# Unit: Unit 2: Atomic Structure and Bonding

## Chapter: Chapter 6: Ionic and Metallic Bonding

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

### 1. Big Idea:

Ions are atoms that gain or lose electrons, forming charged particles that are crucial 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 lose or gain electrons. When an atom loses an electron, it becomes a positively charged ion (cation). When it gains an electron, it becomes a negatively charged ion (anion). These ions interact and bond with each other, creating ionic compounds through electrostatic forces, which are essential in forming stable materials, like salts.

### 3.1 Phenomenon-Based Learning

**Unit Phenomenon**: In cold northern countries, road salt melts ice and snow but metal street signs don’t dissolve in water. Why do salt and metal behave differently?

**Chapter Phenomenon**: Salt dissolves in water, but metals don’t. This is because salts consist of ionic bonds and metals consist of metallic bonds. Ionic bonds break apart in water to release ions, while metallic bonds hold metals together firmly.

### 3.2 Lesson Phenomenon:

When you sprinkle table salt (NaCl) into water, it dissolves, breaking into its ions (Na⁺ and Cl⁻). However, when you place a metal spoon in water, it doesn’t dissolve. This difference is due to the formation of ions in salts, which can interact with water molecules, unlike the metallic bonds in the spoon.

### 4. Vocabulary

1. **Octet Rule**: Atoms tend to gain, lose, or share electrons to achieve a full outer shell of 8 electrons.

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

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

4. **Electrolyte**: A substance that dissolves in water to produce a solution that conducts electricity, often due to the presence of ions.

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

6. **Ionic Radius**: The size of an ion, which can be different from the size of the neutral atom.

7. **Ionization**: The process of forming ions by gaining or losing electrons.

8. **Octet Rule**: A principle stating that atoms achieve maximum stability when they have eight electrons in their outer shell.

### 5. SMART Objectives

By the end of this lesson, you will be able to:

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

2. Write the correct symbols and charges for common ions.

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

### 6. Engage (Ignite)

**Phenomenon Question**:

- Why does table salt dissolve in water while a metal spoon does not?

**Experiment**:

**Materials**:

- Table salt (NaCl)

- Water

- Metal spoon

- Two clear cups

**Procedure**:

1. Fill two clear cups with water.

2. Add a teaspoon of table salt to one cup and stir. Observe what happens.

3. Submerge a metal spoon in the second cup of water. Observe what happens over time.

**Follow-up Questions**:

1. What happens to the salt in the water?

**Answer**: The salt dissolves, breaking into sodium (Na⁺) and chloride (Cl⁻) ions.

2. What happens to the metal spoon in water?

**Answer**: The metal spoon remains unchanged and doesn’t dissolve.

3. Why do you think salt dissolves, but the metal does not?

**Answer**: The salt breaks into ions, which interact with water molecules, while the metal’s bonds hold it together firmly.

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

Atoms are made up of protons, neutrons, and electrons. Protons have a positive charge, while electrons have a negative charge. Normally, an atom has the same number of protons and electrons, so it is neutral. However, atoms can gain or lose electrons. When this happens, the atom becomes an ion.

- **Formation of Ions**:

Ions form when atoms gain or lose electrons to achieve a full outer energy level, usually following the **Octet Rule**. Atoms with fewer electrons in their outer shell tend to lose them and become positively charged **cations**. Atoms with nearly full outer shells tend to gain electrons and become negatively charged **anions**.

- **Predicting Ion Charges**:

The position of an element in the periodic table can help you predict whether it will form a cation or an anion. Elements in groups 1, 2, and 13 typically lose electrons and form cations. Elements in groups 15, 16, and 17 tend to gain electrons and form anions.

**Discussion Questions**:

1. What happens to an atom when it loses electrons?

**Answer**: It becomes a positively charged ion (cation).

2. How does the periodic table help us predict the charge of an ion?

**Answer**: Elements in the same group form ions with the same charge because they have the same number of valence electrons.

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

**Scaffolded Questions**:

1. What happens to an atom’s charge when it gains one electron?

**Answer**: It becomes negatively charged (anion).

2. Which group in the periodic table is most likely to form cations?

**Answer**: Group 1 (alkali metals) is most likely to form cations because they lose one electron.

3. Explain why chlorine (Cl) forms a Cl⁻ ion.

**Answer**: Chlorine has 7 electrons in its outer shell and needs one more to complete the octet. By gaining an electron, it becomes Cl⁻.

### 9. Explain (Lightbulb)

Ions are atoms that have gained or lost electrons, leading to a net charge. This charge plays an important role in chemical bonding, particularly in ionic bonds, which occur between metals and nonmetals. In this lesson, we’ll explore how ions form, how to predict their charges, and why ions are so important in chemistry.

