Unit 2: Atomic Structure and Bonding

## Chapter 6: Ionic and Metallic Bonding

# Lesson 1: Formation and Properties of Ions

### 1. Big Idea:

Ions are formed when atoms gain or lose electrons, creating charged particles that are key to ionic bonding.

### 2. Essential Questions:

**Q1: How are ions formed?**

- **Answer**: Ions are formed when an atom gains or loses electrons. When an atom loses one or more electrons, it becomes a positively charged ion (cation). When it gains one or more electrons, it becomes a negatively charged ion (anion).

**Q2: What role do ions play in chemical bonding?**

- **Answer**: Ions play a key role in ionic bonding. Ionic bonds form when there is an attraction between oppositely charged ions (positive cations and negative anions). These bonds hold the ions together in compounds like salts.

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### 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.

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### 3.2 Lesson Phenomenon

**Lesson Phenomenon:**

When table salt (NaCl) is dropped into water, it dissolves quickly, breaking into ions. However, when a piece of aluminum foil is placed in water, it remains intact. This difference is due to the nature of ionic bonds in salt and metallic bonds in metals. Why do these substances react so differently in water?

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### 4. Vocabulary

- **Octet Rule**: Atoms tend to gain, lose, or share 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 produce a solution that can conduct electricity due to the presence of ions.

- **Electron Affinity**: The tendency of an atom to accept electrons and form an anion.

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

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

- **Octet Rule**: The principle that atoms form ions to achieve a stable electron configuration with eight valence electrons.

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### 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.

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### 6. Engage (Ignite)

**Phenomenon-Related Question:**

Why does table salt dissolve in water, but metals like aluminum foil do not?

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

**Materials Needed:**

- A beaker of water

- Table salt (NaCl)

- A small piece of aluminum foil

**Procedure:**

1. Fill a beaker halfway with water.

2. Add a teaspoon of table salt to the water and stir. Observe what happens.

3. Next, submerge a small piece of aluminum foil in the same water. Observe what happens.

**Follow-up Questions:**

1. What happens to the salt when you add it to the water?

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

2. Does the aluminum foil dissolve like the salt?

- **Answer**: No, the aluminum foil does not dissolve.

3. Why do you think salt dissolves but the aluminum foil does not?

- **Answer**: Salt dissolves because its ionic bonds break in water, and the ions spread out. Aluminum foil, made of metal, has metallic bonds that don’t break in water.

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

**Background Information:**

To understand why salt dissolves in water but metal doesn’t, it’s important to understand the differences between ionic bonds and metallic bonds. Salt, or sodium chloride (NaCl), is made up of ions. When it dissolves in water, the ionic bonds between Na⁺ and Cl⁻ break, allowing the ions to disperse in the water. This is why saltwater can conduct electricity—because of the free-moving ions. On the other hand, aluminum foil is made of metal, where the atoms are bonded by a "sea of electrons" that hold the atoms together. This makes metals strong and prevents them from dissolving in water.

**Interactive Questions:**

1. What type of bond is found in salt?

- **Answer**: Ionic bond.

2. What kind of bond holds metal atoms together?

- **Answer**: Metallic bond.

3. Why can salt conduct electricity when dissolved in water?

- **Answer**: Because the dissolved salt breaks into ions, which carry charges and allow electricity to flow.

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

**Questions**

1. What happens to sodium chloride (NaCl) when it is placed in water?

- **Answer**: It dissolves and breaks into Na⁺ and Cl⁻ ions.

2. Do metals dissolve in water like salts?

- **Answer**: No, metals do not dissolve because their metallic bonds hold the atoms together.

3. What allows salt solutions to conduct electricity?

- **Answer**: The presence of free-moving ions in the solution allows it to conduct electricity.

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### 9. Explain (Lightbulb)

**Lesson Explanation (5000-6000 words):**

Let’s dive into the main concept of this lesson, which is how ions are formed and their role in chemical bonding. To understand how ions form, we need to look at the structure of atoms.

### # 9.1 Formation of Ions

Atoms are made up of protons, neutrons, and electrons. Protons have a positive charge, while electrons have a negative charge. Normally, atoms have an equal number of protons and electrons, making them neutral. However, atoms can gain or lose electrons, which changes their charge.

**Cations (Positive Ions):**

When an atom loses one or more electrons, it becomes a positively charged ion, called a **cation**. This happens because there are now more protons (positive charges) than electrons (negative charges). For example, sodium (Na) loses one electron to become Na⁺.

