# 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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### Essential Questions (EQs):

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

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### 1. Big Idea:

Atoms form ions by losing or gaining electrons to achieve a stable electron configuration, often following the Octet Rule. These ions are crucial in the formation of ionic bonds.

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### 2. Essential Questions:

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

- **Answer:** Ions form when atoms lose or gain electrons. Atoms lose electrons to form positively charged ions (cations) or gain electrons to form negatively charged ions (anions). These ions interact through electrostatic forces to create ionic bonds, which hold compounds together.

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### 3. Phenomenon-Based Learning:

**Phenomenon:**

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, while metals do not. This difference is due to the types of bonds present. Salt contains ionic bonds, where positive and negative ions are attracted to each other. Metals, on the other hand, have metallic bonds and a "sea of electrons" that holds them together, preventing them from dissolving in water.

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### 4. Vocabulary:

- **Octet Rule:** Atoms tend to gain, lose, or share electrons to have a full set of eight valence electrons, resembling the electron configuration of a noble gas.

- **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 produces ions in solution and can conduct electricity.

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

- **Ionic Radius:** The size of an ion, which can change depending on whether an atom gains or loses electrons.

- **Ionization:** The process by which an atom or a molecule acquires a positive or negative charge by gaining or losing electrons.

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### 5. SMART Objectives:

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

1. **Describe how ions are formed** by the loss or gain of electrons.

2. **Write the symbols and charges of ions** based on their electron configuration.

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

4. **Distinguish between ionic and metallic bonding** by examining how different substances interact with water.

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### 6. Engage (Ignite):

Start with a question related to the phenomenon:

**Question:** Why does salt dissolve in water, but metal doesn’t?

**Hands-on Experiment: Dissolving Salt vs. Metal in Water**

**Materials:**

- Table salt (NaCl)

- Small metal pieces (e.g., iron nails)

- Two clear containers

- Water

- Stirring stick

**Procedure:**

1. Fill the two containers with water.

2. Add a spoonful of salt to one container and stir. Observe what happens.

3. Place a small metal piece (like an iron nail) in the second container and stir. Observe what happens.

4. Compare the two results.

**Follow-up Questions:**

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

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

2. **Did the metal dissolve in the water? Why or why not?**

**Answer:** The metal did not dissolve because metals are held together by metallic bonds, which do not break apart in water as ionic bonds do.

3. **What does this tell us about the difference between salt and metal?**

**Answer:** Salt is made of ions, which can separate in water due to ionic bonds. Metals have a different type of bonding (metallic bonds), which remains intact in water.

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

**Background Information:**

Atoms are the building blocks of matter. But atoms don’t always stay neutral. Sometimes, they gain or lose electrons to become ions. These ions are important in making chemical bonds, especially in ionic compounds like salt.

**Interactive Notes:**

- **Ions Formation:** Atoms become ions by gaining or losing electrons. Metals tend to lose electrons and form **cations** (positive ions), while non-metals tend to gain electrons and form **anions** (negative ions).

- **Octet Rule:** Atoms want to have 8 electrons in their outer shell (valence electrons) to be stable. This is known as the **Octet Rule**. This is why atoms lose or gain electrons to form ions.

**Scaffolded Question:**

1. **Why do atoms want to have 8 electrons in their outer shell?**

**Answer:** Atoms want to achieve a stable electron configuration, similar to that of noble gases, which have 8 valence electrons.

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

**Scaffolded Questions:**

1. **What is an ion?**

**Answer:** An ion is an atom or molecule that has gained or lost electrons and now has a charge.

2. **What is the difference between a cation and an anion?**

**Answer:** Cations are positively charged ions (formed by losing electrons), and anions are negatively charged ions (formed by gaining electrons).

3. **How can you predict the charge of an ion based on its position in the periodic table?**

**Answer:** Elements in groups 1, 2, and 3 tend to lose electrons and form positive ions (cations). Elements in groups 16 and 17 tend to gain electrons and form negative ions (anions).

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### 9. Explain (Lightbulb):

When you mix salt with water, the salt dissolves because it is made up of ions. Salt is an **ionic compound**—it contains positively charged sodium ions (Na⁺) and negatively charged chloride ions (Cl⁻). These ions are held together by **ionic bonds**, which are strong electrostatic attractions between oppositely charged ions.

### Formation of Ions:

- **Cations:** Metals tend to lose electrons easily because they have fewer electrons in their outer shell. When a metal atom loses one or more electrons, it becomes a positively charged ion, or **cation**. For example, sodium (Na) loses one electron to become Na⁺.

**Example 1: Sodium Ion Formation**

- Sodium (Na) has 1 electron in its outermost shell.

