Unit 2: Atomic Structure and Bonding

## Chapter 6: Ionic and Metallic Bonding

# Lesson 4: Metallic Bonding and Metal Characteristics

### 1. Big Idea:

The structure of metallic bonds explains why metals have unique properties, such as conductivity, malleability, and luster.

### 2. Essential Questions:

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

- Answer: Metals have a unique bond structure called **metallic bonding**. In this type of bonding, the atoms of metals are arranged in a lattice structure, and the valence electrons are free to move around. This "sea of electrons" allows metals to conduct electricity, be shaped without breaking (malleability), and have a shiny appearance (luster).

### 3. Phenomenon-Based Learning:

### Unit Phenomenon:

In cold northern countries, road salt is spread to melt ice and snow on streets. When salt contacts ice, it melts and dissolves in water. Meanwhile, metal lampposts exposed to the same conditions don’t dissolve or melt. Why does this happen?

**Explanation**: The difference in behavior between salt and metal in water is due to different types of bonding. Salt has ionic bonds, which break apart in water. Metals, on the other hand, have metallic bonds. These bonds, with their "sea of electrons," hold the metal atoms together, making them resistant to dissolving in water.

### Chapter Phenomenon:

Salt dissolves in water, but metals don’t. This is because salts are held together by ionic bonds, which break when they interact with water. Metals, however, have metallic bonds that form a strong lattice, held together by free-moving electrons, which prevents them from breaking apart in water.

### 4. Vocabulary:

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

- **Conductivity**: The ability of a material to allow the flow of electricity or heat.

- **Ductility**: The ability of a material to be stretched into a wire without breaking.

- **Luster**: The way light interacts with the surface of a metal, giving it a shiny appearance.

- **Malleability**: The ability of a metal to be hammered or rolled into thin sheets without breaking.

- **Melting point**: The temperature at which a substance changes from solid to liquid.

- **Metallic lattice**: A regular arrangement of metal atoms, surrounded by a sea of freely moving electrons.

- **Sea of electrons**: The free-moving electrons in a metallic bond that allow metals to conduct electricity and heat.

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

### 5. SMART Objectives:

1. List the properties of metals, such as conductivity, malleability, and luster.

2. Describe how metallic bonds form, focusing on the sea of electrons and the metallic lattice.

3. Analyze the relationship between the structure of metals and their properties, explaining how metallic bonding leads to metal characteristics like ductility and conductivity.

### 6. Engage (Ignite):

### Activity:

**Experiment**: Investigating Conductivity in Metals vs. Salt Solution

**Materials**:

- Copper wire (or aluminum foil)

- Salt

- Water

- Battery

- Light bulb

- Beaker

- Wires with clips

**Procedure**:

1. Set up a simple circuit by connecting the copper wire between the battery and the light bulb.

2. Observe if the bulb lights up (indicating that the metal conducts electricity).

3. Next, dissolve salt in water and connect the wire clips to the saltwater solution.

4. Observe if the bulb lights up again (indicating that the salt solution conducts electricity).

5. Compare the conductivity of the metal wire and the saltwater solution.

**Follow-up Questions**:

- **Why did the copper wire conduct electricity but not melt?**

- Answer: The copper wire conducted electricity because of its metallic bonds. The "sea of electrons" in the metal allows electricity to pass through it without breaking the metal apart.

- **Why did the saltwater solution also conduct electricity?**

- Answer: Salt conducts electricity when dissolved in water because the ionic bonds break, releasing charged particles (ions) that move freely in the solution.

- **What would happen if you replaced the copper wire with another metal, like aluminum?**

- Answer: Aluminum would also conduct electricity due to metallic bonding, as it also has free-moving electrons in its structure.

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

### Background:

Metals have unique properties that make them useful in many areas of life. For example, metals are shiny, can conduct electricity, and are strong yet flexible. These properties come from the way metal atoms bond with each other. In metallic bonding, metal atoms are arranged in a regular pattern called a **metallic lattice**. The valence electrons in metals are not tightly bound to any single atom. Instead, they move freely around the lattice in what we call a **sea of electrons**.

This movement of electrons is what gives metals their ability to conduct electricity (conductivity) and to be shaped without breaking (malleability and ductility). The **sea of electrons** holds the metal atoms together, preventing them from breaking apart easily, even when they are bent or hammered.

**Scaffolded Questions**:

- **What is a metallic lattice?**

- Answer: A metallic lattice is a regular pattern of metal atoms bonded together, surrounded by a sea of electrons.

- **How do valence electrons behave in metals?**

- Answer: In metals, valence electrons move freely around the metallic lattice, forming a sea of electrons.

- **Why can metals conduct electricity?**

- Answer: Metals can conduct electricity because their valence electrons are free to move throughout the lattice, allowing an electric current to pass through.

