Warm-Up | Hydrates

Percent Composition

Percent by [mass] of an element in a compound:

$$\%\ \text{by mass} = \left(\frac{\text{mass of element in compound}}{\text{molar mass of compound}}\right) \times 100$$

Example: What is the [percent] by mass of hydrogen (H) in water (H_2O)?

- [Molar] mass of hydrogen: 1.01 g/mol
- Mass of hydrogen in water: (2)(1.01 g/mol) = 2.02 g/mol
- Molar mass of water: 18.02 g/mol

$$\%\,\text{H} = \left(\frac{2.02\ \cancel{\text{g/mol}}}{18.02\ \cancel{\text{g/mol}}}\right) \times 100 = [11.2]\ \%$$

Lesson Objectives

By the end of this lesson, you should be able to:

- Calculate the percent mass of water in a hydrate.
- Describe hydrates and explain how hydrates are named.
- Explore uses of hydrates in industry and [technology].

Science Practice: Perform mathematical manipulations to calculate the percent mass of water in a hydrate.

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Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

anhydrous	a solid compound with no associated water
hydrate	describes a compound formed by the addition of water molecules to molecules in the crystal state

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Lesson Question

What happens when water becomes trapped in a solid ionic compound?

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Hydrates

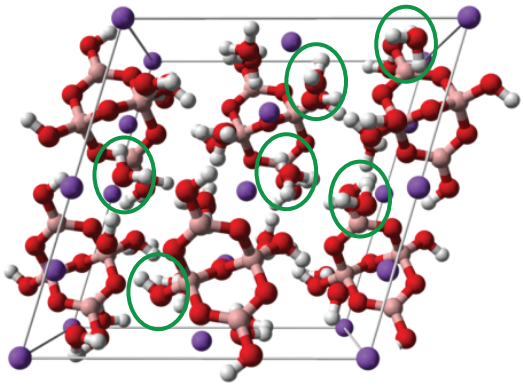
A **hydrate** is a compound formed by the addition of [water] molecules to molecules in the crystal state.

- Water molecules are incorporated into a [crystal] lattice.
  - They are not bonded to the compound.
- Water is present in fixed [ratios].
- **Anhydrous** refers to a solid compound with no associated water. This form can be produced by heating.

Structure of a Hydrate

In many [crystalline] hydrates:

- water is incorporated into the crystal structure.
- water molecules are held in [fixed] positions.



$Na_2B_4O_5(OH)_4 \cdot 8H_2O$

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Naming Hydrates

What is the name of the hydrate $Na_2B_4O_5(OH)_4 \cdot 8H_2O$?

- Start with the name of the [anhydrous] compound.
  - $Na_2B_4O_5(OH)_4$: [sodium] tetraborate
- Identify the [Greek] prefix for the coefficient on the water molecules.
  - [8] = *oct-*
- Combine the anhydrous name, the prefix, and the term *hydrate*.
  - Sodium tetraborate octahydrate

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Writing Hydrate Formulas

Write the chemical formula for the hydrate cobalt (II) chloride hexahydrate.

- Write the formula of the anhydrous compound.
  - cobalt (II) [chloride]: $CoCl_2$
- Identify the Greek prefix for the coefficient on the water molecules.
  - *hex-* = [6]
- Combine the anhydrous formula, the prefix, and the formula for water.
  - [$CoCl_2 \cdot 6H_2O$]

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Calculating Percent Water in a Hydrate

If 10.45 g of the hydrated form of $ZnCl_2$ is heated in an oven for several hours, the mass drops to 6.84 g. Assuming this missing mass is due to waters of hydration evaporating, calculate the [percent] of water in the [original] hydrate.

- Calculate the mass of the water that was lost.

$10.45\ \text{g} - 6.84\ \text{g} =$ [3.61] g

- Divide the mass of the water by the mass of the hydrate and convert to a percent.

