# Unit: Unit 2: Atomic Structure and Bonding

## Chapter: Chapter 6: Ionic and Metallic Bonding

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

## Unit Title: Atomic Structure and Bonding

## Chapter Title: Ionic and Metallic Bonding

# Lesson Title: Formation and Properties of Ions

### Essential Question:

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

### 1. Big Idea:

Ions are formed when atoms gain or lose electrons, and these ions play a crucial role in forming ionic bonds, which are critical in the structure of many substances, like salts.

### 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. An atom that loses electrons becomes positively charged and is called a **cation**. An atom that gains electrons becomes negatively charged and is called an **anion**. These ions are attracted to each other because of opposite charges, forming an **ionic bond**. Ionic bonds hold substances like salts together, giving them their unique properties, such as dissolving in water and conducting electricity when dissolved.

### 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 comes into contact with 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 is because salts are made of ions, held together by **ionic bonds**, while metals are held together by **metallic bonds**. The **ionic bonds** in salt allow it to dissolve in water, while the **metallic bonds** in metals prevent them from breaking apart in water.

### 3.2 Lesson Phenomenon:

When table salt (NaCl) is added to water, it dissolves, breaking into sodium and chloride ions. However, if a piece of metal, like a nail, is placed in water, it does not dissolve. This is because salt forms **ionic bonds**, while the metal forms **metallic bonds**. The process of ion formation and the difference in bonding explain why these substances behave differently in water.

### 4. Vocabulary:

- **Octet Rule:** Atoms tend to gain or lose electrons to achieve a full set of eight valence electrons, like the noble gases.

- **Anion:** A negatively charged ion formed when an atom gains electrons.

- **Cation:** A positively charged ion formed when an atom loses electrons.

- **Electrolyte:** A substance that dissolves in water to give a solution that conducts electric current due to the presence of ions.

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

- **Ionic Radius:** The radius of an ion, which increases when an atom gains electrons and decreases when it loses them.

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

### 5. SMART Objectives:

1. **Describe how ions are formed** when atoms lose or gain electrons.

2. **Write the symbols and charges of ions** for common elements.

3. **Predict the charge of an ion** based on its group in the periodic table.

4. **Explain the role of ions in chemical bonding** and how ionic bonds form between cations and anions.

### 6. Engage (Ignite):

**Phenomenon-Related Task:**

Ask: "Why does salt dissolve in water, but metal does not?"

**Hands-On Experiment:**

- **Materials Needed:** Table salt (NaCl), a small metal nail, two clear beakers, water.

- **Procedure:**

1. Fill two beakers with water.

2. Add a spoonful of salt to one beaker and stir.

3. Place a metal nail in the other beaker.

4. Observe what happens in both beakers.

**Follow-Up Questions:**

1. **What happened to the salt in the water?**

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

2. **What happened to the nail in the water?**

**Answer:** The nail did not dissolve. This is because the metal atoms are held together by metallic bonds, which do not interact with water the same way ionic bonds do.

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

**Answer:** Salt dissolves because it is made of ions, which separate when mixed with water. The nail is made of metal, which has metallic bonds that do not easily break apart in water.

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

Before diving into the lesson, it’s important to understand **how ions are formed** and **why they matter in bonding**. Atoms are made of protons, neutrons, and electrons. The number of electrons in an atom can change, and when this happens, ions are formed.

- **Cations** form when an atom loses electrons. For example, sodium (Na) loses one electron to become a sodium ion (Na⁺).

- **Anions** form when an atom gains electrons. For example, chlorine (Cl) gains one electron to become a chloride ion (Cl⁻).

The attraction between **cations** and **anions** creates **ionic bonds**. This is important because **ionic compounds**, like salt (NaCl), have specific properties, such as dissolving in water and forming electrolytes that can conduct electricity.

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

1. **What is a cation?**

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

2. **What is an anion?**

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

3. **How does the octet rule relate to ion formation?**

**Answer:** The octet rule states that atoms tend to gain or lose electrons to achieve a full set of eight valence electrons, which makes them more stable. This is why atoms form ions.

### 9. Explain (Lightbulb):

Atoms form ions to become more stable. This stability is achieved by following the **octet rule**, which states that atoms tend to gain or lose electrons to have eight electrons in their outer shell, just like the noble gases.

