Unit 2: Atomic Structure and Bonding

## Chapter 6: Ionic and Metallic Bonding

# Lesson 4: Metallic Bonding and Metal Characteristics

# 1. Big Idea:

- **Main Concept**: Metallic bonding is the key to understanding why metals have unique properties like conductivity, malleability, and luster.

- **Subordinate of Chapter’s Big Idea**: Understanding how atoms bond can explain why substances like metals behave differently from salts and other compounds.

### 2. Essential Questions:

- **Question 1**: How does metallic bonding explain the unique properties of metals?

- **Answer**: Metallic bonding occurs when metal atoms share their valence electrons freely in a "sea of electrons." This structure allows metals to conduct electricity, be shaped easily, and stay intact without dissolving like salts.

### 3. Phenomenon-Based Learning:

- **Unit Phenomenon**: In cold northern countries, road salt is spread to melt ice and snow on streets. Salt dissolves in water, but metal street signs and lampposts exposed to the same conditions do not melt or dissolve. Why do salt and metal behave so differently with water?

- **Chapter Phenomenon**: Salt dissolves in water because of ionic bonds, but metals don’t dissolve because of strong metallic bonds. This difference comes from how atoms are held together in salts versus metals.

### 4. Vocabulary:

- **Boiling point**: The temperature at which a substance changes from liquid to gas.

- **Conductivity**: The ability of a material to allow electricity to pass through it.

- **Ductility**: The ability of a material to be stretched into thin wires.

- **Luster**: The shiny appearance of metals.

- **Malleability**: The ability of a material to be hammered or rolled into shapes without breaking.

- **Melting point**: The temperature at which a solid becomes a liquid.

- **Metallic lattice**: The organized structure formed by metal atoms, where positive ions are surrounded by a sea of electrons.

- **Sea of electrons**: A model describing how electrons are shared freely among metal atoms, allowing metals to conduct electricity.

- **Valence electrons**: The outermost electrons of an atom, which are involved in bonding.

### 5. SMART Objectives:

- List the properties of metals such as conductivity, malleability, and ductility.

- Describe how metallic bonds are formed through the sharing of valence electrons in a sea of electrons.

- Analyze how the structure of metallic bonds relates to the properties of metals, like conductivity and malleability.

### 6. Engage (Ignite):

**Phenomenon-Related Question**:

- Why do metal street signs or lampposts not dissolve in water, even though road salt does?

**Hands-on Experiment**:

**Purpose**: To explore the differences in behavior between metals and ionic compounds (like salt) when exposed to water and electricity.

**Materials**:

- A small piece of metal (e.g., aluminum foil)

- Table salt (NaCl)

- Two small bowls of water

- A battery, wires, and a light bulb

- A spoon

**Procedure**:

1. Label one bowl "salt" and the other "metal."

2. Dissolve a tablespoon of salt in the "salt" bowl of water. Stir it up.

3. Place the piece of aluminum foil in the "metal" bowl of water.

4. Set up the battery, wires, and light bulb to create a simple circuit. First, dip the wires into the saltwater. What happens to the light bulb?

5. Next, dip the wires into the metal water bowl. What happens now?

**Follow-up Questions**:

1. Why did the light bulb glow in the saltwater but not in the metal water bowl?

2. What does this tell you about how salt and metal behave differently?

3. How might the structure of the atoms in salt and metal explain this difference?

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

**Background Information**:

Metals and salts behave differently because of the way their atoms bond together. Salt is made of ions held together by strong ionic bonds. When salt is added to water, it dissolves because the water molecules pull the ions apart. Metals, on the other hand, have a special kind of bonding called **metallic bonding**. In metallic bonding, the metal atoms share their **valence electrons** in a **sea of electrons**, which allows the metal to stay together even in water.

- **Key Concept 1**: **Ionic Bonds vs. Metallic Bonds**

In an ionic bond, electrons are transferred from one atom to another, creating positive and negative ions. These ions are held together by strong electrostatic forces. In a metallic bond, the atoms share their electrons freely. The **sea of electrons** allows the metal atoms to slide past each other without breaking.

- **Key Concept 2**: **Metallic Properties Explained by the Sea of Electrons**

The **sea of electrons** explains many of the unique properties of metals. For example, metals are good conductors because the electrons can move freely. Metals are also **malleable** and **ductile** because the atoms can slide past each other without breaking the bonds. This is why metals can be hammered into sheets or drawn into wires without breaking.

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

**Scaffolded Questions**:

1. What happens to salt when it is added to water?

2. How are the atoms in a metal bonded together?

3. How does the sea of electrons allow metals to conduct electricity?

### 9. Explain (Lightbulb):

Metals are very different from other types of materials, like salts, because of the way their atoms bond together. In a salt, like sodium chloride (NaCl), the atoms are held together by **ionic bonds**. In an ionic bond, one atom gives up electrons and becomes a positive ion, while the other atom takes in electrons and becomes a negative ion. These ions are attracted to each other, and that attraction holds the salt together. But when salt is added to water, the water molecules can pull these ions apart, causing the salt to dissolve.

