Unit 2: Atomic Structure and Bonding

Chapter 7: Covalent Bonding

# Lesson 2: Naming and Writing Formulas for Covalent Compounds

# 1. Big Idea:

- Covalent compounds are formed when atoms share electrons and have distinct naming rules based on their molecular structure.

# 2. Essential Questions:

- **How do we name and write formulas for covalent compounds?**

Covalent compounds are named using specific rules that involve Greek prefixes to indicate the number of atoms. The chemical formulas are written by identifying the elements involved and using their respective prefixes to determine the number of atoms.

### 3. Phenomenon-Based Learning

**Unit Phenomenon:**

In northern countries, where winter brings extremely cold weather, streets and roads are often covered in ice and snow. To reduce dangers caused by the ice, road salt is spread on icy streets. The ice seems to vanish as it melts into liquid water. However, metal street signs or lampposts do not melt. Why does the salt dissolve, but not the metal?

**Chapter Phenomenon:**

When road salt is spread on ice, the salt dissolves in the water as it melts. But what happens to the chemical structure of water when it changes from solid ice to liquid water? Is the shape of the water molecule the same during both states?

In this lesson, we will move beyond water and explore how different molecules, like covalent compounds, are named and structured. Understanding how to name and write formulas for these compounds will help explain why some substances dissolve in water and others do not.

# 4. Vocabulary:

- **Naming Conventions:** The specific rules used to name chemical compounds, especially covalent compounds.

- **Greek Prefixes:** Words added to the beginning of a name to show the number of atoms in a covalent compound. For example:

- **Mono-** (1)

- **Di-** (2)

- **Tri-** (3)

- **Tetra-** (4)

- **Penta-** (5)

- **Hexa-** (6)

- **Hepta-** (7)

- **Octa-** (8)

- **Nona-** (9)

- **Deca-** (10)

# 5. SMART Objectives:

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

- Name covalent compounds given their chemical formulas.

- Write the chemical formulas for covalent compounds given their names.

- Determine and apply the rules for naming and writing formulas for covalent compounds.

**Specific, Measurable, Achievable, Relevant, and Time-based (SMART) objectives:**

- **S:** Accurately name covalent compounds using Greek prefixes.

- **M:** Write and name at least 5 covalent compounds correctly.

- **A:** Use the rules of covalent naming conventions with 90% accuracy.

- **R:** Understand the connection between molecular structure and naming.

- **T:** Complete the lesson within a 50-minute class period.

# 6. Engage (Ignite)

**Phenomenon-Related Task:**

Ask: “Why does salt dissolve in water, but metal doesn’t?”

- Explain that the answer lies in the different types of bonds holding these substances together. Salt is ionic, while metal has metallic bonds. Today, we will explore a different type of bond: covalent bonds. Covalent compounds, like water, have unique properties and naming rules.

**Hands-On Experiment: "Creating Covalent Models"**

**Objective:** Build simple covalent compounds using gumdrops and toothpicks as atoms and bonds.

**Materials:**

- Gumdrops (different colors to represent different elements)

- Toothpicks (to represent bonds)

- Paper and pencils for labeling

**Procedure:**

1. Assign each gumdrop color to an element (e.g., red for oxygen, blue for nitrogen, green for chlorine).

2. Use the toothpicks to represent covalent bonds. For example, if two atoms of hydrogen (yellow gumdrops) bond with one oxygen atom (red), you’ll create a model of water, H₂O.

3. Follow the naming rules to label each compound you create. For example, CO₂ is carbon dioxide.

4. Label your models with the correct covalent name and formula.

**Follow-Up Questions:**

1. How many atoms of each element are in your H₂O model? What prefix is used to show the number of hydrogen atoms?

2. If you wanted to make carbon tetrachloride (CCl₄), how many chlorine atoms would you need?

3. How does the structure of these models help you understand how covalent bonds work?

# 7. Pre-Explore (Direct Instruction)

**Background Information:**

Covalent compounds are formed when two or more nonmetals share electrons. Unlike ionic compounds, where electrons are transferred between atoms, covalent bonding involves sharing. This creates molecules that have very specific names and formulas.

In covalent compounds, the names tell us how many atoms of each element are present. To do this, we use Greek prefixes. The first element in the name keeps its normal name (e.g., carbon), while the second element’s name changes to end in “-ide.” For example, CO₂ is carbon dioxide, because it has one carbon atom and two oxygen atoms.

**Interactive Elements:**

- **Note:** The prefix “mono-” is only used on the second element if there is one atom of it, like in carbon monoxide (CO).

- **Discussion Prompt:** Why do you think we use different naming rules for covalent and ionic compounds?

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

**Scaffolded Questions:**

1. What makes covalent compounds different from ionic compounds?

2. How does the number of atoms in a molecule affect its name?

3. Why do we use prefixes like “di-” and “tri-” when naming covalent compounds?

### 9. Explain (Lightbulb)

**Core Concepts:**

1. **Covalent Bonds: How They Work**

Atoms in covalent compounds share electrons to become stable. When two nonmetals combine, they share their outer (valence) electrons. This sharing creates what we call a covalent bond. Unlike ionic bonds, where one atom gives up electrons, covalent bonds involve a tug-of-war where the electrons are shared equally or unequally.