### # Ion Formation

- **Cations (Positive Ions):**

Atoms of metals, such as sodium (Na), lose one or more electrons to become positively charged. For example:

**Na → Na⁺ + 1 e⁻**

Sodium loses one electron to form a sodium ion (Na⁺).

- **Anions (Negative Ions):**

Non-metals, like chlorine (Cl), gain one or more electrons to become negatively charged. For example:

**Cl + 1 e⁻ → Cl⁻**

Chlorine gains one electron to form a chloride ion (Cl⁻).

### # Predicting the Charge of Ions:

You can predict the charge of an ion based on its position on the periodic table. For example:

- **Group 1 elements (like Na):** Lose 1 electron and form +1 ions.

- **Group 2 elements (like Mg):** Lose 2 electrons and form +2 ions.

- **Group 17 elements (like Cl):** Gain 1 electron and form -1 ions.

### # Ionic Bond Formation:

When a cation and an anion come together, they form an **ionic bond**. The opposite charges attract, holding the ions together. For example:

**Na⁺ + Cl⁻ → NaCl**

Sodium (Na⁺) and chloride (Cl⁻) ions form **sodium chloride (NaCl)**, commonly known as table salt.

### # Properties of Ionic Compounds:

- **Solubility in Water:** Ionic compounds, like salt, dissolve in water because water molecules can pull the ions apart, allowing them to move freely.

- **Electrical Conductivity:** When dissolved in water, ionic compounds form ions that can carry electric current, making the solution an **electrolyte**.

- **High Melting and Boiling Points:** Ionic bonds are strong, so it takes a lot of energy to break them, giving ionic compounds high melting and boiling points.

### # Sample Problem 1 (Solved):

**Problem:** Predict the charge of an ion formed by magnesium (Mg).

**Solution:** Magnesium is in Group 2 of the periodic table, so it will lose 2 electrons to achieve a full outer shell. Therefore, the ion formed will have a charge of +2 (Mg²⁺).

**Progress Check:**

**Problem:** Predict the charge of an ion formed by sulfur (S).

**Answer:** Sulfur is in Group 16, so it will gain 2 electrons to achieve a full outer shell. The ion formed will have a charge of -2 (S²⁻).

### Conclusion:

Ions are crucial for understanding chemical bonding. Metals tend to lose electrons and become positively charged **cations**, while non-metals gain electrons and become negatively charged **anions**. The attraction between these opposite charges forms **ionic bonds**, which are responsible for the properties of many compounds, like salt. Understanding how ions form and behave helps explain why substances like salt dissolve in water, while metals do not.

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

Here are three scaffolded questions to check your understanding of the concepts covered in the "Explain" section.

1. **What is an atom, and what are its main parts?**

- **Answer:** An atom is the smallest unit of matter that still retains the properties of an element. The main parts of an atom are the nucleus (which contains protons and neutrons) and the electron cloud (where electrons are found).

2. **How do protons, neutrons, and electrons differ in terms of charge and location within an atom?**

- **Answer:** Protons carry a positive charge and are located in the nucleus. Neutrons have no charge (they are neutral) and are also in the nucleus. Electrons have a negative charge and move around the nucleus in an electron cloud.

3. **Why do atoms of different elements have different properties?**

- **Answer:** Atoms of different elements have different properties because they have different numbers of protons, neutrons, and electrons. The number of protons defines the element, while the arrangement of electrons determines how the atom interacts with others.

---

### 11. Elaborate (Power Up)

Here are some open-ended questions and mini-tasks to deepen your understanding of atomic structure and its relevance to chemistry.

1. **Task:** Create a model of an atom using household items (e.g., clay, beads). Label the protons, neutrons, and electrons. How does your model help you visualize the structure of an atom?

- **Answer:** Creating a model helps visualize the atom's structure by showing the relative positions of protons, neutrons, and electrons. This hands-on activity reinforces the concept that protons and neutrons are in the nucleus, while electrons orbit around the nucleus.

2. **Question:** How might the arrangement of electrons in different energy levels influence an atom's chemical behavior in bonding with other atoms?

- **Answer:** The arrangement of electrons, especially those in the outermost energy level (valence electrons), determines how an atom forms bonds. Atoms tend to bond in ways that fill or empty their outermost shell to achieve a more stable electron configuration, similar to that of noble gases.

3. **Task:** Research and explain how the concept of isotopes can be applied in real-world scenarios, such as in medicine or archaeology.

