Unit 2: Atomic Structure and Bonding

**Chapter 6: Ionic and Metallic Bonding**

# Lesson 3: Naming and Formulas of Ionic Compounds

### 1. Big Idea:

The way ionic compounds are named and their formulas are written depends on the charges of the ions involved. Understanding these rules is key to identifying ionic compounds.

### 2. Essential Questions:

- **How do we name and write formulas for ionic compounds?**

**Answer:**

To name an ionic compound, we name the cation (positive ion) first and the anion (negative ion) second. The formula is written by balancing the charges of the cation and anion.

### 3. 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.

**Link to Lesson:**

The lesson will explore the nature of ionic bonds in salts and how the structure of these compounds affects their properties, such as dissolving in water. Through naming and formula-writing exercises, we will understand the specific ways ionic compounds are formed and interact with water.

### 4. Vocabulary:

- **Anion** – A negatively charged ion.

- **Cation** – A positively charged ion.

- **Criss-Cross Method** – A method used to write the chemical formula of an ionic compound by criss-crossing the charges of the ions to balance them.

- **Polyatomic Ions** – Ions that consist of more than one atom bonded together that function as a single charged particle.

### 5. SMART Objectives:

1. Name common ionic compounds based on their chemical formulas.

2. Write the chemical formulas for ionic compounds given their names.

3. Apply the criss-cross method to balance the charges of the ions in an ionic formula.

4. Identify polyatomic ions and correctly name compounds containing them.

### 6. Engage (Ignite):

**Phenomenon-Based Question:**

Why does salt dissolve in water, but metal street signs don’t, even though both are exposed to the same conditions?

**Hands-On Experiment:**

**Title:** Dissolving Salt vs. Metal in Water

**Materials Needed:**

- Table salt (sodium chloride, NaCl)

- Small metal nails

- Two clear cups

- Water

- Stirring rod

**Procedure:**

1. Fill both cups halfway with water.

2. Add a spoonful of table salt to one cup. Stir and observe what happens.

3. Place a metal nail into the other cup of water. Stir gently and observe.

4. Compare what happens to the salt and the nail in water.

**Follow-Up Questions:**

1. What happened to the salt in water?

**Answer:** The salt dissolved in water, breaking into smaller ions.

2. What happened to the metal nail in water?

**Answer:** The metal nail did not dissolve; it remained intact.

3. Why do you think the salt dissolved but the metal didn’t?

**Answer:** Salt is made of ionic compounds, which separate into ions in water, while metal has metallic bonds, which don't break apart in water.

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

**Background Information:**

In the experiment, salt dissolved in water because it is made of an ionic compound. Ionic compounds are formed when a cation (a positively charged ion) bonds with an anion (a negatively charged ion). Metals, on the other hand, have metallic bonds, which are much stronger and don't break apart in water.

When naming ionic compounds, the cation is always named first, followed by the anion. Writing the formula involves balancing the charges of the cation and anion so that the overall charge of the compound is neutral. The criss-cross method can help balance these charges.

**Interactive Elements:**

- **Discussion Prompt:**

Ask: What do you think happens to the ions in salt when they dissolve in water?

- **Scaffolded Question:**

- How does the charge of an ion affect the way it bonds with another ion?

**Answer:** Oppositely charged ions attract each other, forming a stable ionic bond.

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

**Scaffolded Questions:**

1. What type of ions are present in salt (NaCl)?

**Answer:** Sodium (Na⁺) is a cation, and chloride (Cl⁻) is an anion.

2. What is the charge of a sodium ion (Na⁺)?

**Answer:** Sodium ion has a positive charge of +1.

3. Why does water allow salt to dissolve but not metal?

**Answer:** Water molecules can separate the positive and negative ions in salt, but they cannot break the strong metallic bonds in metal.

### 9. Explain (Lightbulb):

**Exploring the Naming and Writing of Ionic Compounds:**

### Ionic Compounds and Their Bonds

Ionic compounds are formed when atoms transfer electrons. This creates ions – atoms with a charge. A **cation** is an ion with a positive charge because it loses electrons. A **anion** is an ion with a negative charge because it gains electrons. When these oppositely charged ions attract each other, they form an ionic bond.

The simplest example of an ionic compound is **sodium chloride (NaCl)**. Sodium (Na⁺) loses one electron to become a cation, and chlorine (Cl⁻) gains one electron to become an anion. These ions combine in a 1:1 ratio to form NaCl.

### Naming Ionic Compounds

1. **Name the Cation First**:

When naming ionic compounds, the cation (positive ion) is always named first. For example, in NaCl, sodium is the cation, so we call it **sodium**.

2. **Name the Anion Second**:

The anion (negative ion) is named second, and its name usually ends in "-ide." In NaCl, chlorine becomes **chloride**.

Thus, NaCl is called **sodium chloride**.

