# Unit: Unit 3: Chemical Reactions and Stoichiometry

## Chapter: Chapter 10: Stoichiometry

### Lesson: Lesson 4: Hydrates: Their Formulas and Reactions

### Lesson Plan: "Lesson 4: Hydrates: Their Formulas and Reactions"

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### 1. Big Idea:

Hydrates are compounds that include water molecules as part of their structure, and understanding their formulas helps analyze their role in chemical reactions.

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### 2. Phenomenon-Based Learning:

**Unit Phenomenon:**

How can chemical reactions help improve safety features?

**Chapter Phenomenon:**

Chemical equations and the ratios of the substances involved provide insight into how materials are transformed during reactions.

**Lesson Phenomenon:**

Water can sometimes behave differently in a chemical reaction by being part of a compound, like in hydrates. These water-containing compounds affect calculations and reaction outcomes.

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### 3. Vocabulary:

- **Anhydrous formula:** The formula of a compound without water molecules attached.

- **Greek prefix:** A prefix derived from Greek used to indicate the number of water molecules in a hydrate (e.g., mono-, di-, tri-).

- **Hydrates:** Compounds that contain water molecules as part of their crystal structure.

- **Hydrate formula:** The chemical formula of a hydrate (e.g., CuSO₄·5H₂O), showing how many water molecules are attached.

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### 4. SMART Objectives:

By the end of this lesson, learners will be able to:

- Calculate the percent by mass of water in a hydrate.

- Predict the products of reactions involving hydrates.

- Analyze the factors that affect the percent yield of a reaction.

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### 5. Engage (Ignite):

### # Activity: "Finding Water in a Hydrate"

**Materials:**

- Epsom salt (a common hydrate, MgSO₄·7H₂O)

- Heat-safe glass dish or aluminum foil

- Bunsen burner or a candle

- Tongs

- Balance

**Procedure:**

1. Weigh a small amount (about 5 grams) of Epsom salt using a balance. Record the value.

2. Place the salt in a heat-safe dish and gently heat it over a flame. Observe carefully.

3. Note any changes in appearance or texture. You’ll see the salt lose its crystal structure and turn powdery as water evaporates.

4. Remove the dish from heat (use tongs!) and let it cool. Weigh it again.

**Related Questions:**

- What happens to the mass of the salt after heating?

**Answer:** The mass decreases because the water molecules have evaporated.

- Why do you think water is part of the original salt?

**Answer:** It exists as part of the hydrate structure, bonded to the compound.

- How does the loss of water affect the chemical formula?

**Answer:** The formula changes from MgSO₄·7H₂O to MgSO₄, removing the water molecules.

### # AI Integration:

Use a chemistry AI tool (such as ChemCollective or online stoichiometry calculators) and input your observations (e.g., mass before and after heating) to calculate the percent water in the hydrate. Discuss how the tool simplifies these calculations.

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### 6. Pre-Explore (Direct Instruction):

### # Prior Knowledge:

- From 7th grade: The concept of chemical formulas and how elements combine to form compounds.

- From 8th grade: Law of conservation of mass and the basics of chemical reactions.

### # Real-World Connection:

Water is everywhere—even in solid materials. For example, construction materials like plaster or concrete contain hydrates, which influence their properties. The careful removal or addition of water can change the material’s strength and durability.

### # Background Information:

Hydrates are unique because their structure includes water molecules not simply mixed in, but chemically bonded in a specific ratio. When hydrates are heated, the water is released, leaving behind an “anhydrous” form of the compound. For example:

\[

CuSO₄·5H₂O \ \xrightarrow{\text{heat}} \ CuSO₄ + 5H₂O

\]

The water molecules in hydrates are represented using Greek prefixes. For example:

- **Monohydrate:** 1 water molecule (e.g., Na₂CO₃·H₂O)

- **Dihydrate:** 2 water molecules (e.g., CaCl₂·2H₂O)

- **Pentahydrate:** 5 water molecules (e.g., CuSO₄·5H₂O)

### # Interactive Notes:

- Write down the formula for a hydrate and identify the number of attached water molecules.

- Discuss how this water changes the mass of the substance and why it's important to consider in calculations.

**Scaffolded Question:**

Why do we need to account for the water in hydrates when performing stoichiometric calculations?

