Unit 2: Atomic Structure and Bonding

## Chapter 6: Ionic and Metallic Bonding

# Lesson 1: Formation and Properties of Ions

### 1. Big Idea:

Ions are formed when atoms gain or lose electrons, leading to the creation of charged particles that play a crucial role in chemical bonding.

### 2. Essential Questions

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

**Answer:**

Ions are formed when atoms gain or lose electrons to achieve a stable electron configuration, often following the Octet Rule. This process results in the formation of either positively charged ions (cations) or negatively charged ions (anions). These ions are essential in forming ionic bonds, where oppositely charged ions attract each other to create compounds like salts.

### 3.1 Phenomenon-Based Learning

**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 dissolves in water, but metal does not. This behavior is due to the different types of bonding in salts (ionic) and metals (metallic). Metals stay intact because of their metallic bonds and sea of electrons, which prevent them from breaking apart in water.

### 3.2 Lesson Phenomenon

**Lesson Phenomenon:**

Imagine sprinkling table salt into a glass of water. The salt disappears, dissolving into the water. Now, dip a metal spoon into the same water. The spoon does not dissolve. Why does the salt break down, while the spoon stays intact? The answer lies in how ions in salts behave in water and how metallic bonds hold metals together.

### 4. Vocabulary

- **Octet Rule:** The principle that atoms tend to gain, lose, or share electrons to achieve a full set of eight electrons in their outermost energy level.

- **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 produces ions when dissolved in water and can conduct electricity.

- **Electron Affinity:** The amount of energy released when an atom gains an electron to form a negative ion.

- **Ionic Radius:** The radius of an ion, which can differ from the atomic radius depending on whether the ion is a cation or anion.

- **Ionization:** The process in which an atom or molecule gains a charge by losing or gaining electrons.

### 5. SMART Objectives

- 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.

### 6. Engage (Ignite)

**Phenomenon-Related Question:**

Why does table salt dissolve in water, but a metal spoon does not?

**Experiment: Dissolving Salt in Water**

**Materials Needed:**

- A tablespoon of table salt

- A glass of water

- A metal spoon

**Procedure:**

1. Fill the glass with water.

2. Add a tablespoon of salt to the water and stir.

3. Observe what happens to the salt.

4. Now, dip the metal spoon into the water and observe.

**Follow-up Questions:**

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

**Answer:** The salt dissolved in the water, breaking up into ions (sodium and chloride).

2. **Did the metal spoon dissolve in the water?**

**Answer:** No, the metal spoon did not dissolve.

3. **Why do you think the salt dissolved but the spoon did not?**

**Answer:** The salt dissolved because it is made up of ions that separate in water, whereas the metal spoon is held together by metallic bonds, which are not easily broken in water.

This activity demonstrates how ionic compounds, like salt, behave differently from metals when exposed to water.

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

**Background Information:**

Atoms are the building blocks of all matter, and they contain electrons, protons, and neutrons. The behavior of electrons in an atom determines how it interacts with other atoms. When atoms lose or gain electrons, they become **ions**. There are two types of ions:

- **Cations** (positively charged) form when atoms lose electrons.

- **Anions** (negatively charged) form when atoms gain electrons.

This gain or loss of electrons is driven by the **Octet Rule**, which states that atoms tend to have eight electrons in their outer shell to achieve stability, similar to the electron configuration of noble gases.

When ionic compounds like salt dissolve in water, they break into ions that can move freely, allowing the compound to conduct electricity, turning the solution into an **electrolyte**.

**Scaffolded Question:**

- **Why do atoms form cations or anions?**

**Answer:** Atoms form cations or anions to achieve a stable electron configuration, often following the Octet Rule.

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

**Scaffolded Questions:**

1. **What determines whether an atom will form a cation or an anion?**

**Answer:** Whether an atom forms a cation or an anion depends on whether it loses electrons (cation) or gains electrons (anion) to achieve a stable electron configuration.

2. **What is the Octet Rule, and why is it important in ion formation?**

**Answer:** The Octet Rule states that atoms tend to gain or lose electrons to achieve eight electrons in their outer shell, leading to stability. It is important because it explains why atoms form ions.

3. **How does the position of an element on the periodic table help predict the charge of its ion?**

**Answer:** Elements in Groups 1, 2, and 13 typically form positive ions (cations), while elements in Groups 15, 16, and 17 form negative ions (anions). This is because of their electron configurations and tendencies to lose or gain electrons to satisfy the Octet Rule.