- It loses 1 electron to achieve the stable electron configuration of neon (Ne).

- The result is a sodium ion, Na⁺.

**Progress Check 1:**

**What is the charge of a magnesium ion (Mg) if it loses two electrons?**

**Answer:** The charge is Mg²⁺ because magnesium loses two electrons.

- **Anions:** Non-metals tend to gain electrons because they have more electrons in their outer shell. When a non-metal atom gains one or more electrons, it becomes a negatively charged ion, or **anion**. For example, chlorine (Cl) gains one electron to become Cl⁻.

**Example 2: Chloride Ion Formation**

- Chlorine (Cl) has 7 electrons in its outermost shell.

- It gains 1 electron to achieve the stable electron configuration of argon (Ar).

- The result is a chloride ion, Cl⁻.

**Progress Check 2:**

**What is the charge of an oxygen ion (O) if it gains two electrons?**

**Answer:** The charge is O²⁻ because oxygen gains two electrons.

### Predicting Ion Charges Using the Periodic Table:

- **Group 1 Elements (Alkali Metals):** Always form +1 ions (e.g., Na⁺, K⁺).

- **Group 2 Elements (Alkaline Earth Metals):** Always form +2 ions (e.g., Mg²⁺, Ca²⁺).

- **Group 16 Elements (Chalcogens):** Typically form -2 ions (e.g., O²⁻, S²⁻).

- **Group 17 Elements (Halogens):** Typically form -1 ions (e.g., Cl⁻, F⁻).

**Ionic Bonding:**

When a cation meets an anion, they are attracted to each other because of their opposite charges. This attraction forms an **ionic bond**, which is the force that holds the ions together in an ionic compound. For example, sodium (Na⁺) and chloride (Cl⁻) ions bond to form sodium chloride (NaCl), which is common table salt.

### Ionic Radius:

The size of an ion, or **ionic radius**, depends on whether the atom has gained or lost electrons. When an atom loses electrons to form a cation, it becomes smaller because there are fewer electrons repelling each other. When an atom gains electrons to form an anion, it becomes larger because the added electrons increase repulsion.

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

1. **What happens to the size of an atom when it becomes a cation?**

**Answer:** The atom becomes smaller because it loses electrons, reducing electron repulsion.

2. **Why do non-metals typically form negative ions?**

**Answer:** Non-metals gain electrons to achieve a stable electron configuration, which gives them a negative charge.

3. **What is the charge of a chlorine ion, and how does it form?**

**Answer:** A chlorine ion has a charge of Cl⁻. It forms by gaining one electron.

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### Conclusion:

Ions play a fundamental role in chemical bonding, especially in the formation of ionic compounds. By gaining or losing electrons, atoms form ions that can bond together through electrostatic forces. This is why salt dissolves in water—it’s made of ions that separate and interact with water molecules. Metals, on the other hand, do not dissolve because they are held together by metallic bonds, which are different from the ionic bonds in salt. Understanding how ions form and how they bond helps explain many everyday phenomena, such as why road salt works to melt ice but metal remains unaffected.

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

### # Question 1:

**What is an atom?**

Answer: An atom is the smallest unit of matter that retains the properties of an element. It consists of a nucleus containing protons and neutrons, surrounded by electrons.

### # Question 2:

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

Answer: Protons are positively charged and found in the nucleus. Neutrons have no charge (neutral) and are also located in the nucleus. Electrons are negatively charged and orbit around the nucleus in electron clouds.

### # Question 3:

**Why are electrons important in chemical bonding?**

Answer: Electrons, especially those in the outermost energy levels (valence electrons), are crucial in chemical bonding because they are the ones involved in forming bonds between atoms. Atoms bond to achieve a more stable electron configuration.

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### 11. Elaborate (Power Up)

### # Mini-Tasks / Open-Ended Questions

**Task 1:**

Explore how the structure of an atom changes when it becomes an ion.

Answer: When an atom becomes an ion, it either gains or loses electrons. If it gains electrons, it becomes a negatively charged ion (anion). If it loses electrons, it becomes a positively charged ion (cation). The number of protons and neutrons stays the same.

**Task 2:**

What might happen to a molecule if one of its atoms gains or loses an electron?

Answer: If an atom in a molecule gains or loses an electron, the molecule may become charged, leading to an ion. This can affect how the molecule interacts with other molecules, potentially changing its reactivity, structure, or behavior in a chemical reaction.

**Task 3:**

Think of a real-world example where the understanding of atoms and their structure is important. How does this knowledge apply in fields like medicine or technology?

Answer: In medicine, for example, understanding atoms is essential for the development of imaging techniques like MRI or in the delivery of drugs that interact with specific atoms or ions in the body. In technology, knowledge of atoms is used to create semiconductors, which are the foundation of modern electronics.