Some examples of common covalent compounds are water (H₂O), carbon dioxide (CO₂), and methane (CH₄). In each case, the atoms are held together by shared electrons.

**Sample Problem:**

What is the chemical formula for a molecule formed by one sulfur atom and two oxygen atoms?

**Solution:**

Sulfur is "S" and oxygen is "O." If there are two oxygen atoms, the formula is SO₂, called "sulfur dioxide."

### Progress Check:

What is the name of the compound with the formula N₂O₄? (Answer: Dinitrogen tetroxide.)

2. **Naming Covalent Compounds with Greek Prefixes**

Covalent compounds are named using a system of prefixes that tell us how many atoms of each element are present in the molecule. These prefixes include:

- Mono- (1)

- Di- (2)

- Tri- (3)

- Tetra- (4)

- Penta- (5)

- Hexa- (6)

- Hepta- (7)

- Octa- (8)

- Nona- (9)

- Deca- (10)

**Rules for Naming Covalent Compounds:**

- The first element keeps its name, but if there is more than one atom, you add the appropriate prefix.

- The second element always gets a prefix and ends in “-ide.”

For example, CO₂ is called “carbon dioxide” because there is one carbon atom (no prefix needed) and two oxygen atoms (prefix “di-“).

**Sample Problem:**

What is the name of the compound with the formula P₄O₁₀?

**Solution:**

There are four phosphorus atoms and ten oxygen atoms, so the name is “tetraphosphorus decoxide.”

### Progress Check:

What is the correct name for SO₃? (Answer: Sulfur trioxide.)

3. **Writing Covalent Formulas from Names**

To write the formula of a covalent compound from its name, simply look at the prefixes. The prefix tells you how many atoms of each element are in the compound. For example:

- “Dinitrogen monoxide” means two nitrogen atoms (N₂) and one oxygen atom (O), so the formula is N₂O.

**Sample Problem:**

Write the formula for nitrogen trifluoride.

**Solution:**

Nitrogen is “N,” and “tri-” tells us there are three fluorine atoms. So, the formula is NF₃.

**Progress Check:**

Write the formula for carbon tetrachloride. (Answer: CCl₄)

# 10. Explore (Hands-On Activity)

**Hands-On Experiment: "Building Covalent Compounds"**

**Objective:**

Create physical models of covalent compounds using gumdrops and toothpicks, labeling them with the correct names and formulas.

**Procedure:**

1. Pick two or more elements (gumdrop colors) and use toothpicks to represent the bonds.

2. Build models based on the number of atoms in the compound (refer to the prefixes for guidance).

3. Write down the name and formula of each compound your model represents.

**Sample Compounds to Build:**

- Water (H₂O)

- Carbon dioxide (CO₂)

- Methane (CH₄)

**Follow-Up Questions:**

1. How do the prefixes help you determine the number of atoms in each compound?

2. What happens to the name of the compound if you add more atoms of one element?

3. Why do we use “mono-“ only for the second element in a compound?

### 11. Evaluate (Progress Check) - Post Explore

**Scaffolded Questions:**

1. Why do we use Greek prefixes when naming covalent compounds?

2. How can the name of a covalent compound help you write its chemical formula?

3. Why is it important to include “mono-“ for the second element in compounds like carbon monoxide?

# 12. Elaborate (Expand and Apply)

**Real-World Connection:**

Covalent compounds are all around us. Water, carbon dioxide, and methane are just a few examples of covalent compounds that play important roles in everyday life. Understanding how to name and write formulas for these compounds helps us understand the world better.

In cold climates, for example, the salt that melts ice on roads is an ionic compound, but many substances that don’t dissolve in water, like oil, are covalent. Knowing which compounds will dissolve in water and which won’t is crucial in many fields, from environmental science to cooking.

**Application Activity:**

Look around your house for products that contain covalent compounds. List at least three and research their chemical names and formulas.

### 10. Evaluate (Progress Check) - Explain

To evaluate student understanding, here are three scaffolded questions. These questions progress in difficulty based on Depth of Knowledge (DOK) levels.

### Question 1 (DOK 1 - Recall)

**Q:** What is the definition of an atom?

- **Answer:** An atom is the smallest unit of an element that retains the properties of that element. It consists of protons, neutrons, and electrons.

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

**Q:** How does the number of protons in an atom's nucleus affect the element's identity?

- **Answer:** The number of protons in an atom’s nucleus determines the element's atomic number, which defines the element. For example, an atom with 6 protons is a carbon atom.

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

**Q:** Compare and contrast isotopes of the same element. How do they differ, and how are they similar?

- **Answer:** Isotopes of the same element have the same number of protons but different numbers of neutrons. This means they share chemical properties (due to having the same number of protons and electrons) but may have different atomic masses.

# 11. Elaborate (Power Up)

To encourage deeper thinking, here are mini-tasks and open-ended questions:

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

**Q:** Consider the periodic table’s structure. Why are elements with similar properties arranged in the same group (column)?