### Writing Formulas for Ionic Compounds

1. **Use the Criss-Cross Method**:

The charges of the ions must balance so that the overall charge of the compound is zero. One way to write the formula is by using the **criss-cross method**. Here’s how it works:

**Example: Magnesium Chloride (Mg²⁺ and Cl⁻)**

- Write down the ions: Mg²⁺ and Cl⁻.

- Criss-cross the charges: The 2+ charge of magnesium becomes the subscript for chlorine, and the 1- charge of chlorine becomes the subscript for magnesium.

- The formula becomes **MgCl₂**.

2. **Progress Check - Practice Problem:**

Write the formula for aluminum oxide, where aluminum is Al³⁺ and oxygen is O²⁻.

**Answer:** Using the criss-cross method, the formula is **Al₂O₃**.

### Polyatomic Ions

Some ionic compounds contain **polyatomic ions**, which are groups of atoms bonded together that have an overall charge. For example, **sulfate (SO₄²⁻)** is a polyatomic ion. When naming compounds with polyatomic ions, the name of the polyatomic ion remains unchanged.

**Example: Sodium Sulfate (Na⁺ and SO₄²⁻)**

- Since sodium has a +1 charge and sulfate has a -2 charge, you'll need two sodium ions to balance the charge of one sulfate ion.

- The formula is **Na₂SO₄**, and the name is **sodium sulfate**.

### Progress Check - Practice Problem:

1. Name the compound KNO₃.

**Answer:** Potassium nitrate (K⁺ is potassium, and NO₃⁻ is nitrate).

2. Write the formula for calcium phosphate, where calcium is Ca²⁺ and phosphate is PO₄³⁻.

**Answer:** Using the criss-cross method, the formula is **Ca₃(PO₄)₂**.

### Properties of Ionic Compounds

Ionic compounds tend to have high melting points, meaning they are solid at room temperature. This is why, when salt is spread on icy roads, it doesn’t melt until it comes into contact with water. The strong attraction between ions in the solid structure keeps them in place. However, when ionic compounds are placed in water, they dissolve because the water molecules are able to separate the ions from each other.

### Revisiting the Phenomenon:

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

**Answer:**

Salt is made of ionic compounds, which dissolve in water because the ions separate and spread throughout the water. Metals, on the other hand, have metallic bonds, which do not break apart in water, so the metal stays intact.

### Final Progress Check:

1. What is the name of the compound MgO?

**Answer:** Magnesium oxide.

2. Write the formula for barium nitrate, where barium is Ba²⁺ and nitrate is NO₃⁻.

**Answer:** The formula is **Ba(NO₃)₂**.

3. Why do ionic compounds like salt dissolve in water, while metals don’t?

**Answer:** Ionic compounds dissolve because water molecules separate the ions. Metals don't dissolve because their metallic bonds are too strong for water to break apart.

### Conclusion:

In this lesson, we learned the rules for naming and writing formulas for ionic compounds. By using the criss-cross method, we can easily balance the charges between the cation and anion. Additionally, we explored how ionic bonds differ from metallic bonds, explaining why salt dissolves in water but metal doesn’t.

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

Here are three questions to check your understanding of key ideas from the Explain section. Answer these questions to see how well you grasp the concepts.

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

Answer:

An element is a substance made up of only one kind of atom. A compound is made up of two or more different types of atoms that are chemically bonded together. For example, oxygen (O₂) is an element, while water (H₂O) is a compound because it contains hydrogen and oxygen atoms.

**2. How can you tell if a chemical change has occurred? Name two signs.**

Answer:

A chemical change happens when the substances involved become something new. Two signs of a chemical change are the formation of a gas (like bubbles) or a change in color. For example, when iron rusts, it changes color and forms a new substance, iron oxide.

**3. Why is the law of conservation of mass important in chemical reactions?**

Answer:

The law of conservation of mass states that mass cannot be created or destroyed in a chemical reaction. This means the total mass of the reactants (the starting materials) equals the total mass of the products (the substances formed). This law helps chemists balance chemical equations and understand that matter is just rearranged, not lost.

### 11. Elaborate (Power Up)

Now, let’s go deeper! Here are some tasks and questions to help you think more critically.

**1. How would you separate a mixture of sand, salt, and iron filings? Explain the steps.**

Answer:

To separate the mixture, follow these steps:

- First, use a magnet to remove the iron filings from the mixture because iron is magnetic.

- Then, add water to dissolve the salt, leaving the sand behind.

- Use a filter to separate the sand from the saltwater solution.

- Finally, evaporate the water from the saltwater solution to get the salt back as a solid.

**2. Open-ended question:**

Do you think all mixtures can be separated using physical methods? Why or why not?

Answer:

Not all mixtures can be separated easily using physical methods. Some mixtures, like solutions, can require more complex techniques like distillation or chromatography. For example, separating a mixture of gases can be difficult without advanced methods. Also, some chemical mixtures may form new substances, making physical separation impossible.