### 9. Explain (Lightbulb)

**Core Concept: Formation of Ions**

Atoms form ions by gaining or losing electrons in order to achieve a stable electron configuration. The number of electrons lost or gained determines the charge of the ion. For example:

- **Sodium (Na)** in Group 1 has one electron in its outer shell. It loses this electron to achieve a stable configuration, forming a **Na⁺** ion (cation) with a +1 charge.

- **Chlorine (Cl)** in Group 17 has seven electrons in its outer shell. It gains one electron to complete its octet, forming a **Cl⁻** ion (anion) with a -1 charge.

**Why Do Atoms Form Ions?**

Atoms form ions to satisfy the **Octet Rule**. Atoms are more stable when they have eight electrons in their outermost shell, like the noble gases (Group 18). Metals tend to lose electrons and form cations, while nonmetals tend to gain electrons and form anions.

**Ionic Compounds and Bonding**

When cations and anions form, they attract each other because opposite charges attract. This attraction forms an **ionic bond**, creating an ionic compound. For example, when sodium (Na⁺) and chloride (Cl⁻) ions combine, they form **sodium chloride (NaCl)**, which is table salt.

**Sample Problem 1:**

**Question:** Predict the charge of a magnesium (Mg) ion.

**Answer:** Magnesium (Mg) is in Group 2 of the periodic table, meaning it has two electrons in its outer shell. To achieve a stable octet, magnesium will lose two electrons, forming a **Mg²⁺** ion with a +2 charge.

**Progress Check:**

**Question:** Predict the charge of an oxygen (O) ion.

**Answer:** Oxygen (O) is in Group 16, meaning it has six electrons in its outer shell. To achieve a full octet, oxygen will gain two electrons, forming an **O²⁻** ion with a -2 charge.

### Expansion of Key Concepts:

1. **Cation Formation:**

Metals, like sodium or aluminum, tend to lose electrons because they have fewer electrons in their outer shell. This loss of electrons results in a positive charge, forming a cation. For example, sodium (Na) loses one electron to form Na⁺, and aluminum (Al) loses three electrons to form Al³⁺.

2. **Anion Formation:**

Nonmetals, like chlorine or oxygen, tend to gain electrons to complete their outer shell with eight electrons. This gain results in a negative charge, forming an anion. For example, chlorine (Cl) gains one electron to form Cl⁻, and oxygen (O) gains two electrons to form O²⁻.

3. **Predicting Ion Charges Using the Periodic Table:**

- **Group 1 elements** (e.g., sodium) form ions with a +1 charge.

- **Group 2 elements** (e.g., magnesium) form ions with a +2 charge.

- **Group 17 elements** (e.g., chlorine) form ions with a -1 charge.

- **Group 16 elements** (e.g., oxygen) form ions with a -2 charge.

### Hands-On Reflection:

Students can reflect on how their hands-on activity (salt dissolving, spoon not dissolving) relates to the formation of ions. Salt dissolves because it consists of ions that separate in water, while the metal spoon is held together by metallic bonds.

### Conclusion:

This lesson explains the formation of ions, the role of the Octet Rule, and how ionic bonds are essential to forming compounds. By understanding these concepts, students can predict how atoms will behave and combine to form new substances.

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

**Question 1: What is an atom, and why is it important in chemistry?**

Answer: An atom is the smallest unit of an element that retains the properties of that element. Atoms are important in chemistry because they make up all matter, and understanding how they interact helps us understand chemical reactions.

**Question 2: Explain the difference between an element and a compound, and give an example of each.**

Answer: An element is a substance made up of only one type of atom, such as oxygen (O). A compound is a substance made of two or more different types of atoms chemically bonded together, like water (H₂O), which consists of hydrogen and oxygen.

**Question 3: Describe how the structure of an atom affects its chemical properties.**

Answer: The structure of an atom, particularly the number of protons, neutrons, and electrons, determines its chemical properties. For example, the number of electrons in the outer shell (valence electrons) affects how an atom bonds with other atoms. Atoms with similar electron configurations exhibit similar chemical behaviors.

### 11. Elaborate (Power Up)

Here are some mini-tasks and open-ended questions that encourage deeper thinking about the concepts covered:

**Mini-Task 1:**

Draw a model of an atom, labeling its main parts (protons, neutrons, electrons). Show how electrons are arranged in energy levels.

Answer: Students should draw a nucleus containing protons and neutrons, with electrons orbiting in shells or energy levels around the nucleus. The number of protons should match the atomic number of the element chosen.

**Mini-Task 2:**

How would changing the number of neutrons in an atom affect its identity or stability?

Answer: Changing the number of neutrons creates isotopes of the same element, which have the same number of protons but different masses. Isotopes do not change the chemical identity of the element but may affect its stability. Some isotopes are radioactive and may decay over time.

