# Unit: Unit 2: Atomic Structure and Bonding

## Chapter: Chapter 6: Ionic and Metallic Bonding

### 1. Big Idea:

- **Main Concept**: Ions are atoms or molecules that have gained or lost electrons, and their formation is crucial in the creation of ionic bonds, which give rise to many of the properties of salts.

- **Subordinate to Chapter's Big Idea**: The formation of ions leads to the creation of ionic bonds, which differ from metallic bonds in structure and behavior.

### 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 full outer shell of electrons, following the octet rule. This results in the atom acquiring a net positive or negative charge. Positively charged ions are called cations, and negatively charged ions are called anions. These ions attract each other and form ionic bonds, which are the basis of ionic 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 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.

### 3.2 Lesson Phenomenon

- **Lesson Phenomenon**: When salt (sodium chloride) is placed in water, it dissolves into individual ions, sodium (Na⁺) and chloride (Cl⁻). These ions are now free to move in the water, allowing for the conduction of electricity. However, when you place a piece of metal, such as iron, in water, it does not break apart into ions. Why does salt behave this way, while metal does not?

### 4. Vocabulary

- **Octet Rule**: A rule that states atoms tend to gain, lose, or share electrons to achieve a full set of eight valence electrons, making them more stable.

- **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 energy change that occurs when an atom gains an electron to form an anion.

- **Ionic Radius**: The radius of an ion, which can be larger or smaller than the neutral atom depending on whether it gains or loses electrons.

- **Ionization**: The process of an atom losing or gaining electrons to form an ion.

### 5. SMART Objectives

- **By the end of this lesson, you should be able to:**

- 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**:

- **Question**: Why does salt (sodium chloride) dissolve in water, while metal (like iron) does not?

**Hands-on Experiment**:

- **Materials**:

- Table salt (sodium chloride)

- A small piece of metal (like iron or aluminum)

- Two beakers of water

- Conductivity tester (or a simple circuit with a bulb and wires)

**Procedure**:

1. Fill two beakers with water.

2. In one beaker, dissolve a tablespoon of table salt.

3. In the second beaker, place a small piece of metal.

4. Use the conductivity tester to check whether each solution conducts electricity.

5. Record your observations.

**Follow-up Questions**:

1. **What happens when salt dissolves in water?**

- **Answer**: The salt dissociates into sodium (Na⁺) and chloride (Cl⁻) ions.

2. **Did the metal dissolve or conduct electricity in the water?**

- **Answer**: The metal did not dissolve, nor did it conduct electricity when placed in water.

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

- **Answer**: Salt is made of ions that separate in water, while metals have a different type of bonding (metallic bonds) that doesn't allow them to break apart in water.

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

**Background Information**:

- Ions are atoms that have gained or lost electrons. This process is known as ionization. Atoms gain or lose electrons to follow the **octet rule**, which states that atoms are most stable when they have eight electrons in their outermost energy level. When an atom loses one or more electrons, it becomes a **cation** (positively charged). When it gains one or more electrons, it becomes an **anion** (negatively charged).

**Interactive Elements**:

- Ask the following questions during the discussion:

1. **Why would an atom want to gain or lose electrons?**

- **Answer**: Atoms gain or lose electrons to achieve a full outer shell, making them more stable.

2. **Can you think of an example of a cation?**

- **Answer**: Sodium (Na) loses one electron to become Na⁺.

3. **Can you think of an example of an anion?**

- **Answer**: Chlorine (Cl) gains one electron to become Cl⁻.

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

**Scaffolded Questions**:

1. **What is the charge on a sodium ion (Na) if it loses one electron?**

- **Answer**: Na⁺ (It becomes a cation with a +1 charge).

2. **What is the charge on a chlorine ion (Cl) if it gains one electron?**

- **Answer**: Cl⁻ (It becomes an anion with a -1 charge).

3. **Which group on the periodic table would most likely form a +2 ion?**

- **Answer**: Group 2 (Alkaline earth metals like magnesium and calcium).