### How Ions Form

Atoms have protons, neutrons, and electrons. When an atom gains or loses electrons, it becomes charged, forming an ion. The loss or gain of electrons is often related to the **Octet Rule**, which states that atoms are most stable when they have 8 electrons in their outer shell.

1. **Cations (Positively Charged Ions)**:

Cations form when an atom loses one or more electrons. This usually happens to metals. For example, sodium (Na) has one electron in its outer shell. To achieve a stable configuration, it loses this electron and becomes Na⁺. This positively charged ion is now ready to bond with a negatively charged ion (anion).

**Sample Problem**:

Write the symbol for a potassium ion.

**Solution**: Potassium (K) is in group 1 and can lose 1 electron to form K⁺.

**Progress Check**:

Write the symbol for a magnesium ion.

**Answer**: Magnesium (Mg) is in group 2, so it loses 2 electrons to form Mg²⁺.

2. **Anions (Negatively Charged Ions)**:

Anions form when an atom gains one or more electrons. This usually happens to nonmetals. For example, chlorine (Cl) has 7 electrons in its outer shell. To achieve a stable configuration, it gains 1 electron and becomes Cl⁻.

**Sample Problem**:

Write the symbol for a sulfur ion.

**Solution**: Sulfur (S) is in group 16 and gains 2 electrons to form S²⁻.

**Progress Check**:

Write the symbol for an oxygen ion.

**Answer**: Oxygen (O) gains 2 electrons to form O²⁻.

### Predicting the Charge of Ions

The periodic table is a helpful tool for predicting the charge of ions. Elements in the same group tend to form ions with the same charge due to their similar electron configurations.

- **Group 1**: Loses 1 electron → Forms 1⁺ ions

- **Group 2**: Loses 2 electrons → Forms 2⁺ ions

- **Group 16**: Gains 2 electrons → Forms 2⁻ ions

- **Group 17**: Gains 1 electron → Forms 1⁻ ions

### Ionic Bonding

Ionic bonds form between cations and anions. A cation, which is positively charged, will attract an anion, which is negatively charged. This electrostatic attraction is what holds the ions together in a compound. For example, sodium (Na⁺) bonds with chlorine (Cl⁻) to form sodium chloride (NaCl), or table salt.

In the case of salt dissolving in water, the ionic bonds between Na⁺ and Cl⁻ break, and the ions are surrounded by water molecules. This is why salt dissolves in water. Metals, on the other hand, have a different type of bond called **metallic bonding**, which doesn’t break down in water.

**Sample Problem**:

Predict the type of ion aluminum (Al) will form.

**Solution**: Aluminum is in group 13, so it will lose 3 electrons and form Al³⁺.

**Progress Check**:

Predict the ion formed by fluorine (F).

**Answer**: Fluorine is in group 17 and gains 1 electron to form F⁻.

### Conclusion

In this lesson, we’ve explored how ions form, how to predict their charges, and how ionic bonds work. Understanding ions is key to understanding the behavior of many substances, such as how salt dissolves in water while metals do not.

### 10. Evaluate (Progress Check)

Below are three questions to help you review the key ideas from the previous "Explain" section. These questions will help you check your understanding before moving on.

1. **What is an atom made up of?**

- **Answer:** An atom is made up of three main subatomic particles: protons, neutrons, and electrons. Protons and neutrons are located in the nucleus (the center of the atom), while electrons orbit around the nucleus in electron shells.

2. **How is the periodic table organized?**

- **Answer:** The periodic table is organized by increasing atomic number (the number of protons in an atom). Elements are arranged in rows (called periods) and columns (called groups or families) based on their chemical properties. Elements in the same group usually have similar properties because they have the same number of electrons in their outer shell.

3. **Why do atoms form chemical bonds?**

- **Answer:** Atoms form chemical bonds to achieve a stable electron configuration, usually by filling their outermost electron shell. They can do this by sharing electrons (covalent bonds), transferring electrons (ionic bonds), or pooling electrons (metallic bonds).

### 11. Elaborate (Power Up)

Here are some tasks and open-ended questions to deepen your thinking about the concepts we’ve covered:

1. **Mini-Task:** Draw a diagram of an atom of oxygen (O). Label the nucleus, protons, neutrons, and electrons. Show how many electrons are in each shell.

- **Answer:** The oxygen atom has 8 protons and 8 neutrons in its nucleus. Its electrons are arranged with 2 electrons in the first shell and 6 electrons in the second shell.

2. **Open-Ended Question:** How do you think the properties of an element might change if you add or remove protons, neutrons, or electrons?