Metals, on the other hand, are held together by **metallic bonds**. In a metallic bond, the metal atoms don’t give away or take in electrons like they do in an ionic bond. Instead, the metal atoms share their **valence electrons** with all the other metal atoms. These electrons move freely throughout the metal, forming a **sea of electrons**. The positive metal ions are held together by this sea of electrons, which is why metals don’t break apart or dissolve in water like salts do.

Let’s look at the key properties of metals and how they relate to metallic bonding:

### 1. Conductivity:

Metals are great conductors of electricity. This is because the sea of electrons allows electrons to move freely through the metal. When an electric current is applied, the electrons flow through the metal, carrying the current with them.

- **Sample Problem**:

Why do metals conduct electricity while ionic compounds like salt do not?

**Answer**: Metals conduct electricity because of their sea of free-moving electrons. In salt, the ions are held tightly in place in a solid structure and cannot move to conduct electricity.

**Progress Check**:

Why does saltwater conduct electricity, but solid salt does not?

### 2. Malleability and Ductility:

Metals can be bent, hammered into sheets, or stretched into wires without breaking. This is because the atoms in a metal can slide past each other when force is applied without breaking the metallic bond. The sea of electrons holds the metal together even when the shape changes.

- **Sample Problem**:

Why can metals be hammered into thin sheets without breaking?

**Answer**: Metals are malleable because their atoms can slide past each other without breaking the metallic bonds that hold them together.

**Progress Check**:

What property of metals allows them to be drawn into wires?

### 3. Luster:

Metals are shiny because their sea of electrons can easily reflect light. This is why most metals have a bright, reflective appearance.

- **Sample Problem**:

Why do metals like gold and silver have a shiny appearance?

**Answer**: Metals are shiny because the sea of electrons reflects light, giving them their characteristic luster.

**Progress Check**:

What causes the shiny appearance of metals?

### 4. Melting and Boiling Points:

Metals generally have high melting and boiling points. This is because the metallic bonds are very strong, and it takes a lot of energy to break them apart. However, this can vary depending on the type of metal.

- **Sample Problem**:

Why do metals have high melting points compared to salts?

**Answer**: Metals have high melting points because the metallic bonds are strong, and it takes a lot of energy to break the bonds between the metal atoms.

**Progress Check**:

What property of metals explains their high melting and boiling points?

### Making Sense of the Hands-On Activity:

In the hands-on experiment, you observed that saltwater conducted electricity, but the metal in water didn’t cause the light bulb to light up. This is because salt, when dissolved in water, breaks into ions that can move freely and conduct electricity. In contrast, the metal atoms in the aluminum foil didn’t dissolve in water, and the sea of electrons didn’t interact with the water to conduct electricity in the same way. This shows how the bonding in metals and salts leads to different behaviors in water.

### Conclusion:

Metals are unique because of their **metallic bonds**, where atoms share their **valence electrons** in a **sea of electrons**. This structure gives metals their special properties, like **conductivity**, **malleability**, **ductility**, and **luster**. Understanding metallic bonding helps us explain why metals behave differently from other materials like salts, especially when exposed to water or when electricity is involved.

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

1. **What is the difference between an element and a compound?**

- **Answer:** An element is a pure substance made of only one type of atom, such as oxygen (O) or hydrogen (H). A compound is a substance made when two or more different elements chemically bond together, like water (H₂O), which consists of hydrogen and oxygen.

2. **How do atoms bond together to form molecules?**

- **Answer:** Atoms bond together through chemical bonds, which can be covalent or ionic. In covalent bonds, atoms share electrons, like in a water molecule (H₂O). In ionic bonds, atoms transfer electrons, like in sodium chloride (NaCl).

3. **Why is understanding the periodic table important in chemistry?**

- **Answer:** The periodic table organizes elements based on their properties. It helps predict how different elements will react with each other, as elements in the same group (vertical columns) often have similar chemical behaviors. Understanding it allows chemists to anticipate reactions and create new compounds.

### 11. Elaborate (Power Up)

1. **Mini-task:** Imagine you are a scientist trying to create a new compound. What elements would you choose, and why?

- **Answer:** To create a new compound, I would choose elements based on their reactivity and the type of bond I want to form. For example, if I wanted to create a simple salt, I might choose sodium (Na) and chlorine (Cl) because they form an ionic bond easily, resulting in sodium chloride (table salt).

2. **Open-ended question:** How might the properties of a compound be different from the properties of the elements that make it up? Give examples.

- **Answer:** The properties of a compound can be very different from the elements that form it. For example, hydrogen is a flammable gas, and oxygen is necessary for combustion. However, when these elements combine to form water (H₂O), the result is a liquid that puts out fires. This shows how compounds can have entirely new properties.