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

1. **What is the sea of electrons in a metal?**

- Answer: The sea of electrons is the collection of free-moving valence electrons in a metal that allows it to conduct electricity and heat.

2. **How does the structure of a metallic bond differ from an ionic bond?**

- Answer: In a metallic bond, the electrons move freely among metal atoms, while in an ionic bond, electrons are transferred from one atom to another, creating charged ions.

3. **Why can metals be bent or stretched without breaking?**

- Answer: Metals can be bent or stretched because the sea of electrons allows the metal atoms to slide past each other without breaking the bonds between them.

### 9. Explain (Lightbulb):

**Explaining Metallic Bonding and Metal Properties**

### Formation of Metallic Bonds:

In metallic bonds, metal atoms are arranged in a structure called a **metallic lattice**. The outermost electrons, called **valence electrons**, are not tightly attached to any one atom. Instead, they move freely around the lattice, forming a **sea of electrons** that holds the atoms together. This is why metals have several unique properties compared to other materials like salts.

### Properties of Metals Explained by Metallic Bonding:

1. **Conductivity**:

Metals are excellent conductors of electricity and heat because the electrons in the sea of electrons move freely. When electric current is applied, these electrons flow easily through the metal, allowing electricity to pass through.

2. **Malleability and Ductility**:

Metals can be hammered into thin sheets (malleability) or pulled into wires (ductility) because the atoms in the metallic lattice can slide past each other without breaking the bond. The sea of electrons keeps the metal atoms connected even when they are reshaped.

3. **Luster**:

Metals are shiny because their free electrons can absorb and release light energy. When light hits a metal, the electrons vibrate and reflect the light, giving metals their shiny, reflective appearance.

4. **High Melting and Boiling Points**:

The strong attraction between the metal atoms and the sea of electrons gives metals high melting and boiling points. A lot of energy is needed to break the metallic bonds and turn the metal into a liquid or gas.

**Sample Problem**:

**Question**:

Why is copper used in electrical wiring instead of materials like plastic or wood?

**Answer**:

Copper is used in electrical wiring because it has metallic bonds, which provide free-moving electrons. These electrons allow copper to conduct electricity very well. Plastic and wood, on the other hand, are insulators and do not have free electrons, so they cannot conduct electricity.

**Progress Check**:

**Question**: What property of metallic bonds makes metals like copper good conductors of electricity?

**Answer**: The free-moving electrons, or the sea of electrons, in metallic bonds make copper and other metals good conductors of electricity.

**Review the Hands-On Activity**:

- Based on the conductivity experiment, metals conducted electricity because of their free-moving electrons. The salt dissolved in water also conducted electricity, but for a different reason (due to the free ions in the solution). Even though both materials conducted electricity, their bond types are very different: metallic bonding for metals and ionic bonding for salt.

### Conclusion:

In this lesson, we explored metallic bonding and how it explains the unique properties of metals, such as conductivity, malleability, and luster. Metals have a lattice structure where valence electrons move freely, forming a sea of electrons. This structure allows metals to conduct electricity, be shaped without breaking, and have a shiny appearance.

### Chapter 10: Evaluate (Progress Check)

In this section, you will test your understanding of the key concepts covered in the "Explain" section. Make sure to think carefully about each question and reflect on what you've learned.

1. **What is the atomic number of an element, and why is it important?**

- **Answer:** The atomic number of an element is the number of protons in the nucleus of an atom. It is important because it determines the identity of the element and its position on the periodic table.

2. **Describe the difference between a covalent bond and an ionic bond.**

- **Answer:** A covalent bond is when two atoms share electrons, while an ionic bond is when one atom donates an electron to another, creating positively and negatively charged ions that attract each other.

3. **Explain why water is considered a polar molecule. How does this affect its properties?**

- **Answer:** Water is polar because it has an uneven distribution of charge—oxygen has a slight negative charge, and hydrogen has a slight positive charge. This polarity allows water to dissolve many substances and gives it unique properties like high surface tension and the ability to stick to surfaces (adhesion).

### Chapter 11: Elaborate (Power Up)

Now, let’s go deeper into the content you’ve learned. These mini-tasks will challenge your understanding and encourage you to think critically.

1. **Mini-task:** Draw a diagram showing how two water molecules interact through hydrogen bonding. Explain why hydrogen bonds are weaker than covalent bonds.

- **Answer:** Two water molecules interact through hydrogen bonds because the slightly positive hydrogen atom of one molecule is attracted to the slightly negative oxygen atom of another molecule. Hydrogen bonds are weaker than covalent bonds because they involve attractions between partial charges rather than the sharing of electrons.

2. **Open-ended question:** If you could design a new element, what properties would you give it? How would it interact with other elements?

- **Answer:** Students’ answers may vary. A thoughtful response might include discussion of atomic number, reactivity, bonding tendencies (ionic or covalent), and possible uses in technology or medicine.