**Answer:** The water molecules contribute to the total mass and play a role in reactions when released or added.

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**Next Step:** Move from foundational knowledge into the "Explore" phase to calculate the percent composition and analyze reactions involving hydrates!

# Chapter 7: Understanding How Chemical Reactions Improve Safety Features

### Lesson 4: Hydrates – Their Formulas and Reactions

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## Introduction

Chemical reactions are all around us, often hiding in plain sight. They’re responsible for cooking food, powering engines, and even inflating airbags to save lives during car accidents. But chemical reactions aren’t random – they follow specific rules and relationships. In this lesson, we’ll explore one fascinating aspect of chemistry: hydrates. These substances contain water molecules as part of their structure, and understanding how they behave can help us predict the outcomes of some chemical reactions.

Hydrates may seem simple, but they play a big role in understanding the science behind airbags and even in managing real-world challenges, such as making sure reactions are safe and efficient. Let’s dive in to uncover their secrets!

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## 1. What Are Hydrates?

Imagine a sponge soaked with water. It looks solid, but it holds water inside it. Hydrates are a bit like that, except the water is chemically bonded to the solid substance. A **hydrate** is a compound that contains water molecules within its crystal structure. The water molecules are part of the compound, not just sitting on the surface.

### Vocabulary Connection:

- **Hydrate**: A compound that contains water molecules as part of its structure.

- **Anhydrous**: A substance that does not contain water. For example, when you remove the water from a hydrate, you are left with an **anhydrous compound**.

- **Greek Prefix**: These are used in hydrate formulas to indicate how many water molecules are present (e.g., "mono-" for one, "di-" for two, "tri-" for three, etc.).

### Example:

A common hydrate is **copper(II) sulfate pentahydrate** (CuSO₄·5H₂O). The "·5H₂O" means that for every one formula unit of CuSO₄, there are 5 water molecules chemically bonded to it.

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## 2. The Formula of a Hydrate

The formula of a hydrate shows two parts:

1. The **anhydrous compound** (the "dry" part).

2. The **water molecules** bonded to it.

For example:

- **Calcium chloride dihydrate**: CaCl₂·2H₂O

- "CaCl₂" is the anhydrous part.

- "·2H₂O" means 2 water molecules are part of the structure.

### Real-World Connection:

Hydrates are used in everyday life! For example, **plaster of Paris** is made by heating the hydrate gypsum (CaSO₄·2H₂O) to remove water, leaving an anhydrous powder. When water is added back, the plaster hardens.

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## Sample Problem 1: Writing a Hydrate Formula

A sample of magnesium sulfate hydrate is analyzed and found to contain 7 water molecules for every formula unit of magnesium sulfate. What is its chemical formula?

**Solution:**

1. Identify the anhydrous part: Magnesium sulfate = MgSO₄.

2. Count the water molecules: 7 = "hepta-" in Greek.

3. Write the formula: **MgSO₄·7H₂O**.

**Practice Question:**

What is the formula for barium chloride dihydrate?

**(Answer: BaCl₂·2H₂O)**

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## 3. Calculating Percent by Mass of Water in a Hydrate

One way to analyze hydrates is to calculate the percentage of their mass that comes from water. This is called the **percent by mass of water**.

### Formula:

\[ \text{Percent by mass of water} = \left( \frac{\text{Mass of water}}{\text{Total mass of hydrate}} \right) \times 100 \]

### Example:

Find the percent by mass of water in CuSO₄·5H₂O.

**Step 1:** Calculate the molar mass of the hydrate.

- Cu = 63.55 g/mol

- S = 32.07 g/mol

- O₄ = 4 × 16.00 g/mol = 64.00 g/mol

- 5H₂O = 5 × (2 × 1.01 + 16.00) g/mol = 90.10 g/mol

- Total = 63.55 + 32.07 + 64.00 + 90.10 = **249.72 g/mol**

**Step 2:** Calculate the mass of water.

- 5H₂O = 90.10 g/mol

**Step 3:** Use the formula.

\[ \text{Percent by mass of water} = \left( \frac{90.10}{249.72} \right) \times 100 = 36.07\% \]

### Practice Question:

Calculate the percent by mass of water in BaCl₂·2H₂O.

