# Unit: Unit 2: Atomic Structure and Bonding

## Chapter: Chapter 6: Ionic and Metallic Bonding

### Lesson: Lesson 1: Formation and Properties of Ions

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

**Scaffolded Questions:**

1. **What is an atom, and how is it structured?**

- \*Answer:\* An atom is the basic unit of matter, consisting of a nucleus made up of protons and neutrons, with electrons orbiting around the nucleus in electron clouds or energy levels.

2. **Why do elements in the same group of the periodic table have similar chemical properties?**

- \*Answer:\* Elements in the same group have similar chemical properties because they have the same number of electrons in their outermost shell, which determines how they bond and react with other elements.

3. **How does the arrangement of electrons around the nucleus of an atom determine the chemical properties of an element?**

- \*Answer:\* The arrangement of electrons, particularly the number of valence electrons (electrons in the outermost shell), determines how an element interacts with other atoms. Atoms will gain, lose, or share electrons to fill their outer shells, influencing their reactivity and bonding behavior.

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### 11. Elaborate (Power Up)

**Mini-Tasks/Open-Ended Questions:**

1. **Why do elements bond together, and what are the main types of bonds they form? Provide examples for each type.**

- \*Answer:\* Elements bond to achieve stable electron configurations, often by filling their outer electron shells. The main types of bonds are:

- **Ionic bonds**: formed when one atom donates an electron to another, such as in sodium chloride (NaCl).

- **Covalent bonds**: formed when atoms share electrons, such as in water (H₂O).

- **Metallic bonds**: formed between metal atoms where electrons are shared in a 'sea' of electrons, such as in copper (Cu).

2. **How do changes in temperature and pressure affect the state of matter of a substance? Provide examples.**

- \*Answer:\* Temperature and pressure can cause substances to change from one state of matter to another. For example:

- **Heating water** increases its kinetic energy and can change it from a liquid to a gas (boiling).

- **Increasing pressure** on carbon dioxide gas can turn it into a solid form known as dry ice.

- **Decreasing temperature** can cause water to freeze and become solid (ice).

3. **How can the periodic table be used to predict the behavior of elements in chemical reactions?**

- \*Answer:\* The periodic table organizes elements based on their atomic number and electron configuration. Elements in the same group (vertical columns) have similar chemical behaviors because they have the same number of valence electrons. For example, Group 1 (alkali metals) are very reactive because they have one valence electron they readily lose to form positive ions.

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### 12. Final Evaluation

**Debate Question:**

- **"Should we continue relying on fossil fuels for energy or switch completely to renewable energy sources?"**

- \*Arguments for fossil fuels:\* They are currently the most efficient and widely used energy sources worldwide, and switching completely to renewables would be costly and could cause economic disruptions.

- \*Arguments for renewable energy:\* Fossil fuels contribute to environmental pollution and climate change, and renewable energy sources like solar and wind are more sustainable in the long run.

**Multiple-Choice Questions:**

1. **Which subatomic particle determines the identity of an element?**

- a) Electron

- b) Neutron

- c) Proton

- d) Nucleus

- \*Correct Answer:\* c) Proton

- \*Explanation:\* The number of protons in an atom's nucleus, known as the atomic number, defines the element.

2. **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

- \*Correct Answer:\* b) Covalent bond

- \*Explanation:\* Covalent bonds involve the sharing of electron pairs between atoms.

3. **In which group of the periodic table are the noble gases located?**

- a) Group 1

- b) Group 2

- c) Group 17

- d) Group 18

- \*Correct Answer:\* d) Group 18

- \*Explanation:\* Noble gases are located in Group 18 and are known for being inert and non-reactive due to their full valence electron shells.

4. **Which state of matter has a definite shape and volume?**

- a) Solid

- b) Liquid

- c) Gas

- d) Plasma

- \*Correct Answer:\* a) Solid

- \*Explanation:\* Solids have both a definite shape and volume, unlike liquids and gases.

**Long-Answer Questions:**

1. **Explain how the periodic table is arranged and how this arrangement helps predict the properties and behaviors of elements.**

- \*Answer:\* The periodic table is arranged by increasing atomic number (number of protons). Elements are grouped into vertical columns (groups) based on similar chemical properties due to having the same number of valence electrons. Horizontal rows (periods) indicate increasing energy levels of electrons. This arrangement helps predict properties such as reactivity, state of matter, and types of bonds an element will form.

2. **Describe the process of ionic bonding, and give an example of a compound formed through this type of bond.**

- \*Answer:\* Ionic bonding occurs when one atom donates an electron to another atom, creating a positive ion and a negative ion. These opposite charges attract, forming a bond. For example, in sodium chloride (NaCl), sodium donates an electron to chlorine, forming Na⁺ and Cl⁻ ions that are held together by ionic bonds.