**Anions (Negative Ions):**

When an atom gains one or more electrons, it becomes a negatively charged ion, called an **anion**. This is because there are now more electrons than protons. For example, chlorine (Cl) gains one electron to become Cl⁻.

### # 9.2 The Octet Rule

Atoms form ions to become more stable. One way they do this is by following the **Octet Rule**. The octet rule states that atoms tend to gain, lose, or share electrons until they have eight electrons in their outermost energy level (valence shell). This makes them more stable, like the noble gases, which naturally have full outer shells.

For example:

- Sodium (Na) has one electron in its outer shell. By losing that one electron, it achieves a stable octet in the next lower shell, becoming Na⁺.

- Chlorine (Cl) has seven electrons in its outer shell. By gaining one electron, it achieves a stable octet, becoming Cl⁻.

### # 9.3 Predicting Ion Charges

You can predict the charge of an ion based on its position in the periodic table:

- **Group 1 elements** (like sodium) lose one electron to form +1 cations.

- **Group 2 elements** (like magnesium) lose two electrons to form +2 cations.

- **Group 17 elements** (like chlorine) gain one electron to form -1 anions.

- **Group 16 elements** (like oxygen) gain two electrons to form -2 anions.

### # 9.4 The Role of Ions in Chemical Bonding

Ions are essential for **ionic bonding**. Ionic bonds form when there is a strong attraction between oppositely charged ions. For example, in sodium chloride (NaCl), Na⁺ and Cl⁻ are held together by ionic bonds. This creates a stable compound.

Ionic compounds, like salts, have several important properties:

- They form crystal structures.

- They have high melting and boiling points.

- When dissolved in water, they conduct electricity because the ions are free to move.

On the other hand, metals don’t form ionic bonds. Instead, they form **metallic bonds**, where the atoms share a "sea of electrons" that move freely between them. This explains why metals don’t dissolve in water—they remain intact because of these strong metallic bonds.

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### Sample Problem (Solved Example)

**Problem:**

Predict the charge of a magnesium ion based on its position in the periodic table.

**Solution:**

Magnesium (Mg) is in Group 2 of the periodic table, meaning it has two electrons in its outer shell. To follow the octet rule, magnesium will lose these two electrons to achieve a full outer shell. Losing two electrons makes it a cation with a charge of +2 (Mg²⁺).

**Progress Check Question:**

Predict the charge of a sulfur ion based on its position in the periodic table.

- **Answer**: Sulfur is in Group 16, so it gains two electrons to form a -2 anion (S²⁻).

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### Conclusion

Understanding how ions form and what role they play in ionic bonding is key to understanding many chemical reactions. Ions are formed when atoms gain or lose electrons to achieve a stable electron configuration, often following the octet rule. These ions, with their positive or negative charges, are essential for forming ionic bonds that hold compounds like salts together.

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

To ensure you've understood the key ideas, let's go through a few questions. Try your best to answer them before checking the answers.

1. **What is an atom?**

\*Answer:\*

An atom is the smallest unit of matter that retains the properties of an element. It consists of protons, neutrons, and electrons.

2. **What is the difference between an element and a compound?**

\*Answer:\*

An element is made of only one type of atom, while a compound is made of two or more different elements chemically combined in a fixed ratio.

3. **Why do elements combine to form compounds?**

\*Answer:\*

Elements combine to form compounds to achieve a more stable electron configuration. This often happens when atoms share or transfer electrons to fulfill the octet rule, which states that atoms are most stable when they have eight electrons in their outer shell.

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### 11. Elaborate (Power Up)

Let’s dig deeper! Here are some mini-tasks and open-ended questions to stretch your understanding.

1. **Mini-task:**

Consider two elements, sodium (Na) and chlorine (Cl). Explain why sodium and chlorine readily form NaCl (table salt). What happens to their electrons during this process?

\*Answer:\*

Sodium has one electron in its outer shell, and chlorine has seven. Sodium loses its outer electron, becoming a positively charged ion (Na⁺), while chlorine gains that electron, becoming a negatively charged ion (Cl⁻). The opposite charges attract, forming an ionic bond and creating NaCl.

2. **Open-ended question:**

If you had to explain to a friend how chemical bonds form, how would you describe it? Could you give examples of both covalent and ionic bonds?

\*Answer:\*

Chemical bonds form when atoms share or transfer electrons to achieve stability. In a covalent bond, atoms share electrons (like in water, H₂O). In an ionic bond, one atom transfers an electron to another, resulting in oppositely charged ions that attract each other (like in NaCl).

