{ g } MgSO_4 \cdot 7H_2O \times \frac{1 \text{mol } MgSO_4 \cdot 7H_2O}{246.52 \text{ g}} \times \frac{7 \text{ mol } H_2O}{1 \text{mol } MgSO_4 \cdot 7H_2O} \times \frac{18.02 \text{ g } H_2O}{1 \text{mol } H_2O} = 262 \text{ g water}$$

5. How can I figure out the formula of a hydrate? It's all about moles!

Ex: When a 125.0 gram sample of $CoCl_2$ is heated, the remaining anhydrous salt has a mass of 68.2 grams. What is the formula for the hydrate? Or, in other words, if the formula is $CoCl_2 \cdot x\, H_2O$, find *x*.

a. Find the mass of the water that was driven off:

125.0 grams (mass of the hydrate)
\- 68.2 grams (mass of the anhydrous salt, $CoCl_2$)
56.8 grams (mass of the water that was driven off)

b. You're going to want to compare the number of moles of the dry $CoCl_2$ to the number of moles of the water that was driven off, so change the grams of $CoCl_2$ to moles and the grams of water to moles.

$CoCl_2$: Co : 58.93 g/mol
2Cl: 70.90 g/mol
129.83 g/mol

$$68.2 \text{ grams} \times \frac{1 \text{ mole}}{129.83 \text{ g}} = .525 \text{ moles } CoCl_2$$

H_2O: 2H: 2.02 g/mol
O: 16.00 g/mol
18.02 g/mol

$$56.8 \text{ grams} \times \frac{1 \text{ mole}}{18.02 \text{ grams}} = 3.15 \text{ moles } H_2O$$

c. Divide each mole result by the smallest mole result to figure out how many moles of water there are for every mole of $CoCl_2$. (Round your result to the nearest whole number.)

$$\frac{.525 \text{ moles } CoCl_2}{.525} = 1 \text{ mole } CoCl_2 \qquad \frac{3.15 \text{ moles } H_2O}{.525} = 6 \text{ moles } H_2O$$

The formula for the hydrate, then, is $CoCl_2 \cdot 6\, H_2O$. Its official name would be cobalt (II) chloride hexahydrate.