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### 12. Final Evaluation

### # Debate Question:

**Should atomic energy be used as a primary source of global power?**

- Arguments For:

- Atomic energy produces large amounts of electricity with very little fuel.

- It generates fewer greenhouse gases compared to fossil fuels, helping combat climate change.

- Modern technology makes nuclear power plants safer than ever before.

- Arguments Against:

- The disposal of radioactive waste is a significant environmental and safety concern.

- Accidents at nuclear power plants, though rare, can have devastating long-term effects.

- Developing nuclear energy is expensive and takes years to build.

### # Multiple-Choice Questions:

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

- A) Positive

- B) Negative

- C) Neutral

- D) It depends on the atom

**Answer:** C) Neutral.

**Explanation:** Neutrons have no charge, unlike protons (positive) and electrons (negative).

2. **Which part of the atom is responsible for chemical bonding?**

- A) Protons

- B) Neutrons

- C) Electrons

- D) Nucleus

**Answer:** C) Electrons.

**Explanation:** Electrons, especially those in the outermost shell (valence electrons), are involved in chemical bonding.

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

- A) It becomes a negative ion.

- B) It becomes a positive ion.

- C) It becomes neutral.

- D) Nothing changes.

**Answer:** B) It becomes a positive ion.

**Explanation:** When an atom loses an electron, it has more protons than electrons, making it positively charged.

4. **Which of the following best describes the nucleus of an atom?**

- A) It contains only electrons.

- B) It contains protons and neutrons.

- C) It contains only protons.

- D) It is located outside the atom.

**Answer:** B) It contains protons and neutrons.

**Explanation:** The nucleus is composed of protons and neutrons, while electrons orbit around it.

### # Long-Answer Questions:

1. **Explain how the arrangement of electrons in an atom determines its chemical properties.**

**Answer:** The chemical properties of an atom are determined by the number and arrangement of its outermost electrons, called valence electrons. Atoms with similar valence electron configurations tend to exhibit similar chemical behavior. For example, atoms with one valence electron are highly reactive, like sodium (Na), because they easily lose that electron to achieve a stable electron configuration.

2. **Describe how isotopes of the same element are similar and different.**

**Answer:** Isotopes of the same element have the same number of protons but different numbers of neutrons. This means they have the same atomic number but different atomic masses. Isotopes behave similarly in chemical reactions because they have the same electron configuration, but they may have different physical properties, such as mass or stability.

3. **How does the periodic table help predict how elements will react with each other?**

**Answer:** The periodic table groups elements with similar properties together. Elements in the same group (vertical column) have the same number of valence electrons, which allows us to predict their reactivity. For example, elements in Group 1 (alkali metals) are highly reactive because they all have one valence electron that they tend to lose in chemical reactions.

4. **Compare and contrast covalent bonds and ionic bonds.**

**Answer:** Covalent bonds form when atoms share electrons to achieve a stable electron configuration. They typically occur between nonmetals. Ionic bonds, on the other hand, occur when one atom donates an electron to another, creating positive and negative ions that are attracted to each other. Ionic bonds typically form between metals and nonmetals. Covalent bonds result in the formation of molecules, while ionic bonds result in the formation of ionic compounds.

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### 13. Extend (Beyond the Lesson)

### # Suggested Additional Tasks:

1. **Research Task:**

Investigate how the structure of atoms and knowledge of isotopes are used in carbon dating to determine the age of ancient artifacts. Present your findings in a short report.

2. **Application Challenge:**

Think about how atomic theory is applied in modern technology. Research how semiconductors, which are used in computers and smartphones, are made by manipulating atoms of silicon with elements like phosphorus or boron to change their electrical properties.

3. **Real-World Problem:**

Imagine you’re a chemist working to design a new material for spacecraft. Based on what you know about atoms and bonding, what properties would you want the atoms in this material to have? How would different types of bonds affect the strength and durability of the material?

### # Spaced Practice Ideas:

1. **Flashcards for Atomic Structure:**

Create flashcards with terms like "proton," "neutron," "electron," and "isotope." Review them regularly over the next few weeks to reinforce your understanding of atomic structure.

2. **Practice Problems on Chemical Bonding:**

Revisit questions on chemical bonding periodically. Try to predict how different elements will bond based on their position on the periodic table. This will help solidify your knowledge over time.

3. **Cross-Disciplinary Thinking:**

Look for connections between chemistry and other subjects. For example, think about how understanding atoms helps in biology when studying DNA, or in physics when you learn about energy and electricity.

By completing these tasks and engaging with the material over time, you'll deepen your understanding and see how the concepts you’ve learned apply to new problems and situations.