3. **Compare and contrast the properties of metals, nonmetals, and metalloids.**

- \*Answer:\*

- **Metals** are typically shiny, good conductors of heat and electricity, malleable, and ductile. They tend to lose electrons in reactions.

- **Nonmetals** are poor conductors, brittle when solid, and often gain electrons in reactions.

- **Metalloids** have properties of both metals and nonmetals and can act as semiconductors.

4. **How does the law of conservation of mass apply to chemical reactions, and why is it important? Provide an example.**

- \*Answer:\* The law of conservation of mass states that matter cannot be created or destroyed in a chemical reaction; the mass of the reactants must equal the mass of the products. This is important because it helps balance chemical equations. For example, in the reaction of hydrogen with oxygen to form water (2H₂ + O₂ → 2H₂O), the number of hydrogen and oxygen atoms remains the same on both sides of the equation.

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### 13. Extend (Beyond the Lesson)

**Suggested Additional Tasks:**

1. **Challenge:** Design your own experiment to test how temperature affects the solubility of a substance in water. Record your results and explain them based on what you know about particle motion and energy.

2. **Reading:** Research and read about the discovery of the electron by J.J. Thomson. How did this discovery change the model of the atom?

3. **Real-World Application:** Consider the role of chemistry in environmental science. Investigate how chemical principles are applied in efforts to reduce air pollution or develop cleaner energy sources.

4. **Spaced Practice:** Over the next two weeks, keep a journal where you document examples of chemical reactions you observe in everyday life (e.g., cooking, rusting). Reflect on how these reactions align with the principles you’ve learned.

These tasks and readings encourage students to apply their knowledge to new situations, reinforce their understanding of the material, and explore the relevance of chemistry in the real world.

## Unit Title: Atomic Structure and Bonding

## Chapter Title: Ionic and Metallic Bonding

# Lesson Title: Formation and Properties of Ions

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### Essential Questions:

- **How are ions formed, and what role do they play in chemical bonding?**

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### 1. Big Idea:

**Main Concept:** The formation of ions is key to understanding ionic bonding and explains why substances like salts dissolve in water, while metals do not.

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### 2. Essential Questions

1. **How are ions formed, and what role do they play in chemical bonding?**

**Answer:** Ions are formed when atoms lose or gain electrons, resulting in a positive or negative charge. In chemical bonding, ions combine to form ionic compounds. For example, metals typically lose electrons to become positively charged cations, while nonmetals gain electrons to become negatively charged anions. The opposite charges attract, creating ionic bonds that hold the compound together.

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### 3.1 Phenomenon-Based Learning

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**Unit Phenomenon:**

In cold northern countries, road salt is spread to melt ice and snow on streets. As the salt contacts the ice, the ice melts, and the salt dissolves. However, 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 and metals behave differently in the presence of water. Salt dissolves, but metal doesn’t. This happens because of the different types of bonding in salts (ionic) and metals (metallic). Metals stay intact due to their metallic bonds and sea of electrons, which prevent them from breaking apart in water.

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### 3.2 Lesson Phenomenon:

Why does table salt (NaCl) dissolve in water while a metal spoon remains unaffected? This difference in behavior is due to the nature of ionic bonds in salt and metallic bonds in metals. In this lesson, we explore how ions are formed and how their properties lead to ionic bonding, which explains why salt dissolves while metals do not.

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### 4. Vocabulary

- **Octet Rule:** Atoms tend to lose, gain, or share electrons to achieve a full valence shell of eight electrons.

- **Anion:** A negatively charged ion, formed when an atom gains one or more electrons.

- **Cation:** A positively charged ion, formed when an atom loses one or more electrons.

- **Electrolyte:** A substance that dissolves in water to produce a solution that conducts electricity, typically ionic compounds like salts.

- **Electron Affinity:** The energy change that occurs when an atom gains an electron.

- **Ionic Radius:** The size of an ion, which differs from the atomic radius due to the gain or loss of electrons.

- **Ionization:** The process of losing or gaining electrons to form ions.

- **Octet Rule:** Atoms are most stable when they have eight electrons in their outermost energy level (valence shell).

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### 5. SMART Objectives

By the end of this lesson, students will:

- Describe how ions are formed.

- Write the symbols and charges of ions.

- Predict the charge of an ion based on its position on the periodic table.