3. **Extension question:** Could a molecule ever be made of only one element? If so, give an example and explain how it works.

- **Answer:** Yes, a molecule can be made of only one element. For example, oxygen gas (O₂) is made of two oxygen atoms bonded together. This is known as a diatomic molecule because it consists of two atoms of the same element.

### 12. Final Evaluation

### Debate Question:

**Should humans continue to create synthetic compounds, even though some may have harmful environmental effects?**

\*Arguments for:\*

- Synthetic compounds have improved our quality of life. For example, plastics and medicines are synthetic and have many uses.

- With careful regulation, harmful effects can be minimized.

\*Arguments against:\*

- Some synthetic compounds, like certain plastics, pollute the environment and harm wildlife.

- Natural alternatives may be safer for the planet and should be prioritized.

### Multiple-choice Questions:

1. **What is a covalent bond?**

a) A bond where electrons are transferred

b) A bond where electrons are shared

c) A bond that forms between metals

d) A bond that forms between non-metals and metals

- **Correct Answer:** b) A bond where electrons are shared

- **Explanation:** In a covalent bond, atoms share electrons to achieve a full outer shell, which is different from an ionic bond where electrons are transferred.

2. **Which of the following is a compound?**

a) Oxygen (O₂)

b) Sodium (Na)

c) Water (H₂O)

d) Hydrogen (H₂)

- **Correct Answer:** c) Water (H₂O)

- **Explanation:** Water is a compound because it is made of hydrogen and oxygen atoms chemically bonded together, whereas oxygen and hydrogen are elements.

3. **What does the atomic number of an element represent?**

a) The number of protons in the nucleus

b) The number of electrons in the outer shell

c) The number of neutrons in the nucleus

d) The atomic mass of the element

- **Correct Answer:** a) The number of protons in the nucleus

- **Explanation:** The atomic number represents the number of protons in an atom, which defines the element.

4. **Why are noble gases less likely to form compounds?**

a) They have incomplete outer shells

b) They are highly reactive

c) They have full outer electron shells

d) They are unstable

- **Correct Answer:** c) They have full outer electron shells

- **Explanation:** Noble gases have full outer electron shells, which makes them stable and less likely to react or form compounds.

### Long-answer Questions:

1. **Explain why sodium (Na) and chlorine (Cl) form an ionic bond.**

- **Answer:** Sodium (Na) has one electron in its outer shell, and chlorine (Cl) has seven electrons in its outer shell. Sodium wants to lose its one electron to achieve a full outer shell, and chlorine wants to gain one electron to fill its shell. Sodium transfers its electron to chlorine, resulting in an ionic bond because now sodium is positively charged (Na⁺) and chlorine is negatively charged (Cl⁻). These opposite charges attract, forming sodium chloride (NaCl).

2. **Describe how the periodic table is organized and how this organization helps predict the behavior of elements.**

- **Answer:** The periodic table is organized by increasing atomic number (number of protons). Elements are also arranged into groups (columns) and periods (rows). Elements in the same group have similar chemical properties because they have the same number of electrons in their outer shell. For example, elements in Group 1 are highly reactive metals, while elements in Group 18 are noble gases and are mostly unreactive. This organization helps predict how elements will react with each other.

3. **How does the law of conservation of mass apply to chemical reactions? Give an example.**

- **Answer:** The law of conservation of mass states that mass cannot be created or destroyed in a chemical reaction. The total mass of the reactants equals the total mass of the products. For example, when hydrogen gas (H₂) reacts with oxygen gas (O₂) to form water (H₂O), the mass of hydrogen and oxygen before the reaction is equal to the mass of water produced after the reaction.

4. **Why do different elements form different types of bonds (ionic, covalent)?**

- **Answer:** Elements form different types of bonds based on their electronegativity, which is the ability of an atom to attract electrons. If one atom has a much higher electronegativity than another, it will take electrons, forming an ionic bond (like NaCl). If atoms have similar electronegativities, they will share electrons, forming a covalent bond (like in H₂O). The type of bond formed depends on the elements' desire to achieve a stable electron configuration.

### 13. Extend (Beyond the Lesson)

1. **Task:** Research how the discovery of new elements has impacted human history. Choose one element and explain how it has changed technology or industry.

- **Suggested Element:** Silicon (Si). Silicon is used in electronics, especially in semiconductors, which are essential for computers and smartphones.

2. **Challenge:** Investigate how chemistry is used in environmental science to solve pollution problems. For example, how do scientists use chemical reactions to break down pollutants?

3. **Spaced Practice:**

a) Review the difference between ionic and covalent bonds. Next week, try explaining these concepts without looking at your notes.

b) Over the next two weeks, pay attention to how chemistry is used in everyday life. Write down examples like the use of soap (a chemical compound) to clean or how cooking involves chemical reactions.