**(Answer: 14.75%)**

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## 4. Predicting Reactions Involving Hydrates

Hydrates can undergo certain chemical reactions, often related to losing their water molecules. When a hydrate is heated, it usually releases its water and becomes **anhydrous**. This process is called **dehydration**.

### Reaction Example:

**CuSO₄·5H₂O (s) → CuSO₄ (s) + 5H₂O (g)**

Here, the hydrate copper(II) sulfate pentahydrate loses water and becomes the anhydrous form, CuSO₄.

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## Real-World Application: Airbags!

How do hydrates connect to airbags? While airbags don’t directly involve hydrates, they rely on carefully controlled chemical reactions that produce gas rapidly. For example, sodium azide (NaN₃) is used to generate nitrogen gas (N₂) almost instantly during a crash. Engineers must ensure that the chemical reactions produce safe byproducts – similar to how the water in hydrates can affect the outcome of chemical reactions.

Understanding hydrates helps chemists predict the behavior of water in reactions, minimizing risks and maximizing efficiency.

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## Sample Problem 2: Predicting the Product of a Hydrate Reaction

What is the product when heating MgSO₄·7H₂O?

**Solution:**

When heated, the hydrate loses its water:

\[ \text{MgSO₄·7H₂O (s) → MgSO₄ (s) + 7H₂O (g)} \]

**Practice Question:**

Write the reaction for the dehydration of CaCl₂·2H₂O.

**(Answer: CaCl₂·2H₂O (s) → CaCl₂ (s) + 2H₂O (g))**

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## 5. Factors Affecting Percent Yield

In the real world, reactions don’t always go perfectly. Engineers designing airbags or manufacturers working with hydrates need to consider the **percent yield** – the amount of product they actually get compared to what they expect.

### Factors That Affect Percent Yield:

1. **Incomplete reactions**: Not all reactants may convert to products.

2. **Impurities**: Other substances in the mixture might interfere.

3. **Loss of product**: Some product may be lost during handling.

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## Sample Problem 3: Percent Yield

You expect to produce 10.0 g of anhydrous CuSO₄ from CuSO₄·5H₂O, but you only collect 8.5 g. What is the percent yield?

**Solution:**

\[ \text{Percent Yield} = \left( \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \right) \times 100 \]

\[ \text{Percent Yield} = \left( \frac{8.5}{10.0} \right) \times 100 = 85.0\% \]

**Practice Question:**

A reaction is expected to produce 12.0 g of anhydrous MgSO₄ but only yields 9.0 g. What is the percent yield?

**(Answer: 75.0%)**

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## Progress Check Questions

1. What is the formula for sodium carbonate decahydrate?

**(Answer: Na₂CO₃·10H₂O)**

2. If a hydrate contains 3 water molecules for every formula unit of the compound, what Greek prefix would be used?

**(Answer: "Tri-")**

3. Calculate the percent by mass of water in Na₂CO₃·10H₂O.

**(Answer: 62.9%)**

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By understanding hydrates, their reactions, and how to calculate critical factors like percent by mass and percent yield, you’re building skills that connect to real-world applications, from creating safer cars to developing efficient industrial processes. Chemistry saves lives – and now you know part of the "how"!

### 9. Elaborate (Power Up):

**Question 1:** Why do you think water is called the "universal solvent"? Can you give an example from daily life where this property of water is useful?

**Answer:** Water is called the "universal solvent" because it can dissolve many substances due to its polar nature. An example is sugar dissolving in water to make sweet tea. This helps us understand how substances mix in solutions in our daily lives.

**Question 2:** What might happen if water couldn’t dissolve substances? How would this affect living organisms?

**Answer:** If water couldn’t dissolve substances, nutrients and minerals wouldn’t be transported in our bodies or in plants. For instance, blood (which is mostly water) wouldn’t carry oxygen or nutrients to our cells.

**Mini-task:** Create a list of at least three common solutions you use at home or school. Identify the solute and solvent in each.

- Example: Saltwater – Solute: Salt; Solvent: Water.

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### 10. Final Evaluation:

### # Debate Topic:

"Are synthetic materials (like plastics) more harmful or helpful to modern society?"

**Discussion Points:**

- Positive impacts of synthetic materials (e.g., durability, affordability).

- Environmental harm caused by plastics (e.g., pollution, non-biodegradability).

