# 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

1. **What is the molecular formula for water?**

\*Answer:\* The molecular formula for water is H₂O. It consists of two hydrogen atoms and one oxygen atom.

2. **Why is the periodic table organized into groups and periods?**

\*Answer:\* The periodic table is organized into groups (vertical columns) and periods (horizontal rows) to reflect the repeating patterns in the chemical behavior of elements. Elements in the same group have similar chemical properties because they have the same number of valence electrons. Periods represent the energy levels of electrons.

3. **How does the Law of Conservation of Mass apply to a chemical reaction?**

\*Answer:\* The Law of Conservation of Mass states that mass is neither created nor destroyed in a chemical reaction. This means that the total mass of the reactants must be equal to the total mass of the products in a chemical reaction. For example, if you start with 4 grams of reactants, you should end up with 4 grams of products.

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### 11. Elaborate (Power Up)

1. **Mini-Task:**

Write a short explanation of how the atomic structure of an element determines its chemical reactivity.

\*Answer:\* The chemical reactivity of an element is primarily determined by the number and arrangement of its electrons, particularly the outermost electrons, called valence electrons. Atoms with a nearly full or nearly empty outer shell are more reactive because they tend to gain, lose, or share electrons to achieve a stable electron configuration.

2. **Open-ended Question:**

How would the periodic table look different if elements were arranged by their atomic mass rather than their atomic number?

\*Answer:\* If elements were arranged by atomic mass rather than atomic number, the periodic table would lose its clear pattern of chemical behavior seen in groups. While atomic mass increases generally with atomic number, there are exceptions where elements with lower atomic numbers have a higher atomic mass. This would disrupt the alignment of elements with similar properties.

3. **Additional Question:**

What might happen if the electron configuration of an element is changed? For example, if an atom gains or loses an electron.

\*Answer:\* When an atom gains or loses an electron, it becomes an ion. If it gains an electron, it becomes negatively charged (anion). If it loses an electron, it becomes positively charged (cation). This change can make the atom more reactive and affect its ability to bond with other atoms.

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### 12. Final Evaluation

### # Debate Question:

**Should scientists focus on developing new elements or on finding practical uses for the elements we already know?**

\*Arguments For Developing New Elements:\*

- Expanding our knowledge of matter and the universe.

- Potential discovery of elements with unique properties useful in technology, industry, or medicine.

\*Arguments For Using Existing Elements:\*

- Many elements are under-utilized, and we could focus on discovering new applications.

- Practical uses of existing elements could address current global challenges such as energy, climate change, and healthcare.

### # Multiple-Choice Questions:

1. **Which of the following elements is a noble gas?**

a) Sodium

b) Chlorine

c) Neon

d) Hydrogen

\*Answer:\* c) Neon

\*Explanation:\* Neon is a noble gas, which means it has a full outer shell of electrons and is very unreactive.

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

a) Positive

b) Negative

c) Neutral

d) Variable

\*Answer:\* a) Positive

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

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

a) Transfer of electrons between atoms

b) Sharing of electrons between atoms

c) Attraction between oppositely charged ions

d) Formation of a lattice structure

\*Answer:\* b) Sharing of electrons between atoms

\*Explanation:\* A covalent bond involves the sharing of electrons between atoms to achieve a stable electron configuration.

4. **Which of the following best explains the reactivity of alkali metals?**

a) They have a full outer electron shell.

b) They have one valence electron, which they easily lose.

c) They are gases at room temperature.

d) They form covalent bonds with nonmetals.

\*Answer:\* b) They have one valence electron, which they easily lose.

\*Explanation:\* Alkali metals, found in Group 1 of the periodic table, are highly reactive because they have one valence electron that they lose easily to form positive ions.

### # Long-Answer Questions:

1. **How does the periodic table help predict the properties of elements?**

\*Answer:\* The periodic table is organized in a way that elements in the same group have similar chemical properties because they have the same number of valence electrons. For example, elements in Group 1 (alkali metals) are all highly reactive and tend to form +1 ions. The periods (rows) indicate the number of electron shells an atom has, which also affects its chemical behavior. This organization helps scientists predict how an element will react and what kind of compounds it will form.

2. **Explain why ionic compounds tend to have high melting and boiling points.**

\*Answer:\* Ionic compounds have high melting and boiling points because they are formed by strong electrostatic forces between oppositely charged ions. These forces, known as ionic bonds, require a large amount of energy to break. As a result, ionic compounds remain solid at room temperature and only melt or boil at very high temperatures.

3. **Describe how the electron configuration of an atom is related to its position in the periodic table.**

\*Answer:\* The electron configuration of an atom determines its position in the periodic table. The number of electron shells is equal to the period number, and the number of valence electrons determines the group number (for Groups 1, 2, and 13-18). For example, an element in Group 1 has one valence electron, while an element in Group 17 has seven valence electrons. This configuration influences the element’s chemical properties and reactivity.

4. **What is the difference between a physical change and a chemical change? Provide an example of each.**

\*Answer:\* A physical change involves a change in a substance's physical properties, such as shape, state, or size, without changing its chemical identity. For example, melting ice is a physical change because the water remains H₂O. A chemical change, on the other hand, involves a change in the substance's chemical composition. For example, when iron rusts, it reacts with oxygen to form iron oxide, a new substance.

