Unit 2: Atomic Structure and Bonding

Chapter 7: Covalent Bonding

# Lesson 1 : Covalent Bonding and Molecular Structure

### 1. Big Idea:

- Covalent bonds are formed when atoms share electrons to achieve a stable electron configuration, resulting in the formation of molecules.

- This lesson builds on the chapter's big idea that covalent bonding is one of the key ways atoms combine to form compounds.

### 2. Essential Questions:

- **How do covalent bonds form, and how do they differ from ionic bonds?**

- Covalent bonds form when two atoms share one or more pairs of electrons to achieve stability. This is different from ionic bonds, where atoms transfer electrons. In covalent bonding, atoms are held together by shared electrons between them, while in ionic bonding, oppositely charged ions are attracted to each other.

### 3. Phenomenon-Based Learning:

### Phenomenon:

- **Unit Phenomenon:**

In northern countries, where winter brings extremely cold weather, streets and roads are often covered in ice and snow. This creates hazardous conditions for both pedestrians and drivers. To reduce these dangers, road salt is spread on icy streets to help melt the ice and snow. As the salt comes into contact with the ice, ice and snow seem to vanish. However, metal street signs and lampposts do not vanish under the same conditions.

- **Chapter Phenomenon:**

When road salt is spread on icy streets, it melts the ice into water. Although water in its liquid form looks different from ice, it is still the same substance. But does the molecular structure of water change? Is there a way to predict the shapes of molecules? We know that water dissolves salt, but why does it behave this way, and why don't all substances dissolve in water?

### 4. Vocabulary:

- **Covalent bond:** A chemical bond formed when atoms share one or more pairs of electrons.

- **Single bond:** A type of covalent bond where two atoms share one pair of electrons.

- **Double bond:** A type of covalent bond where two atoms share two pairs of electrons.

- **Triple bond:** A type of covalent bond where two atoms share three pairs of electrons.

### 5. SMART Objectives:

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

1. **Describe the formation of covalent bonds** between atoms and differentiate between single, double, and triple bonds.

2. **Identify the properties of covalent compounds** and compare them to ionic compounds.

3. **Construct Lewis structures for simple covalent molecules** such as H₂, O₂, and CO₂.

### 6. Engage (Ignite):

Begin the lesson by asking students:

- **Phenomenon-Related Question:**

"Why does water dissolve road salt in winter, but the metal signs and lampposts remain unchanged?"

To capture student interest, conduct a hands-on experiment:

**Hands-On Experiment:**

**Objective:** Observe the difference between covalent and ionic compounds when dissolved in water.

**Materials Needed:**

- Table salt (NaCl)

- Sugar (C₆H₁₂O₆)

- Two beakers

- Distilled water

- Stirring stick

**Procedure:**

1. Fill two beakers with distilled water.

2. Add a teaspoon of table salt to one beaker and stir.

3. Add a teaspoon of sugar to the other beaker and stir.

4. Observe what happens to each substance as it dissolves.

**Follow-Up Questions:**

1. Which substance dissolved more easily?

2. Does the sugar-water or salt-water solution conduct electricity?

3. What can you infer about the types of bonds in salt and sugar based on their behavior in water?

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

**Background Information:**

In the previous unit, we learned about ionic bonds, where atoms transfer electrons to form ions. Now, we explore **covalent bonds**—a different type of bond where atoms share electrons. Covalent bonding occurs in molecules like **water (H₂O)**, **oxygen (O₂)**, and **carbon dioxide (CO₂)**. These molecules are made possible through the sharing of electrons between atoms.

**Interactive Elements:**

- **Discussion:** Ask students to recall how ionic bonds work and compare them to covalent bonds.

- **Scaffolded Questions:**

- Why do atoms bond in the first place?

- How do shared electrons hold atoms together in covalent bonds?

- What would happen if atoms didn’t share electrons?

### 8. Evaluate (Progress Check) - Pre-Explore:

- **Question 1 (DOK 1):** What is a covalent bond, and how does it differ from an ionic bond?