### 9. Explain (Lightbulb)

**Introduction to Ions and Ionic Bonding**

At the core of chemistry is the idea that atoms bond with one another to form molecules and compounds. One of the most important ways atoms bond is through the formation of **ions**. Ions are atoms that have gained or lost electrons, giving them a net charge. This transformation is crucial because it allows the atoms to bond with others through **ionic bonds**, leading to the formation of compounds like table salt (sodium chloride, NaCl).

In this lesson, we’ll explore how ions are formed, how to write their symbols, and how to predict their charges based on their position on the periodic table. We’ll also look at how ions behave in water and what makes ions different from metals when exposed to water.

**How Ions Are Formed**

Atoms are made up of protons, neutrons, and electrons. The protons in the nucleus have a positive charge, while the electrons orbiting the nucleus have a negative charge. Normally, atoms are neutral, meaning they have the same number of protons and electrons. However, atoms will often gain or lose electrons under certain conditions, and when they do, they no longer remain neutral.

When an atom **loses an electron**, it has more protons than electrons, and it becomes a **positively charged ion**, called a **cation**. For example, a sodium atom (Na) normally has 11 protons and 11 electrons. If it loses one electron, it will have 11 protons and only 10 electrons. This gives it a **+1 charge**, and we write it as Na⁺.

On the other hand, when an atom **gains an electron**, it gets more electrons than protons, and it becomes a **negatively charged ion**, called an **anion**. For instance, a chlorine atom (Cl) typically has 17 protons and 17 electrons. If it gains one extra electron, it will have 17 protons and 18 electrons, giving it a **-1 charge**, and we write it as Cl⁻.

**The Octet Rule**

Why do atoms gain or lose electrons in the first place? It all comes down to the **octet rule**. This rule states that atoms are most stable when they have eight electrons in their outermost energy level (or shell). Atoms will gain, lose, or share electrons to reach this stable configuration.

For example:

- Sodium (Na) has only one electron in its outermost shell. It can achieve a stable octet by **losing** that electron, becoming Na⁺.

- Chlorine (Cl) has seven electrons in its outer shell. It can achieve a stable octet by **gaining** one electron, becoming Cl⁻.

**Predicting the Charge of Ions Using the Periodic Table**

The periodic table is a powerful tool in predicting the charge of ions. Elements in the same group (column) of the periodic table have similar chemical properties, including how they form ions.

- **Group 1 elements** (like sodium, Na) have one electron in their outer shell. They tend to lose that electron and form **+1 ions**.

- **Group 2 elements** (like magnesium, Mg) have two electrons in their outer shell. They tend to lose both electrons and form **+2 ions**.

- **Group 17 elements** (like chlorine, Cl) have seven electrons in their outer shell. They tend to gain one electron to achieve a full octet and form **-1 ions**.

By looking at an element’s position on the periodic table, you can often predict whether it will form a cation or an anion and what the charge on that ion will be.

**Ionic Compounds and Ionic Bonds**

Ions are not just important on their own—they also play a crucial role in forming **ionic compounds**. When a cation and an anion come together, they form an ionic bond, which is a type of chemical bond. The positively charged cation is attracted to the negatively charged anion, and the result is a neutral compound.

A classic example of an ionic compound is **sodium chloride (NaCl)**, or table salt. Sodium (Na) loses one electron to form Na⁺, while chlorine (Cl) gains one electron to form Cl⁻. These oppositely charged ions attract each other, and the result is an ionic bond between them.

**Ions in Water: Why Salt Dissolves, but Metal Does Not**

Now, let’s return to the phenomenon we explored earlier: Why does salt dissolve in water, but metal doesn’t?

When ionic compounds like sodium chloride (NaCl) are placed in water, the water molecules pull the Na⁺ and Cl⁻ ions apart. This process is called **dissociation**. Once the ions are separated, they are free to move around in the water. These free-moving ions allow the solution to conduct electricity, which is why saltwater is a good conductor.

Metals, on the other hand, do not dissolve in water. This is because metals are held together by **metallic bonds**, which involve a "sea of electrons" that flow freely among the metal atoms. These bonds are strong and do not break apart when exposed to water, so the metal remains intact.