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### 13. Extend (Beyond the Lesson)

1. **Challenge Task:**

Research how the discovery of new elements has contributed to advancements in technology or medicine. Write a short report on one element and its role in a modern application (e.g., technetium in medical imaging or silicon in electronics).

2. **Real-World Application Question:**

How do you think the understanding of chemical reactions and the periodic table can help in solving environmental problems like pollution or climate change?

\*Sample Reflection:\* Understanding chemical reactions can help in developing cleaner energy sources, reducing emissions, and creating sustainable materials. For example, catalysts can be developed to speed up reactions that convert harmful gases into less dangerous substances.

3. **Spaced Practice Suggestion:**

Over the next week, keep a journal of how chemistry is part of your everyday life. Observe and note down any chemical reactions you encounter, such as cooking food, rusting of metals, or the use of cleaning products. This will help reinforce your understanding of concepts like chemical changes, mixtures, and compounds.

4. **Additional Reading:**

Explore the concept of "Green Chemistry" and how scientists are working to design chemical processes that reduce waste and environmental impact.

## Unit Title: Atomic Structure and Bonding

## Chapter Title: Ionic and Metallic Bonding

# Lesson Title: Formation and Properties of Ions

### Essential Questions:

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

### 1. Big Idea:

- **Ions form when atoms gain or lose electrons, and their formation is essential for ionic bonding which holds compounds like salts together.**

### 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 obtain a full outer shell of electrons, achieving a more stable configuration. This is often referred to as the **octet rule**. Atoms that lose electrons become positively charged ions (cations), while atoms that gain electrons become negatively charged ions (anions). These charged ions are crucial in forming **ionic bonds**, where oppositely charged ions attract, resulting in the formation of ionic compounds such as 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:

- Imagine taking a piece of table salt (NaCl) and a piece of aluminum foil (Al) and placing both in a glass of water. The salt dissolves and breaks apart into ions, while the aluminum foil remains unchanged. Why does the salt dissolve into ions while the metal stays intact? This difference lies in the nature of the bonds within the two substances: **ionic bonds** in salt and **metallic bonds** in the foil. Understanding how ions form will help explain this behavior.

### 4. Vocabulary:

- **Octet Rule:** Atoms tend to gain, lose, or share electrons to achieve a full set of eight valence 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 produces ions when dissolved in water, allowing the solution to conduct electricity.

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

- **Ionic Radius:** The size of an ion, which can differ from the size of its neutral atom.

- **Ionization:** The process of removing one or more electrons from an atom to form a cation.

- **Ionic Bond:** The electrostatic force that holds oppositely charged ions together in an ionic compound.

### 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):

### # Activity: Dissolving Salt vs. Metal in Water

- **Materials:**

- Table salt (NaCl)

- Aluminum foil

- Two glasses of water

- Stirring stick

**Procedure:**

1. Place a teaspoon of table salt in one glass of water and stir. Observe what happens to the salt over time.

2. Place a piece of aluminum foil in the second glass of water. Stir and observe what happens.

3. Compare the results.

**Follow-up Questions:**

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

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

2. **Why didn’t the aluminum foil dissolve in water?**

- **Answer:** The aluminum foil did not dissolve because metals have metallic bonds, which are much stronger and do not break apart in water like ionic bonds do.

3. **What does the difference in behavior between salt and aluminum tell you about the types of bonding in these materials?**

- **Answer:** Salt has ionic bonds that break apart in water, forming ions, while aluminum has metallic bonds that remain intact in water.

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

- **Background Information:**

Atoms are neutral because they have an equal number of protons (positive charge) and electrons (negative charge). However, atoms can lose or gain electrons, and when they do, they become charged particles called **ions**. Atoms tend to form ions in order to achieve a stable electron configuration, often following the **octet rule**, which states that atoms are most stable when they have eight electrons in their outermost energy level.

- **Cations** are formed when atoms lose electrons and become positively charged. For example, sodium (Na) loses one electron to form Na⁺.

- **Anions** are formed when atoms gain electrons and become negatively charged. For example, chlorine (Cl) gains one electron to form Cl⁻.

The periodic table helps predict the charge of ions. Elements in the same group tend to form ions with the same charge. For example, all elements in Group 1 (alkali metals) form +1 cations, while elements in Group 17 (halogens) form -1 anions.

**Discussion Question:**

- **Why do some atoms lose electrons while others gain electrons?**

- **Answer:** Atoms lose or gain electrons depending on the number of electrons they have in their outermost shell. Atoms with only a few electrons in their outer shell (like sodium) tend to lose electrons to achieve a full outer shell, while atoms with almost a full outer shell (like chlorine) tend to gain electrons.

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

1. **Why does sodium form a +1 ion while chlorine forms a -1 ion?**

- **Answer:** Sodium has one electron in its outer shell, so it loses that electron to achieve a stable configuration, forming a +1 cation (Na⁺). Chlorine has seven electrons in its outer shell, so it gains one electron to have a full outer shell, forming a -1 anion (Cl⁻).