- **Question 2 (DOK 2):** Why do atoms share electrons in a covalent bond? What benefit do they gain from sharing electrons?

- **Question 3 (DOK 3):** Compare the properties of salt (NaCl) and sugar (C₆H₁₂O₆) based on their behavior when dissolved in water. What does this tell you about the type of bonds in each substance?

### 9. Explain (Lightbulb):

Now let's dive deeper into covalent bonds and their properties.

### 9.1 Formation of Covalent Bonds:

Covalent bonds form when **atoms share electrons** to achieve a full outer electron shell, also known as a **stable electron configuration**. This is commonly seen in nonmetals. For example, in a **hydrogen molecule (H₂)**, each hydrogen atom has one electron. By sharing their electrons, they each achieve the electron configuration of helium, which is more stable.

- **Single Bond:**

- A **single bond** occurs when atoms share one pair of electrons. For example, in **H₂**, each hydrogen atom shares one electron with the other hydrogen atom, forming a single bond.

- **Double Bond:**

- A **double bond** happens when atoms share two pairs of electrons. A common example is **oxygen (O₂)**, where each oxygen atom shares two pairs of electrons with the other, creating a double bond.

- **Triple Bond:**

- A **triple bond** is formed when atoms share three pairs of electrons. **Nitrogen (N₂)** is an example of a molecule with a triple bond, where each nitrogen atom shares three pairs of electrons with the other.

**Sample Problem:**

**Question:** How many pairs of electrons are shared in a molecule of O₂?

**Answer:** In O₂, two pairs of electrons are shared between the oxygen atoms, forming a double bond.

**Progress Check:**

**Question:** How many pairs of electrons are shared in a molecule of N₂?

### 9.2 Properties of Covalent Compounds:

Covalent compounds have different properties compared to ionic compounds.

- **Low Melting and Boiling Points:**

Covalent compounds like **water (H₂O)** and **methane (CH₄)** have lower melting and boiling points compared to ionic compounds like **sodium chloride (NaCl)**. This is because the forces between molecules in covalent compounds are weaker than the forces between ions in ionic compounds.

- **Poor Conductors of Electricity:**

Covalent compounds generally do not conduct electricity because they do not have charged particles (ions). For example, water (H₂O) and sugar (C₆H₁₂O₆) do not conduct electricity in their solid or liquid forms.

- **Solubility:**

While some covalent compounds dissolve in water (like sugar), many do not (like oil). This depends on whether the covalent compound can interact with water molecules.

**Sample Problem:**

**Question:** Why does NaCl conduct electricity when dissolved in water, but sugar (C₆H₁₂O₆) does not?

**Answer:** NaCl is an ionic compound and breaks apart into ions when dissolved in water, which allows it to conduct electricity. Sugar, on the other hand, is a covalent compound and does not break into ions, so it does not conduct electricity.

**Progress Check:**

**Question:** Why do covalent compounds generally have low melting points compared to ionic compounds?

### 9.3 Constructing Lewis Structures:

**Lewis structures** are diagrams that represent the bonding between atoms in a molecule and the lone pairs of electrons that may exist. To draw a Lewis structure, follow these steps:

1. **Determine the total number of valence electrons** in the molecule.

2. **Arrange the atoms** with the least electronegative atom in the center (except for hydrogen, which is always on the outside).

3. **Pair electrons** to form covalent bonds.

4. **Distribute remaining electrons** as lone pairs around the atoms to complete the octet rule (for most atoms, except hydrogen, which requires only 2 electrons).

**Example: Water (H₂O)**

- Total valence electrons: 8 (2 from hydrogen, 6 from oxygen)

- The oxygen atom is in the center, with two hydrogen atoms attached by single bonds.

- Two lone pairs of electrons remain on the oxygen atom.