**Solved Sample Problem**

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

**Solution**:

1. Magnesium is in **Group 2** of the periodic table.

2. Group 2 elements have two electrons in their outermost shell, and they tend to lose both electrons to achieve a stable octet.

3. Since magnesium loses two electrons, it forms a **+2 ion**.

The symbol for the magnesium ion is **Mg²⁺**.

**Progress Check Question**:

**Problem**: Predict the charge of the ion formed by oxygen (O).

**Answer**:

1. Oxygen is in **Group 16** of the periodic table.

2. Group 16 elements have six electrons in their outermost shell. To achieve a stable octet, oxygen will **gain two electrons**.

3. Since oxygen gains two electrons, it forms a **-2 ion**.

The symbol for the oxygen ion is **O²⁻**.

**Conclusion**

In this lesson, we explored how ions are formed by gaining or losing electrons, how to predict the charge of ions using the periodic table, and the difference between ionic and metallic bonds. Ions form the basis of many everyday substances, including salt. When placed in water, ionic compounds dissociate into their individual ions, allowing them to conduct electricity, while metals do not behave the same way due to the nature of metallic bonds. Understanding how ions form, and their role in chemical bonding, is crucial for understanding the behavior of different materials in various environments.

Sure! Let's assume the "Explain" section in the lesson is about "The Periodic Table and Atomic Structure." Here's how I would structure the sections you’ve requested:

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

1. **What is the atomic number of an element, and how does it relate to the number of protons in an atom?**

**Answer**: The atomic number of an element is the number of protons in the nucleus of an atom. It identifies the element and is unique to each element. For example, the atomic number of hydrogen is 1 because it has 1 proton.

2. **How are elements arranged in the periodic table?**

**Answer**: Elements in the periodic table are arranged in order of increasing atomic number. They are organized into periods (horizontal rows) and groups (vertical columns) based on their chemical properties. Elements in the same group typically have similar chemical properties due to having the same number of valence electrons.

3. **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 (valence electrons). For example, all elements in Group 1 have one valence electron, which results in similar reactivity patterns.

### 11. Elaborate (Power Up)

1. **Mini-task**: Compare the reactivity of alkali metals (Group 1) as you move down the group. Why does reactivity increase?

**Answer**: As you move down Group 1 in the periodic table, the alkali metals become more reactive. This happens because the outer electron is farther from the nucleus and experiences less electrostatic attraction. As a result, it is easier to lose that electron, which increases the reactivity.

2. **Open-ended question**: How would the periodic table look if it were arranged by atomic mass instead of atomic number? What problems might arise from this type of arrangement?

**Answer**: If the periodic table were arranged by atomic mass, the order of some elements would be different. This could cause elements with different chemical properties to be placed in the same group. For example, iodine (I) has a lower atomic mass than tellurium (Te), but based on their chemical properties, iodine should come after tellurium. The modern periodic table avoids such inconsistencies by using atomic number instead of atomic mass.

3. **Additional question**: How does the arrangement of electrons in an atom determine its chemical behavior?

**Answer**: The chemical behavior of an atom is largely determined by the arrangement of its electrons, particularly the number of electrons in its outermost shell (valence electrons). Atoms tend to react in ways that allow them to achieve a full outer shell, either by gaining, losing, or sharing electrons. For example, noble gases are unreactive because they already have a full outer shell.

### 12. Final Evaluation

### Debate Question

**Should elements be arranged on the periodic table by their physical properties (e.g., melting points, densities) rather than their atomic number?**

- **Argument for**: Arranging elements by physical properties could help scientists quickly identify materials with similar properties for industrial or practical applications. For instance, metals with high melting points would be grouped together, aiding in material selection for projects that require heat resistance.

- **Argument against**: The current arrangement by atomic number reflects the underlying structure of atoms and provides a logical way to organize elements with similar chemical properties. Physical properties can vary widely within a group, so arranging elements by these properties could obscure important chemical relationships.

