Unit 2: Atomic Structure and Bonding

Chapter 6: Ionic and Metallic Bonding

# Lesson 3: Naming and Formulas of Ionic Compounds

1. Big Idea:  
  
Ionic compounds are formed from cations (positively charged ions) and anions (negatively charged ions). Naming these compounds and writing their chemical formulas follows specific rules based on the charges of the ions involved.  
  
  
  
 2. Essential Questions:  
  
- \***How do we name and write formulas for ionic compounds?\***   
Answer:   
To name an ionic compound, we first name the cation (metal) and then the anion (non-metal). The anion's name often ends in "-ide," unless it involves a polyatomic ion. To write the formula, we balance the charges of the cation and anion so that the overall charge of the compound is neutral. This is often done using the criss-cross method.  
  
- \***Why do some substances, like road salt, dissolve in water, while metals like street signs do not**?\*   
Answer:   
Ionic compounds like road salt dissolve in water because the water molecules pull apart the charged ions. Metals, on the other hand, do not dissolve in water because their atoms are bonded by metallic bonds, which are much stronger and do not break apart easily in water.  
  
  
  
 3. Phenomenon-Based Learning:  
  
**Unit Phenomenon:**In northern countries, road salt is spread on icy streets to help melt the ice and snow. The salt appears to make the ice and snow vanish, while metal street signs and lampposts exposed to the same conditions remain intact. Why does salt dissolve in water, but metal does not?  
  
**Chapter Phenomenon**:   
When road salt melts ice, it dissolves in the water, but metal does not dissolve. This difference in behavior is due to the types of bonds that hold the substances together. Salt is an ionic compound that dissolves in water, while metals are held together by metallic bonds, which do not dissolve easily.  
  
  
  
 4. Vocabulary:  
  
- Anion: A negatively charged ion (gains electrons).  
- Cation: A positively charged ion (loses electrons).  
- Criss-cross method: A technique used to write the 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 but behave as a single unit with a charge (e.g., SO₄²⁻).  
  
  
  
 5. SMART Objectives:  
  
By the end of this lesson, students will be able to:  
  
1. Name ionic compounds given their chemical formulas.  
2. Write the chemical formulas for ionic compounds given their names.  
3. Determine the rules for naming and writing formulas for ionic compounds.  
4. Explain why ionic compounds dissolve in water, but metals do not.  
  
  
  
 6. Engage (Ignite):  
  
**Pathfinder: Phenomenon-related question**:   
Imagine ice and snow covering the roads during winter. Road salt is spread to melt the ice, but the metal street signs remain unaffected. Why does the road salt seem to vanish, while the metal remains unchanged?  
  
**Hands-on Experiment**:  
 **Materials:**  
- Table salt (NaCl)  
- Water  
- Spoon  
- Beaker  
- Small metal object (e.g., paperclip)  
- Ice cubes  
  
**Procedure:**  
1. Fill the beaker with water and drop a spoonful of salt into it. Stir the solution.  
2. Observe what happens to the salt in the water.  
3. Next, drop a small metal object (like a paperclip) into the water. Stir and observe.  
4. Finally, place a few ice cubes in the solution and observe what happens to the ice.  
  
**Follow-up Questions:**1. What happens to the salt when it is added to water?  
2. Did the metal dissolve or change in the water? Why or why not?  
3. Why do you think the ice started to melt when salt was added?  
  
  
  
 7. Pre-Explore (Direct Instruction):  
  
**Background Information:**   
Ionic compounds are made of ions—cations and anions—that are held together by strong electrostatic forces. When ionic compounds are placed in water, the water molecules interact with the ions, pulling them apart and causing the compound to dissolve. Metals, on the other hand, are held together by metallic bonds, which are much stronger and do not dissolve in water.  
  
**Interactive Elements:**   
1. Discussion: Ask students to think about different substances they know that dissolve in water (like salt) and those that do not (like metal). Why might that be?  
2. **Scaffolded Questions**:  
 - What do you notice about the behavior of salt when it dissolves in water?  
 - How do the properties of salt and metal differ when exposed to water?  
  
  
  
 8. Evaluate (Progress Check) - Pre-Explore:  
  
1. What is the difference between an ionic bond and a metallic bond?   
(Answer: Ionic bonds occur between metals and non-metals and involve the transfer of electrons. Metallic bonds involve the sharing of electrons among metal atoms.)  
  
2. Why do ionic compounds dissolve in water, but metals do not?   
(Answer: Water molecules pull apart the charged ions in ionic compounds, but metallic bonds are too strong to be broken by water.)  
  
3. What happens to the ions in a salt when it dissolves in water?   
(Answer: The ions separate and spread evenly throughout the water.)  
  
  
  
 9. Explain (Lightbulb):  
  
**Core Concept**: Naming and Writing Formulas for Ionic Compounds  
  
When we name ionic compounds, we need to remember that they are made of two parts: the cation (usually a metal) and the anion (usually a non-metal). To name an ionic compound, follow these steps:  
  
1. **Name the cation (metal):** The name of the metal stays the same. For example, Na⁺ is called sodium.  
2. **Name the anion (non-metal):** The anion's name changes slightly, often ending in "-ide." For example, Cl⁻ is called chloride.  
  