**Lewis Structure for H₂O:**

```

H

|

H - O :

```

**Example Problem:**

**Construct the Lewis structure for methane (CH₄).**

**Answer:**

- Total valence electrons: 8 (1 from each hydrogen, 4 from carbon)

- Carbon is the central atom, with four hydrogen atoms attached by single bonds.

**Progress Check:**

**Construct the Lewis structure for oxygen (O₂).**

### 10. Evaluate (Progress Check) - End of Lesson:

- **Question 1:** Explain the difference between a single, double, and triple covalent bond.

- **Question 2:** Why do covalent compounds tend to have low melting points?

- **Question 3:** Construct the Lewis structure for carbon dioxide (CO₂).

### 11. Extend (Wrap-Up and Reflection):

- **Reflection Question:** How does understanding covalent bonding help explain the behavior of substances in everyday life, like why sugar dissolves in water but oil does not?

- **Challenge Question:** Predict how the molecular shape of water changes when it freezes into ice. Does the way water molecules bond change the overall structure?

### 10. Evaluate (Progress Check)

This section confirms students' understanding of the key concepts covered in the "Explain" section. The questions are scaffolded to increase in difficulty, from basic recall to deeper analysis.

### Question 1 (DOK 1 - Recall):

**What is the chemical formula for water?**

**Answer:**

The chemical formula for water is **H₂O**. This means each water molecule has two hydrogen atoms and one oxygen atom.

### Question 2 (DOK 2 - Skill/Concept):

**Explain why water is a polar molecule.**

**Answer:**

Water is a polar molecule because the oxygen atom is more electronegative than the hydrogen atoms. This creates a difference in charge between the oxygen (slightly negative) and the hydrogen (slightly positive). The unequal sharing of electrons gives water its polarity.

### Question 3 (DOK 3 - Strategic Thinking):

**How does the polarity of water contribute to its ability to dissolve many substances?**

**Answer:**

The polarity of water allows it to dissolve many substances because the positive and negative ends of the water molecules can surround and interact with the positive and negative parts of other molecules. For example, when salt (NaCl) dissolves in water, the water molecules surround the Na⁺ and Cl⁻ ions, separating them and dissolving the salt.

### 11. Elaborate (Power Up)

In this section, students are encouraged to deepen their understanding through mini-tasks and open-ended questions that challenge them to think critically and apply what they’ve learned.

### Task 1 (DOK 2 - Conceptual Understanding):

**Draw a diagram of a water molecule. Label the hydrogen and oxygen atoms and indicate areas of positive and negative charge.**

**Answer:**

Students should draw a V-shaped water molecule, with the oxygen atom (O) at the center and the hydrogen atoms (H) attached to it at an angle. The oxygen side should be labeled as slightly negative (δ-) and the hydrogen sides as slightly positive (δ+).

### Task 2 (DOK 3 - Strategic Thinking):

**How would the properties of water change if it were a non-polar molecule?**

**Answer:**

If water were a non-polar molecule, it would not have the same ability to dissolve many substances, especially ionic compounds like salts. Water’s high boiling point and surface tension would also decrease, as these properties rely on the strong intermolecular forces (hydrogen bonds) formed by its polarity.

### Task 3 (DOK 3 - Extended Thinking):

**Design a simple experiment to test the solubility of different substances (e.g., salt, sugar, oil) in water.**

**Answer:**

Students could take three small containers of water and dissolve salt in the first, sugar in the second, and oil in the third. They would observe which substances dissolve and which do not. The salt and sugar would dissolve because they are polar, while the oil would not because it is non-polar.

### 12. Final Evaluation

This section assesses students' understanding of the unit through a mix of debate, multiple-choice, and long-answer questions.

### Debate Question (DOK 4 - Extended Thinking):

**"Should freshwater resources be conserved more carefully due to the unique properties of water?"**

**Arguments for Discussion:**

- Water’s ability to dissolve essential nutrients is critical for life.

- The unique properties of water (e.g., high specific heat) help regulate Earth's climate.

- Freshwater is a limited resource, and misuse may lead to scarcity.