- Possible solutions like recycling or biodegradable plastics.

**Debate Paragraph:**

Synthetic materials such as plastics have revolutionized industries by providing cheap and durable options for packaging, construction, and technology. However, their environmental impact is significant, with oceans and landfills overloaded with plastic waste. The debate hinges on whether their benefits outweigh the long-term harm they cause, and how we can balance innovation with sustainability.

**MCQ:**

Which of the following is a suggested solution to reduce the environmental impact of plastics?

A) Increase plastic production

B) Use biodegradable alternatives

C) Stop all recycling programs

D) Ban the use of water bottles

**Correct Answer:** B) Use biodegradable alternatives.

**Explanation:** Biodegradable plastics can break down naturally, reducing pollution.

### # Assessment Questions:

**ACT-Style Multiple-Choice Questions:**

1. **What is the main reason water is a good solvent?**

A) It is non-polar.

B) It has strong ionic bonds.

C) It is a polar molecule.

D) It evaporates easily.

**Correct Answer:** C) It is a polar molecule.

**Explanation:** Water’s polarity allows it to interact with and dissolve polar substances.

2. **Why is it important for blood to be a good solvent?**

A) To keep the body cool.

B) To transport nutrients and oxygen.

C) To store heat in the body.

D) To make the blood thicker.

**Correct Answer:** B) To transport nutrients and oxygen.

**Explanation:** Blood’s solvent properties allow it to carry dissolved nutrients and oxygen throughout the body.

3. **Which of the following is an example of a solution?**

A) Sand mixed with water.

B) Oil floating on water.

C) Sugar dissolved in water.

D) Pebbles in a jar.

**Correct Answer:** C) Sugar dissolved in water.

**Explanation:** A solution is a homogeneous mixture, like sugar evenly dissolved in water.

4. **Which property of water contributes most to its role in regulating Earth’s climate?**

A) Its ability to dissolve gases.

B) Its high boiling point.

C) Its high specific heat capacity.

D) Its ability to expand when frozen.

**Correct Answer:** C) Its high specific heat capacity.

**Explanation:** Water absorbs and releases heat slowly, helping to moderate Earth’s temperature.

**Long-Answer Questions:**

1. **Explain why the polarity of water molecules makes it a good solvent. Use an example to support your answer.**

**Answer:** Water’s polarity means it has a slight positive charge on one side and a slight negative charge on the other. This allows it to attract and interact with charged or polar molecules. For example, salt dissolves in water because the positive part of water molecules attracts the negative chloride ions, while the negative part attracts the positive sodium ions.

2. **Describe how recycling plastics can reduce environmental damage. Provide an example of a recycling method.**

**Answer:** Recycling plastics reduces waste sent to landfills and oceans, decreases the need for new plastic production, and conserves resources. One method is mechanical recycling, where plastics are cleaned, melted, and reshaped into new products like bottles or packaging.

3. **Why is water vital to life in terms of its solvent properties? Discuss its role in both plants and humans.**

**Answer:** Water dissolves nutrients and minerals, allowing them to be transported. In humans, water in the bloodstream dissolves oxygen and nutrients for delivery to cells. In plants, water dissolves and carries nutrients from the soil to the leaves for photosynthesis.

4. **Compare and contrast the benefits and drawbacks of synthetic materials, focusing on their use in packaging.**

**Answer:** Synthetic materials like plastics are lightweight, durable, and inexpensive, making them ideal for packaging. However, their drawbacks include environmental pollution and long decomposition times. Efforts like biodegradable packaging are being developed to balance these issues.

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### 11. Extend (Beyond the Lesson):

**Tasks/Challenges:**

1. **Household Experiment:** Try dissolving different substances (e.g., salt, sugar, oil) in water. Record observations on what dissolves and what doesn’t. Think about the reasons why.

2. **DIY Recycling Project:** Create something useful from plastic waste, like a plant pot from a plastic bottle.

**Readings:**

- "The Life of a Plastic Bottle: From Creation to Recycling."

- "How Water Shapes Our World: The Science of Solvents."

**Hints for Upcoming Topics:**

- "In our next lesson, we’ll explore acids and bases. Did you know water plays a key role in determining how strong an acid or base is? Stay tuned to learn why!"