### Assessment Questions

**Multiple-Choice Questions:**

1. **Which of the following elements is in Group 2 of the periodic table?**

- a) Sodium (Na)

- b) Magnesium (Mg)

- c) Chlorine (Cl)

- d) Carbon (C)

**Correct Answer**: b) Magnesium (Mg)

**Explanation**: Group 2 elements are the alkaline earth metals. Magnesium (Mg) is one of them.

2. **What do all atoms of the same element have in common?**

- a) The same number of protons

- b) The same number of neutrons

- c) The same number of electrons

- d) The same atomic mass

**Correct Answer**: a) The same number of protons

**Explanation**: The atomic number (which is the number of protons) defines the element. While the number of neutrons and electrons can vary, all atoms of the same element have the same number of protons.

3. **What is the relationship between the group number and the number of valence electrons for main group elements?**

- a) Group number equals atomic number

- b) Group number equals the number of protons

- c) Group number equals the number of valence electrons

- d) Group number equals the atomic mass

**Correct Answer**: c) Group number equals the number of valence electrons

**Explanation**: For main group elements, the group number represents the number of valence electrons. For example, elements in Group 1 have one valence electron.

4. **Which of the following best explains why noble gases are unreactive?**

- a) They have full outer electron shells.

- b) They have no protons.

- c) They have an odd number of neutrons.

- d) They have low atomic numbers.

**Correct Answer**: a) They have full outer electron shells.

**Explanation**: Noble gases are unreactive because they already have a full valence shell, making them stable and unlikely to gain or lose electrons.

**Long-Answer Questions:**

1. **Explain why elements in the same period have different chemical properties but elements in the same group have similar chemical properties.**

**Answer**: Elements in the same period have different chemical properties because they have different numbers of electrons and different electron configurations. Their valence electrons are in different energy levels, which affects their reactivity. However, elements in the same group have the same number of valence electrons, which results in similar chemical properties because they tend to react in the same way to achieve a full outer shell.

2. **Describe how the periodic table is organized, including how elements are grouped and why the order of elements is important.**

**Answer**: The periodic table is organized by increasing atomic number, which reflects the number of protons in an atom. Elements are arranged in periods (horizontal rows) according to their increasing atomic number and in groups (vertical columns) based on their chemical properties. Elements in the same group have similar chemical behavior because they have the same number of valence electrons. The order is important because it reflects the periodic trends in properties such as atomic size, ionization energy, and electronegativity.

3. **Why do elements on the left side of the periodic table tend to lose electrons, while elements on the right side tend to gain electrons?**

**Answer**: Elements on the left side of the periodic table (mainly metals) have fewer valence electrons, and it is energetically favorable for them to lose these electrons to achieve a full outer shell. On the other hand, elements on the right side (non-metals) have more valence electrons and are closer to filling their outer shell, so they tend to gain electrons to complete their outer shell and become stable.

4. **Compare and contrast the properties of metals, non-metals, and metalloids based on their position in the periodic table.**

**Answer**: Metals, typically found on the left side of the periodic table, are shiny, malleable, ductile, and good conductors of heat and electricity. Non-metals, located on the right side of the periodic table, are often brittle, poor conductors, and can be gases or dull solids. Metalloids, found along the "staircase" line between metals and non-metals, have properties intermediate between metals and non-metals, such as being semiconductors.

### 13. Extend (Beyond the Lesson)

- **Task**: Research the discovery of the periodic table by Dmitri Mendeleev. What challenges did he face, and how did he predict the existence of elements that hadn’t yet been discovered?

- **Reading**: Read about the properties of transition metals and their applications in modern technology. How do their unique electron configurations make them useful in electronics, catalysis, and construction materials?

- **Challenge**: Imagine you are a scientist tasked with discovering a new element. What properties would you expect it to have based on its position in the periodic table? Predict its possible applications.

- **Spaced Practice**: Over the next few weeks, revisit the periodic trends (atomic size, ionization energy, electronegativity) and relate them to real-world applications. For example, how do these trends explain the materials used in batteries or electronics?

This structure provides a range of activities to check for understanding, deepen thinking, and extend learning beyond the classroom.