### Multiple-Choice Questions (DOK 1-2)

**1. What is the main reason water is a polar molecule?**

a) The hydrogen atoms are larger than the oxygen atom.

b) Oxygen shares electrons equally with hydrogen.

c) Oxygen is more electronegative than hydrogen.

d) Water molecules are round.

**Answer:** c) **Oxygen is more electronegative than hydrogen.**

Explanation: The oxygen atom pulls electrons closer to itself, creating a negative charge around the oxygen and a positive charge around the hydrogen atoms.

**2. Which of the following substances is most likely to dissolve in water?**

a) Oil

b) Sodium chloride (NaCl)

c) Plastic

d) Copper

**Answer:** b) **Sodium chloride (NaCl)**

Explanation: Sodium chloride is an ionic compound, and water can dissolve it due to its polarity.

**3. What type of bond forms between water molecules?**

a) Covalent bond

b) Ionic bond

c) Hydrogen bond

d) Metallic bond

**Answer:** c) **Hydrogen bond**

Explanation: Hydrogen bonds form between the slightly positive hydrogen atom of one water molecule and the slightly negative oxygen atom of another.

**4. If water were non-polar, which property would likely be affected?**

a) Water’s ability to freeze

b) Water’s ability to dissolve salts

c) Water’s density

d) Water’s color

**Answer:** b) **Water’s ability to dissolve salts**

Explanation: Water’s polarity is what allows it to dissolve ionic compounds like salts.

### Long-Answer Questions (DOK 3-4)

**1. Explain how water’s high specific heat helps regulate Earth's climate.**

**Answer:**

Water’s high specific heat means it can absorb a lot of heat without a significant increase in temperature. This property helps regulate the Earth's climate by moderating temperature swings. Oceans, lakes, and rivers absorb heat during the day and release heat slowly at night, keeping temperatures within a narrower range.

**2. Describe how hydrogen bonds affect the properties of water.**

**Answer:**

Hydrogen bonds are responsible for many of water’s unique properties. They give water a high boiling point because it takes more energy to break the bonds between molecules. Hydrogen bonds also create surface tension, allowing small insects to walk on water, and cause water to expand when it freezes.

**3. How does the structure of a water molecule contribute to its role as a "universal solvent"?**

**Answer:**

Water’s polarity allows it to dissolve many substances, especially ionic and other polar compounds. The slightly positive hydrogen atoms attract negative ions, while the slightly negative oxygen atom attracts positive ions. This helps break apart compounds and dissolve them in water.

**4. If Earth had no water, how would life be different?**

**Answer:**

Without water, life as we know it would not exist. Water is essential for biochemical reactions, transporting nutrients, and regulating temperature in living organisms. Most life forms rely on the solvent properties of water to carry nutrients, remove waste, and maintain homeostasis. Earth’s climate would also likely be more extreme due to the lack of water’s temperature-regulating effects.

### 13. Extend (Beyond the Lesson)

This section provides additional tasks and resources to extend students' learning and allow them to apply their knowledge to real-world situations.

### Suggested Readings:

- **"The Water Cycle" by National Geographic:** This article provides an in-depth look at how water moves through the environment and its importance to life on Earth.

- **"Water: A Biography" by Giulio Boccaletti:** A book exploring the role water has played throughout human history and its impact on civilizations.

### Application Task:

**Real-World Problem:**

**"What would happen if our freshwater supplies were contaminated?"**

Students can research the effects of water contamination on ecosystems and human health. They can also explore solutions like water filtration and conservation efforts.

### Spaced Practice:

- **Week 1:** Review the properties of water and draw a diagram of a water molecule.

- **Week 2:** Revisit the concept of polarity and how water dissolves substances.

- **Week 3:** Take a quiz on the unique properties of water and their importance to life.

- **Week 4:** Write a short essay on how water’s properties affect climate and ecosystems.

These extended activities and spaced practice help reinforce students' understanding and encourage them to apply their knowledge to new scenarios.