3. **Additional Question:**

Do you think the properties of a compound are the same as the properties of the elements that form it? Why or why not?

\*Answer:\*

No, the properties of a compound are often very different from the properties of the elements that form it. For example, sodium is a soft, reactive metal, and chlorine is a poisonous gas, but together they form table salt, which is safe to eat.

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### 12. Final Evaluation

### # Debate Question

**Should we continue using chemical fertilizers in farming, or should we switch to organic alternatives?**

- **Arguments for chemical fertilizers:**

Chemical fertilizers can increase crop yields and are easier to use in large-scale farming. They provide nutrients quickly, which helps plants grow faster.

- **Arguments for organic alternatives:**

Organic fertilizers are better for the environment because they don’t cause as much soil degradation or water pollution. They also promote sustainable farming practices.

### # Assessment Questions

**Multiple-Choice Questions:**

1. **Which of the following is a compound?**

a) Hydrogen (H₂)

b) Oxygen (O₂)

c) Water (H₂O)

d) Nitrogen (N₂)

\*Answer:\* c) Water (H₂O)

\*Explanation:\* Water is a compound because it is made of two different elements, hydrogen and oxygen.

2. **Which of the following particles has a negative charge?**

a) Proton

b) Neutron

c) Electron

d) Nucleus

\*Answer:\* c) Electron

\*Explanation:\* Electrons are negatively charged, protons are positively charged, and neutrons have no charge.

3. **What type of bond forms when atoms share electrons?**

a) Ionic bond

b) Covalent bond

c) Metallic bond

d) Hydrogen bond

\*Answer:\* b) Covalent bond

\*Explanation:\* A covalent bond forms when atoms share electrons, as opposed to transferring them, which happens in ionic bonds.

4. **What is the main reason elements form chemical bonds?**

a) To change their identity

b) To gain or lose protons

c) To achieve a stable electron configuration

d) To increase their atomic mass

\*Answer:\* c) To achieve a stable electron configuration

\*Explanation:\* Atoms form chemical bonds to become more stable, usually by filling their outer electron shells.

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**Long-Answer Questions:**

1. **Explain how an ionic bond forms between sodium (Na) and chlorine (Cl).**

\*Answer:\*

Sodium has one electron in its outer shell. Chlorine has seven electrons in its outer shell. Sodium transfers its one outer electron to chlorine. This gives sodium a positive charge (Na⁺) and chlorine a negative charge (Cl⁻). The opposite charges attract, forming an ionic bond.

2. **Describe the difference between an element and a compound, and provide an example of each.**

\*Answer:\*

An element is made of only one type of atom and cannot be broken down into simpler substances. For example, oxygen (O₂) is an element. A compound is made of two or more different elements chemically combined in a fixed ratio. Water (H₂O) is a compound because it contains hydrogen and oxygen atoms.

3. **How do the properties of a compound compare to the properties of the elements that make it up? Provide an example.**

\*Answer:\*

The properties of a compound are often very different from the properties of the elements that form it. For example, hydrogen and oxygen are both gases, but when they combine to form water (H₂O), the result is a liquid with different properties, like being able to put out fires.

4. **Why is it important for scientists to understand chemical bonding?**

\*Answer:\*

Understanding chemical bonding is crucial because it explains how atoms combine to form different substances. This knowledge helps scientists predict how substances will behave, create new materials, and understand biological processes. For example, knowing how bonds form in DNA helps scientists understand genetics.

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### 13. Extend (Beyond the Lesson)

To further explore the fascinating world of chemistry, here are some activities and tasks that will extend your learning:

1. **Task:**

Research how chemical reactions are used in cooking. For example, why does bread rise when you add yeast? Write a short paragraph explaining one reaction that happens in the kitchen.

2. **Challenge Question:**

How do engineers use the principles of chemistry to design new materials, like biodegradable plastics? Research and write a brief explanation.

3. **Real-World Problem:**

Imagine you’re in charge of designing a new type of battery. Based on what you know about atoms and bonding, what kinds of materials would you use? Explain your choices.

4. **Spaced Practice Activity:**

Over the next week, keep a journal of all the times you encounter chemistry in your daily life. For example, when you use soap, cook food, or even breathe. At the end of the week, write a reflection on how chemistry is present in everyday activities.

By revisiting these ideas regularly, you’ll strengthen your understanding of how atoms, elements, and compounds interact in the world around you!