- **Answer:** Isotopes are atoms of the same element with different numbers of neutrons. In medicine, radioactive isotopes like iodine-131 are used in treatments and diagnostics. In archaeology, carbon-14 dating helps determine the age of ancient artifacts by measuring the decay of this radioactive isotope.

---

### 12. Final Evaluation

### # Debate Question

**Debate:** Should the development of nuclear energy be expanded, considering both its potential benefits and risks?

- **Arguments For:** Nuclear energy is a powerful and efficient source of energy. It produces large amounts of electricity with minimal greenhouse gas emissions compared to fossil fuels. Additionally, advancements in safety protocols have reduced the risks of accidents.

- **Arguments Against:** The production of nuclear energy generates radioactive waste, which remains hazardous for thousands of years. There is also the risk of nuclear accidents (e.g., Chernobyl, Fukushima) that can have long-lasting environmental and health impacts.

---

### # Assessment Questions

**Multiple-Choice Questions:**

1. **What is the charge of an electron?**

a) Positive

b) Negative

c) Neutral

d) No charge

- **Answer:** b) Negative

- **Explanation:** Electrons have a negative charge, which balances the positive charge of protons in an atom.

2. **Which particle in an atom defines the element?**

a) Proton

b) Neutron

c) Electron

d) All of the above

- **Answer:** a) Proton

- **Explanation:** The number of protons in an atom's nucleus determines the element. For example, hydrogen has one proton, and helium has two.

3. **What happens when an atom gains or loses an electron?**

a) It becomes a different element

b) It becomes an isotope

c) It becomes an ion

d) It remains neutral

- **Answer:** c) It becomes an ion

- **Explanation:** When an atom gains or loses electrons, it becomes an ion, either positively charged (cation) or negatively charged (anion).

4. **Which of the following is NOT found in the nucleus of an atom?**

a) Proton

b) Neutron

c) Electron

d) None of the above

- **Answer:** c) Electron

- **Explanation:** Electrons are located in the electron cloud surrounding the nucleus, not inside it.

**Long-Answer Questions:**

1. **Explain the relationship between the number of protons, neutrons, and electrons in an atom and how it affects the atom's identity and stability.**

- **Answer:** The number of protons determines the identity of the atom (element). The number of neutrons can vary, leading to different isotopes of the same element. Electrons balance the charge of protons; the atom is neutral when the number of electrons equals the number of protons. If an atom gains or loses electrons, it becomes an ion. Stability is influenced by the balance of forces within the nucleus and the arrangement of electrons.

2. **Describe 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 (number of protons). Elements are arranged in rows by periods and columns by groups. Elements in the same group have similar chemical properties because they have the same number of valence electrons. The periodic table helps predict properties such as reactivity, state of matter, and bonding behavior.

3. **Compare and contrast how ionic and covalent bonds are formed.**

- **Answer:** Ionic bonds form when one atom donates an electron to another, resulting in positive and negative ions that attract each other. Covalent bonds form when two atoms share electrons. Ionic bonds typically occur between metals and non-metals, while covalent bonds usually occur between non-metals. Ionic compounds tend to form crystal lattices, while covalent compounds form distinct molecules.

4. **How do isotopes differ from each other, and why are some isotopes radioactive?**

- **Answer:** Isotopes of an element have the same number of protons but different numbers of neutrons, which results in different atomic masses. Some isotopes are radioactive because their nuclei are unstable. These isotopes undergo radioactive decay to achieve more stability, releasing energy in the process.

---

### 13. Extend (Beyond the Lesson)

Here are some additional tasks and readings to challenge your understanding and apply what you’ve learned.

1. **Task:** Explore how the atomic model evolved over time by researching key scientists like Dalton, Thomson, Rutherford, and Bohr. Create a timeline showing how each scientist contributed to our current understanding of the atom.

2. **Reading:** Read an article on how nuclear reactions are used to generate energy in nuclear power plants. Consider the environmental and safety challenges these plants face.

3. **Challenge Question:** Imagine you are an engineer designing a new type of battery for electric cars. How would your understanding of ions and electron movement help you create a more efficient battery?

4. **Application:** Investigate how the periodic table is used to design new materials, such as superconductors or lightweight alloys for airplanes. How does knowledge of atomic structure assist in these real-world applications?

5. **Spaced Practice:** Over the next few weeks, revisit the key concepts of atomic structure by completing periodic quizzes and revisiting your notes. Practice drawing atom diagrams and explaining how atoms bond to form molecules.