# Unit: Unit 3: Chemical Reactions and Stoichiometry

## Chapter: Chapter 10: Stoichiometry

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

# Lesson 4: Hydrates - Unraveling Water's Chemical Mysteries

## 1. Big Idea

The water molecules in hydrates are part of their structure, and understanding their formulas helps predict how these compounds behave in chemical reactions.

## 2. Essential Questions

- How do hydrates form, and how can we determine their composition?

- How do water molecules change a compound's properties?

- What role do hydrates play in real-world chemical systems?

## 3. Phenomenon-Based Learning

### Unit Phenomenon

How can chemical reactions help improve safety features?

### Chapter Phenomenon

How do quantities of particles, mass, and volume relate to each other in chemical equations?

### Lesson Phenomenon

Water is a complex substance that can be involved in chemical reactions in multiple ways. Sometimes it stands alone, and other times it's integrated into compounds as hydrates. How do these water-containing compounds affect chemical reactions?

## 4. Vocabulary

- **Hydrates**: Compounds that contain water molecules as part of their structure, represented in their chemical formulas.

- **Anhydrous formula**: The formula of a compound after all the water has been removed.

- **Greek prefix**: Prefixes used to indicate the number of water molecules in a hydrate.

- **Hydrate formula**: The complete formula of a hydrate, showing both the compound and its water molecules (e.g., CuSO₄·5H₂O).

## 5. SMART Objectives

- 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.

## 6. Engage (Ignite): The Crystal Water Challenge

### Phenomenon-Driven Exploration: Safety in Chemical Reactions

**Guiding Question**: How can understanding the hidden water in chemical compounds improve safety in real-world applications?

### # Hands-On Investigation: Crystal Water Transformation

**Materials**:

- Copper(II) sulfate pentahydrate (CuSO₄·5H₂O)

- White paper or ceramic tile

- Dropper or pipette

- Water

- Small heat-safe dish

- Candle or alcohol burner (with adult supervision)

- Safety goggles

- Tweezers or tongs

**Step-by-Step Procedure**:

1. **Observation Stage**:

- Examine the copper sulfate crystals

- Note their color, shape, and appearance

- Record initial observations in a data table

2. **Color Change Experiment**:

- Place a small amount of crystal on white paper

- Carefully add a drop of water

- Observe and document what happens

3. **Heating Transformation**:

- Carefully heat a small sample of the crystals

- Watch the color and physical changes

- Record detailed observations

**AI Exploration Task**:

Use an AI tool to investigate:

- "What happens to copper sulfate when it loses its water molecules?"

- "How do hydrates change during chemical reactions?"

**Reflection Questions**:

1. What color changes did you observe during the experiment?

**Answer**: The crystals likely changed from blue to white when heated or when water was removed.

2. How might the water molecules affect the compound's properties?

**Answer**: Water molecules can change the color, structure, and chemical reactivity of the compound.

3. Why do you think understanding hydrates is important for safety?

**Answer**: Knowing how compounds change can help predict their behavior in various conditions, crucial for designing safe chemical systems.

## 7. Pre-Explore (Direct Instruction)

### Connecting Prior Knowledge

- Recall how water is essential in everyday life and reactions

- Remember chemical formulas from previous grades

- Understand that compounds can have complex structures

### Real-World Link

Hydrates are everywhere! From silica gel packets that absorb moisture to concrete setting and hardening, these water-containing compounds play crucial roles in many processes.

### Background Information

Hydrates are special compounds where water molecules are chemically bonded to the main substance. They're not just wet—the water is an integral part of the chemical structure.

## 8. Explain (Lightbulb): Deep Dive into Hydrate Chemistry

### Big Idea: Water as a Structural Component

Hydrates are more than just compounds with water—they're chemical puzzles where water molecules are integral to the substance's very structure.

### # What Are Hydrates?

Hydrates are chemical compounds that contain water molecules as a fixed part of their crystal structure. This isn't just water mixed in—it's chemically bonded and mathematically precise.

**Key Characteristics**:

- Water molecules are part of the compound's formula

- Represented by a dot (·) in chemical notation

- Can dramatically change properties when water is added or removed

### ## Chemical Formula Decoding

**Example**: CuSO₄·5H₂O (Copper Sulfate Pentahydrate)

- CuSO₄: Base compound (anhydrous part)

- 5H₂O: Five water molecules integrated into the structure

- The dot (·) shows precise water attachment

### # Vocabulary Deep Dive

1. **Hydrates**:

- Compounds with water molecules chemically integrated into their structure

- Water is not a separate component but part of the chemical formula

2. **Anhydrous Formula**:

- The compound's formula after all water is removed

- Represents the "bare" chemical structure

3. **Greek Prefixes**:

- Special prefixes indicating water molecule count

- Examples:

**mono- (1 water molecule)**

**di- (2 water molecules)**

**penta- (5 water molecules)**

### # Calculating Water Content

**Problem-Solving Approach**:

Calculating the percent of water in a hydrate requires precise molar mass calculations.

**Sample Calculation**: Copper Sulfate Pentahydrate (CuSO₄·5H₂O)

**Step 1**: Calculate Molar Masses

- CuSO₄: 63.55 + 32.07 + (4 × 16.00) = 159.62 g/mol

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

- Total hydrate mass: 249.72 g/mol

**Step 2**: Percent Water Calculation

\[

\text{Percent Water} = \left( \frac{\text{Mass of Water}}{\text{Total Hydrate Mass}} \right) \times 100

\]

\[

= \left( \frac{90.10}{249.72} \right) \times 100 = 36.07\%

\]

**Practice Problem**:

Calculate the water percentage in Na₂CO₃·10H₂O (Sodium Carbonate Decahydrate)

**Solution**:

- Na₂CO₃ mass: 105.99 g/mol

- 10H₂O mass: 10 × 18.02 = 180.20 g/mol

- Total mass: 286.19 g/mol

- Percent water: \((\frac{180.20}{286.19}) \times 100 = 62.96\%\)

### # Real-World Safety Connections

**Airbag Chemistry**:

Hydrates in chemical systems can significantly impact reaction rates and gas production. In airbag design, understanding how water molecules interact can mean the difference between a life-saving deployment and a potential failure.

## 9. Elaborate (Power Up)

### Open-Ended Exploration

1. Design an experiment to demonstrate how water affects a chemical compound's properties.

2. Research real-world applications of hydrates in industry or technology.

### Extension Activities

- Create a poster explaining hydrate formation

- Develop a model showing water molecule integration in crystal structures

## 10. Final Evaluation

### Multiple Choice Questions

1. What does the dot (·) represent in a hydrate formula?

a) Multiplication

b) Chemical bonding of water molecules

c) Separation of compounds

d) Water dissolution

2. What happens when a hydrate is heated?

a) It becomes more complex

b) It loses water molecules

c) It increases in mass

d) It changes color permanently

### Constructed Response

Explain how understanding hydrates is important in chemical safety and design.

## 11. Extend (Beyond the Lesson)

### Research Opportunities

- Investigate hydrates in pharmaceutical preparations

- Explore hydration in mineral formations

- Study water's role in chemical stability

### Reflective Journal Prompt

Write about a time you observed water changing a substance's properties in everyday life.

## Safety and Ethical Considerations

- Always conduct chemical experiments under supervision

- Handle chemical compounds with care

- Understand the importance of precise measurements in chemical research

## Conclusion

Hydrates reveal chemistry's intricate dance—where water isn't just a passive participant, but an active molecular partner changing compounds' very essence.