$\frac{3.61\ \text{g}}{10.45\ \text{g}} \times 100 =$ [34.5] %

Calculating Percent Water in a Hydrate

- Calculate the mass of the water lost during [dehydration]

mass of hydrate − mass of anhydrous = mass of water

- Calculate the percent by mass of water

$$\%\ \text{water} = \left(\frac{\text{mass of water}}{\text{mass of hydrate}}\right) \times 100$$

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Determining the Formula for a Hydrate

A sample of hydrated $CuCl_2$, copper (II) chloride, has a mass of 0.235 g. When it is heated and [dehydrated], the anhydrous sample has a mass of 0.185 g. What is the chemical formula for the hydrate?

- Calculate the number of [moles] of anhydrous compound in the sample.

  $0.185\ g / 134.45\ g =$ [1.376×10^{-3}] moles

- Calculate the number of moles of water present in the hydrate.

$$\begin{array}{r} 0.235 \\ -0.185 \\ \hline .050g \end{array}$$

$0.050\ g / 18.02\ g/mol =$ [2.78×10^{-3}] mol of water

Calculation continuation . . .

- Calculate the molar ratio of water to the anhydrous compound.

$$\frac{2.78 \times 10^{-3}\ mol}{1.376 \times 10^{-3}\ mol} = [2.0]$$

- Round to the nearest integer and write the chemical formula according to the [rules] for writing hydrate formulas.

[$CuCl_2 \cdot 2H_2O$]

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Determining the Formula for a Hydrate

- Calculate the number of moles of anhydrous compound in the sample.
  - Calculate the molar mass of the anhydrous compound.
  - Use [dimensional] analysis.
- Calculate the number of moles of water present in the hydrate.
  - Molar mass of water = 18.02 g/mol
- Calculate the molar ratio of water to the [anhydrous] compound.

$$\text{mole ratio} = \frac{\#\text{moles } H_2O}{\#\text{moles anhydrous compound}}$$

- Round to the nearest integer and write the chemical formula according to the rules for writing hydrate formulas.

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Absorbent Gels

Super-absorbent materials

- Super-absorbing [polymers] can absorb 300 to 500 times their weight in water.
- Each [monomer] is a salt of a carboxylic acid, which binds water tightly.
- Polymers have millions of water-absorbing monomers per molecule.
- Water absorbed into a polymer becomes a gel.

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Hydrates Are Everywhere

Uses of hydrates:

- Desiccants
- Fuel-filtering systems
- Water retention in soils
- Toys (slime)
- Fire extinguishers
- Artificial snow
- Wound dressings
- Toxic-spill cleanup

Summary | Hydrates

Lesson Question

What happens when water becomes trapped in an ionic compound?

Answer

(Sample answer) In an ionic compound, water is incorporated into the crystal structure. The water molecules are held in fixed positions within the solid. The amount of water in a hydrate is calculated using the mass of hydrated compound minus the mass of the compound in an anhydrous state.

Slide 2

Hydrate Names and Formulas

- Hydrates are compounds with water molecules incorporated into the crystal structure.
- Waters of hydration are often present in stoichiometric amounts.
- Strong [dipole-dipole] forces keep the waters in place.
- Hydrates can be “dehydrated” by gentle heating.
- Chemical formulas for hydrates use “dot” notation.
- Names of hydrates use Greek prefixes to indicate the number of water molecules per formula unit.

Summary | Hydrates

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Calculations Involving Hydrates

- The [percent] by mass of water in a hydrate can be calculated if the mass of the hydrate and the mass of the anhydrous sample are known.
- The chemical formula for a hydrate can be determined by calculating the molar ratio of water to anhydrous compound in the sample.

Uses of Hydrates

- Some uses of hydrates rely on their ability to absorb water.
  - Diapers
  - Desiccants
  - Fuel filters
- Some uses of hydrates rely on their ability to store and release water.
  - Soil conditioners
  - Flame retardants
- Some hydrates are valued for their [physical] properties.
  - Toys
  - Artificial snow

Summary | Hydrates

Use this space to write any questions or thoughts about this lesson.