So, **NaCl** is named **sodium chloride.**  
  
**Polyatomic Ions:**   
Some ionic compounds contain polyatomic ions, which are groups of atoms that behave as a single unit with a charge. For example, the ion SO₄²⁻ is called sulfate. When naming compounds with polyatomic ions, the name of the ion stays the same. For example, Na₂SO₄ is called sodium sulfate.  
  
**Writing Formulas for Ionic Compounds:**  
  
To write the chemical formula of an ionic compound, follow these steps:  
  
1. **Identify the cation and anion** and their charges. For example, sodium (Na⁺) and chloride (Cl⁻).  
2. **Balance the charges** so that the total charge of the compound is zero. This can be done using the criss-cross method, where the charge on the cation becomes the subscript for the anion, and vice versa.  
  
For example, in the case of Na⁺ and Cl⁻:  
- The charges (+1 and -1) are already balanced, so the formula is NaCl.  
  
For magnesium chloride, Mg²⁺ and Cl⁻:  
- The charges are not balanced, so we use the criss-cross method. The 2+ charge from magnesium becomes the subscript for chlorine, and the 1- charge from chloride becomes the subscript for magnesium. The formula is MgCl₂.  
  
**Example Problem:**Write the chemical formula for calcium nitrate.   
- Calcium is Ca²⁺, and nitrate is NO₃⁻.  
- Using the criss-cross method, the formula becomes Ca(NO₃)₂.  
  
**Progress Check:**- Write the formula for potassium sulfate.   
(Answer: K₂SO₄)  
  
**Why Road Salt Dissolves in Water, but Metal Does Not:**When road salt (NaCl) is added to water, the Na⁺ and Cl⁻ ions separate and dissolve in the water. This is because water molecules are polar, meaning they have a partial positive charge on one side and a partial negative charge on the other. The negative end of the water molecule is attracted to the positive Na⁺ ions, and the positive end is attracted to the negative Cl⁻ ions, pulling them apart.  
  
Metallic bonds, on the other hand, are a "sea of electrons" where electrons are shared among many metal atoms. These bonds are much stronger than ionic bonds, so metals do not dissolve in water as easily as salts do.  
  
  
  
 10. Elaborate (Deepen Understanding):  
  
**Sample Problem:**Name the following ionic compound: FeCl₃.   
- Answer: The cation is iron, and the anion is chloride. Since this compound contains Fe³⁺, the name is iron(III) chloride.  
  
**Progress Check:**Name the following compound: CuSO₄.   
(Answer: Copper(II) sulfate)  
  
  
  
 11. Extend (Connect to Phenomenon):  
  
Now that you understand how to name and write formulas for ionic compounds, think back to the phenomenon. Why does salt dissolve in water, but metals do not? Use your understanding of ionic bonds and metallic bonds to explain how the properties of these substances affect their behavior in water.  
  
 10. Evaluate (Progress Check) - Explain  
  
In this section, we will evaluate your understanding of key concepts through scaffolded questions. The questions will progressively become more challenging, helping you confirm your knowledge.  
  
Question 1 (DOK 1: Recall)   
**What is the chemical formula for water?**Answer:   
The chemical formula for water is H₂O.   
- This question checks basic recall of learned information.  
  
  
  
Question 2 (DOK 2: Application)   
**How would you describe the process of evaporation in terms of molecular motion**?  
  
Answer:   
Evaporation occurs when molecules in a liquid gain enough energy to escape into the air as gas. As temperature increases, the molecules move faster, and those with the most energy overcome the attraction to other molecules and leave the liquid.   
- This question encourages students to explain a process by applying what they know about molecular behavior.  
  
  
  
Question 3 (DOK 3: Strategic Thinking)   
**If you were to increase the amount of solute in a solution, how would this affect the boiling point? Explain your reasoning.**Answer:   
Increasing the amount of solute in a solution raises the boiling point. This happens because the solute particles interfere with the liquid molecules’ ability to escape into the gas phase, so more heat energy is required to reach the boiling point.   
- This question requires students to use what they know and apply it to a new situation, demonstrating deeper understanding.  
  
  
  
 11. Elaborate (Power Up)  
  
Here, you’ll deepen your knowledge and think critically about the concepts you’ve learned. These mini-tasks help you see how the material applies in different contexts.  
  
**Mini Task 1** (DOK 2: Application)   
Design an experiment to show how temperature affects the rate of a chemical reaction. What materials would you use, and how would you measure the reaction rate?  
  
Answer:   
You could design an experiment using baking soda and vinegar. At different temperatures (cold, room temperature, and warm), mix the two and measure how long it takes for the reaction to stop (or how much gas is produced in a set time). Materials would include baking soda, vinegar, thermometers, and a stopwatch.   
- This task helps students apply their understanding of the relationship between temperature and reaction rate.  
  