**3. Open-ended question:**

What might happen if the law of conservation of mass did not hold true? How would this impact our understanding of chemistry?

Answer:

If the law of conservation of mass didn’t hold, reactions might lose or gain mass unexpectedly, making it hard to predict or control chemical reactions. Our understanding of chemical equations and reactions would change completely. This would also affect industries, like pharmaceuticals, where exact amounts of chemicals are needed to create medicines safely.

### 12. Final Evaluation

Let’s move on to the final evaluations. These questions will test your understanding and allow you to apply what you’ve learned.

### Debate Question:

**Is chemical energy the most important form of energy in everyday life?**

**Arguments for Discussion:**

- **Yes:** Chemical energy powers most of our daily activities, from the food we eat to the gasoline that fuels our cars. Without it, life as we know it wouldn’t exist.

- **No:** Other forms of energy, like electrical or solar energy, are becoming more important in today’s world. For example, renewable energy sources are now crucial for reducing pollution and stopping climate change.

### 4 Multiple-Choice Questions:

**1. Which of the following is NOT a sign of a chemical reaction?**

A. Color change

B. Formation of a gas

C. Melting of a solid

D. Formation of a precipitate

Correct Answer: C. Melting of a solid

Explanation: Melting is a physical change, not a chemical one. The other options involve new substances being formed, which are signs of chemical reactions.

**2. What is the law of conservation of mass?**

A. Matter can be created during a chemical reaction.

B. Matter can be destroyed during a chemical reaction.

C. Mass is neither created nor destroyed in a chemical reaction.

D. Mass changes depending on the type of chemical reaction.

Correct Answer: C. Mass is neither created nor destroyed in a chemical reaction.

Explanation: The law of conservation of mass states that mass remains constant throughout a chemical reaction.

**3. Which of the following is an example of a compound?**

A. Oxygen (O₂)

B. Gold (Au)

C. Water (H₂O)

D. Hydrogen (H₂)

Correct Answer: C. Water (H₂O)

Explanation: Water is a compound made of hydrogen and oxygen atoms chemically bonded together.

**4. What type of change occurs when ice melts into water?**

A. Chemical change

B. Physical change

C. Both a chemical and physical change

D. Neither a chemical nor physical change

Correct Answer: B. Physical change

Explanation: Melting ice is a physical change because no new substance is formed—it's just a change in state from solid to liquid.

### 4 Long-Answer Questions:

**1. Describe how the particle arrangement changes when a solid becomes a liquid and then a gas.**

Answer:

In a solid, particles are tightly packed and vibrate in place. When the solid becomes a liquid, the particles gain energy and move more freely, but they are still close together. As the liquid turns into a gas, the particles gain even more energy and spread out, moving quickly and freely in all directions.

**2. Explain how the periodic table is organized and why it is important for understanding chemical reactions.**

Answer:

The periodic table is organized by increasing atomic number (the number of protons in an atom). Elements in the same column (group) have similar chemical properties because they have the same number of valence electrons. This organization helps chemists predict how different elements will react with each other. Elements in the same group often form similar compounds, making the periodic table a key tool in chemistry.

**3. Why is it important to balance a chemical equation? Provide an example of a balanced equation.**

Answer:

Balancing a chemical equation ensures the law of conservation of mass is followed, meaning the same number of atoms are present on both sides of the reaction. For example, the balanced equation for the reaction between hydrogen and oxygen to form water is:

\[ 2H₂ + O₂ \rightarrow 2H₂O \]

This equation shows that two molecules of hydrogen react with one molecule of oxygen to produce two molecules of water, with the same number of each type of atom on both sides.

**4. How does temperature affect the rate of a chemical reaction?**

Answer:

Temperature affects the speed of a chemical reaction because it impacts how fast the reactant particles move. When the temperature increases, particles move faster and collide more often with enough energy to react, speeding up the reaction. Conversely, lowering the temperature slows down particle movement, decreasing the reaction rate.

### 13. Extend (Beyond the Lesson)

Here are some extra tasks and readings that will help you think more about how the concepts you've learned apply to the real world.

**1. Extended Reading Task:**

Research how chemists use chromatography to separate mixtures in forensic science. Write a short report explaining how this method helps solve crimes.

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

Think about the food you eat every day. Identify three examples of chemical reactions that take place during cooking, and explain why they are chemical changes, not physical ones.

**3. Challenge Task:**

Create an experiment at home where you try to separate two substances from a mixture using physical methods (for example, separating salt from water by evaporation). Write down your steps and results.

**4. Spaced Practice Task:**

Over the next two weeks, revisit your understanding of the law of conservation of mass by balancing five chemical equations each week. Try to increase the complexity of the equations as you go. This will help reinforce your skills in balancing chemical reactions.

By continuing to explore and practice, you will deepen your understanding of chemistry concepts and prepare for more advanced topics!