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### 6. Engage (Ignite)

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**Activity: Salt vs. Metal in Water**

**Materials Needed:**

- Table salt (NaCl)

- Small metal object (spoon or coin)

- Two beakers of water

- Stirring rod

**Procedure:**

1. Add a teaspoon of table salt to a beaker of water and stir.

2. Observe and record what happens to the salt.

3. Place a small metal object (like a spoon or coin) into a second beaker of water.

4. Observe and record what happens to the metal after a few minutes.

**Follow-Up Questions:**

1. **What happened to the salt when it was added to water?**

**Answer:** The salt dissolved in the water, breaking down into sodium (Na⁺) and chloride (Cl⁻) ions.

2. **What happened to the metal when it was placed in water?**

**Answer:** The metal did not dissolve. It remained intact in the water because the metallic bonds are not affected by water.

3. **Based on this activity, why do you think salt dissolves in water while metal doesn’t?**

**Answer:** Salt dissolves in water because it is made of ions that separate and interact with water molecules. Metal, on the other hand, is held together by metallic bonds that are not disrupted by water.

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

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Atoms are made up of protons, neutrons, and electrons. Protons have a positive charge, neutrons are neutral, and electrons have a negative charge. In an atom, the number of electrons equals the number of protons, so the atom is neutral. However, atoms can lose or gain electrons, forming ions.

When an atom loses one or more electrons, it becomes positively charged and is known as a **cation**. When it gains one or more electrons, it becomes negatively charged and is known as an **anion**.

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**Interactive Element:**

Ask students to consider the following:

- What happens to an atom's charge when it gains electrons? (It becomes negative.)

- What happens when it loses electrons? (It becomes positive.)

- Why do you think metals tend to form cations, while nonmetals form anions?

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

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**Questions:**

1. **What is a cation?**

**Answer:** A cation is a positively charged ion formed when an atom loses electrons.

2. **What is an anion?**

**Answer:** An anion is a negatively charged ion formed when an atom gains electrons.

3. **How is the formation of ions related to the periodic table?**

**Answer:** The position of an element on the periodic table helps predict whether it will lose or gain electrons to form ions. Metals, found on the left side, tend to lose electrons and form cations, while nonmetals, on the right side, tend to gain electrons and form anions.

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### 9. Explain (Lightbulb)

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**Formation of Ions**

Atoms become ions when they lose or gain electrons to achieve a stable electron configuration, often following the **Octet Rule**. This rule states that atoms are more stable when they have eight electrons in their outermost energy level (valence shell). For example, sodium (Na) has one electron in its outer shell. To become more stable, sodium loses this electron, forming a Na⁺ ion with a charge of +1.

Nonmetals like chlorine (Cl), on the other hand, have seven valence electrons and need one more to complete their octet. When chlorine gains an electron, it forms a Cl⁻ ion with a charge of -1.

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**Properties of Ions**

Ions have different properties compared to neutral atoms. For instance:

- **Cations** like Na⁺ are smaller than their neutral atoms because they lose electrons and the remaining electrons are pulled closer to the nucleus.

- **Anions** like Cl⁻ are larger than their neutral atoms because they gain electrons, increasing the distance between the electrons and the nucleus.

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**Predicting Ion Charge Using the Periodic Table**

The periodic table can help predict the charge of ions.

- **Group 1 elements** (like sodium) lose one electron to form +1 cations.

- **Group 2 elements** (like magnesium) lose two electrons to form +2 cations.

- **Group 17 elements** (like chlorine) gain one electron to form -1 anions.

- **Group 16 elements** (like oxygen) gain two electrons to form -2 anions.

This trend occurs because atoms want to achieve a stable electron configuration, similar to the noble gases at the far right of the periodic table.

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**Sample Problem: Predict the Charge of an Ion**

**Question:** What is the charge of an ion formed by magnesium (Mg)?

**Solution:**

Magnesium is in Group 2 of the periodic table, so it loses two electrons to form a +2 ion. The symbol for the magnesium ion is Mg²⁺.

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**Progress Check:**

**Question:** What is the charge of an ion formed by sulfur (S)?

**Answer:** Sulfur is in Group 16 of the periodic table, so it gains two electrons to form a -2 ion. The symbol for the sulfur ion is S²⁻.

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**Role of Ions in Chemical Bonding**

Ions play a crucial role in **ionic bonding**, which occurs between metals and nonmetals. When metals lose electrons, they form positively charged cations. Nonmetals gain these electrons, forming negatively charged anions. The opposite charges attract, creating a strong bond between the ions. This is why **ionic compounds** like salt (NaCl) are held together so tightly.

In water, ionic compounds dissolve because the water molecules surround the ions and break the ionic bonds. This process is why salt dissolves in water, forming an **electrolyte** solution that can conduct electricity.

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### Conclusion:

The formation of ions is critical to understanding how ionic compounds behave both in solid form and when dissolved in water. Through this lesson, you’ve observed how salt dissolves in water due to the ionic bonds breaking, while metals do not dissolve because of their metallic bonds. Understanding ions also helps explain how elements bond and form compounds, and how we can predict the behavior of these compounds based on their ionic nature.

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