  
  
**Mini Task 2** (DOK 3: Strategic Thinking)   
Predict what would happen if you combined a strong acid with a strong base. Write a hypothesis and explain the chemical reaction that would take place.  
  
Answer:   
Hypothesis: If a strong acid like hydrochloric acid (HCl) is mixed with a strong base like sodium hydroxide (NaOH), the reaction will result in the formation of water and salt (a neutralization reaction).   
Explanation: HCl will donate protons (H⁺) and NaOH will donate hydroxide ions (OH⁻). These will combine to form water (H₂O), while the remaining Na⁺ and Cl⁻ ions will form sodium chloride (NaCl), which is table salt.   
- This task pushes students to think strategically by predicting outcomes based on chemical knowledge.  
  
  
  
**Mini Task 3** (DOK 3: Strategic Thinking)   
How would you explain the concept of solubility to a younger student? What examples would you use to help them understand?  
  
Answer:   
Solubility is how much of something can dissolve in a liquid. For example, if you add sugar to tea, it dissolves because sugar is soluble in water. But if you add too much sugar, some of it won't dissolve because you've reached the limit of solubility.   
- This task encourages students to explain complex concepts in simple terms, reinforcing their understanding.  
  
  
  
 12. Final Evaluation   
  
**Debate Question:**   
Should chemical reactions that release large amounts of energy, like nuclear reactions, be used as a primary energy source?   
- Points for Discussion:   
 - Pro: Nuclear energy produces large amounts of energy and reduces reliance on fossil fuels.   
 - Con: Nuclear energy poses risks such as radiation and long-term environmental damage from nuclear waste.   
 - Pro: Nuclear power plants emit low levels of greenhouse gases compared to coal or gas plants.   
 - Con: Accidents like Chernobyl show that nuclear energy can be dangerous.   
  
  
  
**Multiple-Choice Questions:**  
  
1. What happens to the particles in a substance when it is heated?   
A) They stop moving   
B) They move slower   
C) They move faster   
D) They change shape   
Correct Answer: C) They move faster   
Explanation: Heating a substance increases the energy of its particles, causing them to move faster.  
  
  
  
2. Which of the following is an example of a physical change?   
A) Rusting of iron   
B) Burning wood   
C) Melting ice   
D) Baking a cake   
Correct Answer: C) Melting ice   
Explanation: Melting ice is a physical change because it only changes state from solid to liquid, but the chemical structure of water remains the same.  
  
  
  
3. What is the pH of a neutral solution?   
A) 0   
B) 7   
C) 14   
D) 4   
Correct Answer: B) 7   
Explanation: A neutral solution, like pure water, has a pH of 7.  
  
  
  
4. Which of the following increases the rate of a chemical reaction?   
A) Decreasing temperature   
B) Reducing surface area   
C) Adding a catalyst   
D) Removing reactants   
Correct Answer: C) Adding a catalyst   
Explanation: A catalyst speeds up a chemical reaction without being consumed in the process.  
  
  
  
**Long-Answer Questions:**  
1**. Explain why increasing the surface area of a reactant increases the rate of a chemical reaction.   
Answer:**   
Increasing the surface area of a reactant exposes more of its particles to interact with the other reactant(s). This increases the number of collisions between particles, which results in a faster reaction rate.  
  
  
  
**2. Describe the difference between an endothermic and an exothermic reaction. Provide examples of each.   
Answer:**   
An endothermic reaction absorbs energy from its surroundings, usually in the form of heat (e.g., dissolving ammonium nitrate in water). An exothermic reaction releases energy, usually as heat (e.g., combustion of wood).  
  
  
  
3**. How does the law of conservation of mass apply to chemical reactions?   
Answer:**   
The law of conservation of mass states that mass cannot be created or destroyed in a chemical reaction. This means that the mass of the reactants must equal the mass of the products.  
  
  
  
4. **Why do ionic compounds tend to have high melting points?   
Answer:**   
Ionic compounds have strong electrostatic forces of attraction between their positively and negatively charged ions. It takes a lot of energy to break these bonds, which is why they have high melting points.  
  
  
  
 13. Extend (Beyond the Lesson)  
  
**Additional Readings and Challenges:**  
- **Read:** Research about how chemical reactions are used in everyday life, such as in batteries, food preservation, or medicine.  
   
- **Challenge:** Investigate how different types of insulation affect the rate of heat loss from a container of hot water. Which materials are best at slowing down heat transfer?  
  
- **Real-World Application:**   
 Look into how chemists use catalysts in industry to speed up reactions. For example, how is the production of ammonia for fertilizers made more efficient through the use of a catalyst in the Haber process?  
  
**Spaced Practice:**  
- Week 1: Review the types of chemical reactions and examples from class. Try to identify examples of these reactions in your daily life (e.g., rusting, cooking).  
- Week 2: Revisit the concept of reaction rates. Design a simple experiment to test how temperature affects the rate of dissolving sugar in water.  
- Week 3: Test your understanding of acids and bases by creating a pH scale using household items such as vinegar, baking soda, and soap.