3. **Mini-task:** Compare the role of electrons in ionic and covalent bonds. How do these roles affect the properties of the substances formed?

- **Answer:** In ionic bonds, electrons are transferred, leading to the formation of charged ions. This creates substances like salts that are typically solid and have high melting points. In covalent bonds, electrons are shared, forming molecules that can be gases, liquids, or solids, often with lower melting points.

### Chapter 12: Final Evaluation

### Debate Question:

**Should scientists focus more on developing synthetic elements in laboratories, or spend more time studying naturally occurring elements on Earth?**

- **Arguments for synthetic elements:** Synthetic elements can have unique properties that could be used in advanced technology, medicine, or energy production. They also push the boundaries of what we know about chemistry and physics.

- **Arguments for naturally occurring elements:** Studying natural elements helps us understand the world we live in and can lead to discoveries about Earth’s processes. Natural elements are more abundant and may have untapped potential.

### Multiple-Choice Questions:

1. **What is the main factor that determines the chemical reactivity of an element?**

a) Number of protons

b) Number of neutrons

c) Number of electrons in the outer shell

d) Atomic mass

- **Answer:** c) Number of electrons in the outer shell

- **Explanation:** The electrons in the outer shell, or valence electrons, determine how an element will bond with other elements.

2. **Which of the following is true about ionic compounds?**

a) They have low melting points.

b) They conduct electricity when dissolved in water.

c) They are gases at room temperature.

d) They are formed by sharing electrons.

- **Answer:** b) They conduct electricity when dissolved in water

- **Explanation:** Ionic compounds dissolve in water and dissociate into ions, which allows them to conduct electricity.

3. **Water has a high surface tension because of**

a) Covalent bonds

b) Ionic bonds

c) Hydrogen bonds

d) Non-polarity

- **Answer:** c) Hydrogen bonds

- **Explanation:** The hydrogen bonds between water molecules create a strong attraction at the surface, leading to high surface tension.

4. **Which of the following is a property of covalent compounds?**

a) They are good conductors of electricity in solid form.

b) They have high melting points.

c) They can be gases, liquids, or solids at room temperature.

d) They form charged ions.

- **Answer:** c) They can be gases, liquids, or solids at room temperature

- **Explanation:** Covalent compounds can exist in different states depending on the strength of the forces between their molecules.

### Long-Answer Questions:

1. **Explain how the periodic table is organized and how this organization helps predict the properties of elements.**

- **Answer:** The periodic table is organized by increasing atomic number, which corresponds to the number of protons in an atom. Elements in the same group (column) have the same number of valence electrons, which makes them behave similarly in chemical reactions. The table is also divided into metals, nonmetals, and metalloids, which helps predict whether an element will be a good conductor of electricity, how it will bond with other elements, and other properties.

2. **Describe how ionic and covalent bonds are formed. Give an example of each type of bond.**

- **Answer:** Ionic bonds are formed when one atom transfers electrons to another atom, creating oppositely charged ions that attract each other. An example is sodium chloride (NaCl). Covalent bonds form when two atoms share electrons to fill their outer shells. An example is water (H₂O), where oxygen shares electrons with two hydrogen atoms.

3. **Why is water considered essential for life? Discuss its chemical properties.**

- **Answer:** Water is essential for life because of its unique chemical properties. It is a polar molecule, which allows it to dissolve many substances, facilitating chemical reactions in living organisms. Water has a high specific heat, meaning it can absorb or release a lot of heat without changing temperature, helping regulate body temperature. Its cohesion and adhesion properties also play critical roles in transporting nutrients in plants and animals.

4. **Compare and contrast metals and nonmetals in terms of their physical and chemical properties.**

- **Answer:** Metals are typically shiny, malleable, ductile, and good conductors of heat and electricity. They tend to lose electrons in chemical reactions, forming positive ions. Nonmetals, on the other hand, are often dull, brittle, and poor conductors of heat and electricity. They tend to gain or share electrons in reactions, forming negative ions or covalent bonds.

### Chapter 13: Extend (Beyond the Lesson)

**Additional Tasks:**

1. **Research Assignment:** Investigate how water’s properties affect weather patterns and climate. How does water’s ability to absorb heat impact the environment? Write a short report summarizing your findings.

2. **Real-World Challenge:** Think about how ionic and covalent compounds are used in everyday life. Identify two examples of each and explain their importance in household products or industrial processes.

3. **Spaced Practice Activity:** Every week, return to the periodic table and choose one group (e.g., Alkali Metals, Noble Gases). Write down the similarities and differences among the elements in that group. Over time, this will help reinforce your understanding of periodic trends.

4. **Reading Extension:** Read an article about the discovery of new elements in the lab. What challenges do scientists face when creating new elements? How do these discoveries impact technology?

These tasks will help you apply what you’ve learned to broader contexts and deepen your understanding of the material over time.