- **Answer:** Adding or removing protons changes the element itself because the number of protons defines the element. Adding or removing neutrons changes the isotope of the element but doesn't affect the chemical properties much. However, adding or removing electrons changes the charge of the atom, turning it into an ion, which can significantly alter its chemical reactivity.

3. **Open-Ended Question:** Imagine you are a scientist discovering a new element. What would be the first few things you would do to classify it on the periodic table?

- **Answer:** To classify a new element, I would first determine its atomic number (the number of protons). Next, I would investigate its electron configuration to figure out which group and period it belongs to. I would also test its physical and chemical properties to see if they match with any other elements in the same group.

### 12. Final Evaluation

### Debate Question:

**Debate Topic:** "Should we continue to spend money on studying elements that are very rare or only exist for a short time, like some of the synthetic elements?"

**Points for Discussion:**

- **For:** Studying rare or synthetic elements can lead to new technologies, better understanding of atomic structure, and advancements in fields like medicine and energy.

- **Against:** These elements are expensive to study, and their practical applications may be limited. The money could be better spent on more immediate scientific challenges.

### Assessment Questions

### Multiple-Choice Questions:

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

a) Neutron

b) Proton

c) Electron

d) Nucleus

- **Answer:** b) Proton

- **Explanation:** The number of protons in an atom determines which element it is, as each element has a unique atomic number.

2. **Which of the following best describes a covalent bond?**

a) Electrons are shared between atoms.

b) Electrons are transferred from one atom to another.

c) Electrons are pooled in a "sea" of electrons.

d) Neutrons are shared between atoms.

- **Answer:** a) Electrons are shared between atoms.

- **Explanation:** In a covalent bond, atoms share electrons to achieve a full outer electron shell.

3. **What is the atomic number of an element with 6 protons, 6 neutrons, and 6 electrons?**

a) 6

b) 12

c) 18

d) 24

- **Answer:** a) 6

- **Explanation:** The atomic number is defined by the number of protons in an atom, which in this case is 6.

4. **Which group in the periodic table contains the most reactive metals?**

a) Group 1 (Alkali Metals)

b) Group 2 (Alkaline Earth Metals)

c) Group 17 (Halogens)

d) Group 18 (Noble Gases)

- **Answer:** a) Group 1 (Alkali Metals)

- **Explanation:** Alkali metals are the most reactive metals because they have just one electron in their outermost shell and tend to lose that electron easily to form positive ions.

### Long-Answer Questions:

1. **Explain why elements in the same group of the periodic table have similar chemical properties.**

- **Answer:** Elements in the same group have the same number of electrons in their outermost shell, which determines how they will bond with other elements. Because their outer electron configurations are similar, they tend to react in similar ways.

2. **Describe the difference between an ionic bond and a covalent bond. Give an example of each.**

- **Answer:** In an ionic bond, electrons are transferred from one atom to another, resulting in positive and negative ions that attract each other. An example is sodium chloride (NaCl). In a covalent bond, electrons are shared between atoms, such as in a molecule of water (H₂O).

3. **Why do noble gases tend to not form chemical bonds with other elements?**

- **Answer:** Noble gases already have a full outer electron shell, making them very stable. They do not need to gain, lose, or share electrons, so they rarely form bonds with other elements.

4. **How can the discovery of new elements impact society? Give two potential examples.**

- **Answer:** The discovery of new elements can lead to technological advancements. For example, rare elements are used in electronics like smartphones and computers. Additionally, new elements could lead to breakthroughs in medicine, such as radioactive elements used in cancer treatments.

### 13. Extend (Beyond the Lesson)

To further your understanding of the concepts covered, here are some additional activities and readings:

1. **Task:** Research how elements like gold or silicon are used in modern technology. Write a short paragraph explaining what you learned.

- **Challenge:** Find out how the periodic table helps scientists predict the properties of elements that haven’t been discovered yet.

2. **Reading:** Explore the history of the periodic table. How did Dmitri Mendeleev organize the elements, and what predictions did he make about undiscovered elements?

- **Challenge:** Look into how modern scientists have discovered new elements that fit into the gaps Mendeleev predicted.

3. **Spaced Practice Activity:** Revisit your notes on atomic structure and periodic trends. One week from now, try drawing the periodic table from memory. Then, compare your version to the actual periodic table and see how much you remembered.

4. **Real-World Application:** Imagine you are working for a company that mines rare earth elements. What challenges might you face in obtaining these elements, and how could you use chemistry knowledge to solve these challenges?

By engaging in these activities, you’ll not only reinforce what you’ve learned but also see how chemistry applies to everyday life and future advancements!