- **Answer:** Elements in the same group have similar chemical properties because they have the same number of valence electrons, which influence how they react with other elements.

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

**Q:** How might changes in the number of neutrons in an atom affect its stability? Provide an example of an isotope and its use in real life.

- **Answer:** Changes in the number of neutrons can make an atom unstable, leading to radioactivity. For example, Carbon-14 is an unstable isotope used in carbon dating to determine the age of ancient materials.

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

**Q:** How does the arrangement of electrons in an atom influence its reactivity with other elements? Use an example from the periodic table to support your answer.

- **Answer:** The arrangement of electrons, particularly the number of electrons in the outermost shell (valence electrons), influences an atom's reactivity. For instance, sodium (Na) has one valence electron, making it highly reactive, especially with elements like chlorine (Cl), which needs one electron to complete its outer shell.

# 12. Final Evaluation

### Debate Question:

**Should the periodic table be organized by atomic mass instead of atomic number?**

- **Arguments for atomic mass:** Initially, the periodic table was arranged by atomic mass, and elements with similar properties often fell into groups.

- **Arguments for atomic number:** The modern periodic table is arranged by atomic number, which correctly reflects the element's identity and properties because the number of protons defines an element, not its mass.

### Assessment Questions:

### Multiple-Choice Questions:

**Q1:** What is the charge of a proton?

- (A) Negative

- (B) Positive

- (C) Neutral

- (D) Depends on the atom

- **Answer:** (B) Positive

- **Explanation:** Protons have a positive charge, and this charge is constant across all atoms.

**Q2:** Which subatomic particle is responsible for the chemical bonding of atoms?

- (A) Proton

- (B) Neutron

- (C) Electron

- (D) Nucleus

- **Answer:** (C) Electron

- **Explanation:** Electrons, particularly those in the outermost shell (valence electrons), are involved in chemical bonding.

**Q3:** What type of bond is formed when electrons are shared between two atoms?

- (A) Ionic bond

- (B) Covalent bond

- (C) Metallic bond

- (D) Hydrogen bond

- **Answer:** (B) Covalent bond

- **Explanation:** A covalent bond occurs when two atoms share electrons to achieve a full outer shell.

**Q4:** Which of the following elements is most reactive?

- (A) Neon

- (B) Oxygen

- (C) Fluorine

- (D) Nitrogen

- **Answer:** (C) Fluorine

- **Explanation:** Fluorine is the most reactive non-metal because it is highly electronegative and only needs one electron to complete its valence shell.

### Long-Answer Questions:

**Q1:** Explain how the periodic table is organized and how this organization reflects the properties of elements.

- **Answer:** The periodic table is organized by increasing atomic number (number of protons). Elements are arranged in rows (periods) and columns (groups or families). Elements in the same group have similar chemical properties because they have the same number of valence electrons. As you move across a period, elements become less metallic and more non-metallic in character.

**Q2:** Describe how ionic bonds form and give an example.

- **Answer:** Ionic bonds form when one atom donates an electron to another atom, resulting in the formation of ions. The atom that loses an electron becomes a positively charged ion, while the atom that gains the electron becomes a negatively charged ion. These opposite charges attract, forming an ionic bond. For example, sodium (Na) donates an electron to chlorine (Cl), forming sodium chloride (NaCl).

**Q3:** Compare the characteristics of metals, non-metals, and metalloids.

- **Answer:** Metals are typically shiny, conductive, malleable, and ductile. Non-metals are often dull, brittle (if solid), and poor conductors of heat and electricity. Metalloids have properties intermediate between metals and non-metals; they can conduct electricity but not as well as metals and are often used as semiconductors.

**Q4:** Explain why noble gases are chemically inert.

- **Answer:** Noble gases are chemically inert because they have a full valence shell of electrons. This makes them stable and unreactive under normal conditions. Since they do not need to gain, lose, or share electrons, they rarely form chemical bonds.

# 13. Extend (Beyond the Lesson)

To enhance understanding, here are additional tasks and challenges:

### Task 1: Research Project

**Task:** Choose a real-world application of isotopes (e.g., medical imaging, carbon dating, or nuclear energy). Explain how isotopes are used and the benefits and risks associated with their use.

- **Purpose:** This task encourages students to apply their knowledge of isotopes to real-world situations, deepening their understanding of how atomic structure affects practical applications.

### Task 2: Periodic Table Exploration

**Task:** Research an element from the periodic table that is essential for life (e.g., carbon, oxygen, nitrogen). Explain its role and why it is vital for living organisms.

- **Purpose:** This task connects chemistry to biology, showing how elements play crucial roles in life processes.

### Spaced Practice Activity:

**Assignment:** Over the next week, revisit content on atomic structure and periodic trends. Each day, answer a new question or complete a small task, such as:

- **Day 1:** Draw and label an atom of your choice.

- **Day 2:** Explain why atoms form bonds.

- **Day 3:** Compare the reactivity of two elements from different groups.

- **Day 4:** Identify an example of a chemical reaction and describe the role of the reactants.

**Purpose:** Spaced practice helps reinforce knowledge by allowing students to revisit concepts over time, improving retention and understanding.