**Mini-Task 3:**

Think about how chemical reactions occur. How does understanding the arrangement of electrons help predict how atoms will bond with each other?

Answer: Electrons, especially those in the outermost shell (valence electrons), determine how atoms bond. Atoms with incomplete outer shells tend to react with other atoms to complete their electron configurations, either by sharing (covalent bonds) or transferring (ionic bonds) electrons.

### 12. Final Evaluation

**Debate Question:**

"Should we prioritize using chemical compounds from natural sources or synthetic compounds in industries such as medicine and food production?"

**Points for Discussion:**

- Natural compounds can be more sustainable and environmentally friendly, but they may be harder to produce in large quantities.

- Synthetic compounds are often cheaper and easier to produce in large amounts but may have unknown long-term effects on health or the environment.

**Multiple-Choice Questions:**

1. **What is the charge of a proton?**

- A) Neutral

- B) Positive

- C) Negative

- D) No charge

Answer: B) Positive.

Explanation: Protons have a positive charge, while neutrons are neutral, and electrons have a negative charge.

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

- A) Oxygen (O)

- B) Carbon (C)

- C) Water (H₂O)

- D) Helium (He)

Answer: C) Water (H₂O).

Explanation: Water is a chemical compound made of hydrogen and oxygen atoms bonded together. The other options are elements.

3. **How many electrons can the first energy level of an atom hold?**

- A) 2

- B) 4

- C) 8

- D) 18

Answer: A) 2.

Explanation: The first energy level of an atom can hold a maximum of 2 electrons.

4. **What happens to an atom if it gains an electron?**

- A) It becomes a positive ion.

- B) It becomes a negative ion.

- C) It becomes neutral.

- D) It stays the same.

Answer: B) It becomes a negative ion.

Explanation: When an atom gains an electron, it becomes negatively charged, forming a negative ion (anion).

**Long-Answer Questions:**

1. **Explain how ionic bonds and covalent bonds are different, and give an example of each.**

Answer:

Ionic bonds form when one atom transfers electrons to another, resulting in oppositely charged ions that attract each other. An example is sodium chloride (NaCl). Covalent bonds form when atoms share electrons, as seen in molecules like water (H₂O). In ionic bonds, the atoms involved become charged, while in covalent bonds, they remain neutral.

2. **Describe the process of how an atom becomes an isotope and explain the importance of isotopes in science.**

Answer:

An atom becomes an isotope when it gains or loses neutrons. Isotopes of the same element have the same number of protons but different atomic masses. Isotopes are important in science for applications such as carbon dating, medical diagnostics (radioisotopes), and studying atomic structures.

3. **If you had two atoms of the same element but one is an ion and the other is neutral, how would you tell them apart based on their electron configuration?**

Answer:

The ion would have either more or fewer electrons than the neutral atom. A positive ion (cation) would have fewer electrons, while a negative ion (anion) would have more electrons. The number of protons would remain the same, but the difference in electrons would affect the atom's charge.

4. **How does the periodic table help predict an element’s chemical properties? Provide an example.**

Answer:

The periodic table organizes elements based on their atomic number and electron configurations. Elements in the same group have similar properties because they have the same number of valence electrons. For example, elements in Group 1, like sodium (Na) and potassium (K), are highly reactive metals because they both have one valence electron.

### 13. Extend (Beyond the Lesson)

To extend learning and deepen understanding, consider the following activities and readings:

**Task 1: Research Project on Real-World Applications**

Ask students to research how the understanding of chemical bonding is used in real-world applications, such as in developing new materials or medicines. They can present their findings in a short report or presentation. For example, how do chemists use knowledge of covalent bonds to create polymers like plastic?

**Task 2: Debate on the Use of Synthetic vs. Natural Chemicals**

Organize a classroom debate on the ethics and practicality of using synthetic chemicals (such as artificial sweeteners) versus natural chemicals in everyday products. How do these choices affect human health and the environment?

**Task 3: Spaced Practice Questions**

Provide a series of practice questions for students to revisit over time. These questions can include:

- Naming common compounds and identifying their types of bonds.

- Predicting chemical reactions based on the periodic table.

- Drawing electron dot structures to show bonding in molecules.

**Additional Reading:**

Assign a reading on the discovery of elements and how the periodic table was developed. This can include stories of famous scientists like Dmitri Mendeleev and how their work changed our understanding of chemistry.

By revisiting these concepts through spaced practice and applying them to new situations, students will reinforce their understanding and be better prepared for more advanced chemistry topics.