

## Hydrates

**Unit:** Moles

**NGSS Standards/MA Curriculum Frameworks (2016):** HS-PS1-2, HS-PS1-3

**Mastery Objective(s):** (Students will be able to...)

- Determine the number of water molecules in a hydrate

**Success Criteria:**

- Empirical formula is calculated correctly (if necessary).
- Number of water molecules in each formula unit is calculated correctly.
- Formula of hydrate is written correctly, with the empirical first, then a dot, then the number of H<sub>2</sub>O molecules.
- Algebra and rounding to appropriate number of significant figures is correct.

**Tier 2 Vocabulary:** hydrate

**Language Objectives:**

- Explain the concept of a hygroscopic compound.
- Explain the process of determining the amount of water in a hydrate, both numerically and experimentally.

**Notes:**

hydrate: an ionic solid that has H<sub>2</sub>O molecules loosely bound to its crystals.

water of hydration: the water molecules that are bound into a hydrate.

anhydrous: a compound that has had its water of hydration removed, usually by heating.

hygroscopic: a compound that can absorb water from the air. In a humid environment, an anhydrous compound will absorb water until it becomes the hydrate.

### Naming of Hydrates

The name of a hydrate is the name of the compound followed by a number prefix and the word "hydrate".

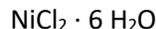
The number prefix (the same ones we used for molecular compounds; found in "Table J. Number Prefixes" on page 540 of your Chemistry Reference Tables) indicates the number of H<sub>2</sub>O molecules in the hydrate. For example, the compound nickel (II) chloride forms a hydrate that contains six water molecules. Its name is therefore:

nickel (II) chloride hexahydrate

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### Chemical Formula of a Hydrate

The chemical formula of a hydrate is the chemical formula of the compound followed by a dot and the number of H<sub>2</sub>O molecules bound to it. For example, the chemical formula of nickel (II) chloride hexahydrate is:



### Molar Mass of a Hydrate

The molar mass of a hydrate includes the mass of the water of hydration. This means a hydrate will have a larger molar mass than the anhydrous compound. For example, the molar mass of NiCl<sub>2</sub> is 129.60 g. The molar mass of H<sub>2</sub>O is 18.015 g. The molar mass of 6 H<sub>2</sub>O molecules is  $6 \times 18.015 = 108.09$  g.

Therefore, the molar mass of NiCl<sub>2</sub> · 6 H<sub>2</sub>O is  $129.60 + 108.09 = 237.69$  g

### Experimentally Determining the Water of Hydration

You can figure out the formula of a hydrate by weighing it, heating it to remove the water of hydration, and figuring out how many moles of water were removed for every mole of the compound.

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**Sample Problem:**

Q: Sodium sulfate forms a hydrate. We want to find the chemical formula of the hydrate. Suppose you weighed out 32.22 g of the hydrate. After heating it to remove all of the water, the final mass was 14.20 g.

A: The formula of anhydrous sodium sulfate is  $\text{Na}_2\text{SO}_4$ , which has a molar mass of 142.05 g. We have:

$$\frac{14.20 \text{ g Na}_2\text{SO}_4}{1} \times \frac{1 \text{ mol Na}_2\text{SO}_4}{142.05 \text{ g Na}_2\text{SO}_4} = 0.10 \text{ mol Na}_2\text{SO}_4$$

The amount of water removed was  $32.22 - 14.20 = 18.02 \text{ g}$ .

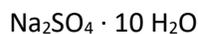
This 18.02 g of  $\text{H}_2\text{O}$  is:

$$\frac{18.02 \text{ g H}_2\text{O}}{1} \times \frac{1 \text{ mol H}_2\text{O}}{18.0152 \text{ g H}_2\text{O}} = 1.000 \text{ mol H}_2\text{O}$$

Our sample had 1 mole of  $\text{H}_2\text{O}$  and 0.1 mole of  $\text{Na}_2\text{SO}_4$ . This is 10 times as much  $\text{H}_2\text{O}$  as  $\text{Na}_2\text{SO}_4$ :

$$\frac{1 \text{ mol H}_2\text{O}}{0.1 \text{ mol Na}_2\text{SO}_4} = \frac{10 \text{ H}_2\text{O}}{1 \text{ Na}_2\text{SO}_4}$$

Therefore, the formula must be:



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3. 14.70 g of a hydrate of  $\text{CaCl}_2$  is heated to dryness. The anhydrous sample has a mass of 11.10 g after evaporating the  $\text{H}_2\text{O}$ . Use the following steps to determine the chemical formula of the hydrate.
- Find the moles of anhydrous compound left at the end.
  - Find the moles of water evaporated. (You'll need to find the grams of water evaporated, and then convert to moles.)
  - Find the ratio of the moles of water evaporated to the moles of the anhydrous compound. This will be the number of water molecules in the hydrate.
  - Write the formula for the hydrate (*using the number of water molecules that you found in part c*)?

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