2. **What is the octet rule?**

- **Answer:** The octet rule states that atoms tend to gain, lose, or share electrons in order to have eight electrons in their outermost shell, achieving a stable configuration.

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

- **Answer:** Magnesium is in Group 2 of the periodic table, so it loses two electrons to form a +2 cation (Mg²⁺).

### 9. Explain (Lightbulb):

### # Formation of Ions:

Atoms are composed of three types of subatomic particles: protons, neutrons, and electrons. Protons carry a positive charge, electrons carry a negative charge, and neutrons are neutral. In a neutral atom, the number of protons is equal to the number of electrons, balancing the overall charge.

However, atoms can gain or lose electrons, and when this happens, the atom becomes an **ion**. There are two types of ions:

- **Cations**: When an atom loses one or more electrons, it becomes a positively charged ion. This is because it has more protons than electrons. For example, a sodium atom (Na) loses one electron to become a sodium ion, Na⁺.

- **Anions**: When an atom gains one or more electrons, it becomes a negatively charged ion because it has more electrons than protons. For example, a chlorine atom (Cl) gains one electron to become a chloride ion, Cl⁻.

### # The Octet Rule:

Atoms form ions primarily to achieve a stable electron configuration. For most elements, this means having eight electrons in their outermost energy level (or two for very small atoms like hydrogen and helium). This tendency is called the **octet rule**. Atoms will gain, lose, or share electrons to reach this stable configuration.

### # Ion Formation and the Periodic Table:

The periodic table is a powerful tool for predicting how atoms will form ions. Elements in the same group (vertical column) of the periodic table tend to form ions with the same charge.

- **Group 1 elements** (alkali metals) have one electron in their outer shell. They tend to lose this electron to form +1 cations. For example, lithium (Li) forms Li⁺, sodium (Na) forms Na⁺, and potassium (K) forms K⁺.

- **Group 2 elements** (alkaline earth metals) have two electrons in their outer shell. They tend to lose both electrons to form +2 cations. For example, magnesium (Mg) forms Mg²⁺ and calcium (Ca) forms Ca²⁺.

- **Group 17 elements** (halogens) have seven electrons in their outer shell. They tend to gain one electron to form -1 anions. For example, fluorine (F) forms F⁻, chlorine (Cl) forms Cl⁻, and bromine (Br) forms Br⁻.

- **Group 16 elements** (oxygen group) have six electrons in their outer shell and tend to gain two electrons to form -2 anions. For example, oxygen (O) forms O²⁻.

### # Example Problem:

**Problem:** Predict the ion formed by calcium (Ca) and write its symbol and charge.

**Solution:** Calcium is in Group 2 of the periodic table, meaning it has two electrons in its outer shell. To achieve a stable configuration (octet rule), calcium will lose these two electrons, forming a +2 ion. The symbol for the calcium ion is Ca²⁺.

**Progress Check:**

**Question:** Predict the ion formed by fluorine (F) and write its symbol and charge.

**Answer:** Fluorine is in Group 17, so it will gain one electron to achieve a stable configuration. The symbol for the fluoride ion is F⁻.

### # Ionic Bonds in Compounds:

When a cation and an anion come together, they form an **ionic bond** due to the attraction between their opposite charges. This is how ionic compounds are formed, like sodium chloride (NaCl), where Na⁺ and Cl⁻ ions are held together by ionic bonds.

Ionic compounds often dissolve in water because the water molecules are able to separate the ions from each other, allowing them to move freely in the solution. This is why salt dissolves in water, and the resulting solution can conduct electricity (because of the free-moving ions, known as **electrolytes**).

### # Why Metals Don’t Dissolve:

Metals do not dissolve in water because they have a different type of bond—**metallic bonds**. In metallic bonds, the atoms are held together by a "sea of electrons" that are free to move throughout the metal. This gives metals their unique properties, such as conductivity and malleability, and prevents them from breaking apart in water.

### Solved Problem:

**Problem:** Explain why sodium (Na) forms a +1 ion, while chlorine (Cl) forms a -1 ion, and how they combine to form sodium chloride (NaCl).

**Solution:** Sodium has one electron in its outer shell, so it loses that electron to form a Na⁺ ion. Chlorine has seven electrons in its outer shell, so it gains one electron to form a Cl⁻ ion. The Na⁺ and Cl⁻ ions are attracted to each other due to their opposite charges, forming the ionic compound sodium chloride (NaCl).

### Progress Check:

**Question:** Predict the ion formed by oxygen (O) and write its symbol and charge.

**Answer:** Oxygen is in Group 16, so it will gain two electrons to achieve a stable configuration. The symbol for the oxide ion is O²⁻.

### Conclusion:

Ions play a crucial role in chemical bonding, particularly in the formation of ionic compounds. Atoms form ions by gaining or losing electrons to achieve a stable electron configuration, typically following the octet rule. The periodic table is a useful tool for predicting the charge of ions based on an element’s position. Understanding how ions form and interact helps explain the properties of substances like salts, which dissolve in water, and metals, which do not.