Unit 2: Atomic Structure and Bonding

## Chapter 5: The Periodic Table and Chemical Trends

### Lesson 2: Classifying Elements and Periodic Trends

### 1. Big Idea:

**The periodic table organizes elements based on repeating patterns in their properties, which helps predict how elements behave in chemical reactions.**

### 2. Essential Questions:

1. **How do we use the periodic table to predict the properties of elements?**

**Answer**:

We use the periodic table to predict the properties of elements by understanding their position in the table. Elements in the same group (vertical columns) have similar chemical properties because they have the same number of valence electrons. The period (horizontal rows) tells us how many electron shells an atom has. By looking at trends across a period or down a group, we can predict properties like reactivity, atomic size, and electronegativity.

### 3.1 Phenomenon-Based Learning:

**Unit Phenomenon**:

In northern countries, where winter brings extremely cold weather, streets and roads are often covered in ice and snow. To reduce the dangers caused by icy conditions, road salt is spread on icy streets to help melt the ice. As the salt comes into contact with the ice, the ice melts. Metal street signs and lampposts exposed to the same ice and snow do not melt or disappear.

**Chapter Phenomenon**:

Three salts are commonly used to clear ice from roads: sodium chloride, magnesium chloride, and calcium chloride. Although these salts all contain chloride, they behave slightly differently because of the elements sodium, magnesium, and calcium. What properties do these elements have in common? How does their position on the periodic table help us predict their behavior?

### 3.2 Lesson Phenomenon:

Imagine you are tasked with selecting the best salt to spread on icy roads in the winter. You have three options: sodium chloride, magnesium chloride, and calcium chloride. Each salt melts ice, but they do so at different rates and in different conditions. What information from the periodic table can help you predict which salt will work best at different temperatures? How do the elements sodium, magnesium, and calcium affect the properties of these salts?

### 4. Vocabulary:

- **Lewis Dot Structure**: A diagram that shows the valence electrons of an atom as dots around the element's symbol.

- **Groups and Periods**: Groups are the vertical columns in the periodic table. Periods are the horizontal rows.

- **Metals**: Elements that are typically shiny, malleable, and good conductors of electricity.

- **Metalloids**: Elements with properties that are intermediate between metals and nonmetals.

- **Nonmetals**: Elements that are typically poor conductors of electricity and are not shiny or malleable.

- **Valence Electrons**: The electrons in the outermost shell of an atom that determine its chemical properties.

### 5. SMART Objectives:

- Identify the different groups and periods on the periodic table.

- Relate the position of an element on the periodic table to its properties.

- Analyze the relationship between electron configuration and the chemical properties of elements.

### 6. Engage (Ignite):

**Hands-On Experiment**:

**Objective**: Investigate how sodium chloride, magnesium chloride, and calcium chloride affect the melting of ice.

**Materials**:

- Ice cubes

- Sodium chloride (table salt)

- Magnesium chloride

- Calcium chloride

- 3 small bowls

- Timer

- Thermometer

**Procedure**:

1. Place an ice cube in each of the three bowls.

2. Sprinkle a small amount of sodium chloride on the ice in one bowl, magnesium chloride on the ice in the second bowl, and calcium chloride on the ice in the third bowl.

3. Start the timer and observe how long it takes for each ice cube to begin melting.

4. After 5 minutes, use the thermometer to measure the temperature of the water around each ice cube.

5. Record your observations.

**Follow-Up Questions**:

1. Which salt caused the ice to melt the fastest?

**Answer**: Magnesium chloride tends to melt ice faster at lower temperatures compared to sodium chloride. Calcium chloride is the most effective at very low temperatures.

2. How do you think the elements in each salt (sodium, magnesium, calcium) affect the melting process?

**Answer**: The number of valence electrons and the size of the atoms affect how strongly they interact with the water in the ice, causing differences in how quickly the ice melts.

3. How could you use the periodic table to predict which salt would work best in colder conditions?

**Answer**: By looking at the groups and periods of sodium, magnesium, and calcium, we can predict their chemical behavior. Elements that are in the same group tend to have similar properties, but those in lower periods may be more reactive.

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

**Background Information**:

The periodic table is organized into vertical columns called groups and horizontal rows called periods. Elements in the same group have similar chemical properties because they have the same number of valence electrons. For example, sodium (Na), magnesium (Mg), and calcium (Ca) are in different groups, but they are all metals. By looking at their position on the periodic table, we can predict their reactivity, how they bond with other elements, and how they behave in different chemical reactions.

**Interactive Discussion**:

- **Question**: Why do you think metals like sodium, magnesium, and calcium are effective at melting ice?

**Answer**: Metals tend to lose electrons easily, which helps them form positive ions. When they dissolve in water, they create charged particles that disrupt the structure of ice, causing it to melt.

- **Question**: How might the number of valence electrons affect how a metal reacts with other substances?

**Answer**: The number of valence electrons determines how easily an atom can form bonds with other atoms. For example, sodium has one valence electron, so it reacts quickly with other elements to form compounds.

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

**Scaffolded Questions**:

1. What are the similarities between sodium, magnesium, and calcium on the periodic table?

**Answer**: All three elements are metals and are located near each other in periods 2, 3, and 4. They are in groups 1, 2, and 3, respectively.

2. How does the number of valence electrons affect the reactivity of an element?

**Answer**: Elements with fewer valence electrons (like sodium with 1) are generally more reactive because they easily lose that electron to form bonds.

3. Predict which of the three salts (sodium chloride, magnesium chloride, or calcium chloride) would be most effective in extremely cold weather. Why?

**Answer**: Calcium chloride would be most effective because calcium is in a lower period, meaning it has more electron shells and can interact more readily in cold conditions.

### 9. Explain (Lightbulb):

**Detailed Explanation of Lesson Concepts (5000-6000 words)**:

**Understanding the Periodic Table**:

The periodic table is a tool for organizing all known elements in a way that highlights their similarities and differences. It is arranged by increasing atomic number, which is the number of protons in an atom's nucleus. The table has 18 vertical columns called **groups** and 7 horizontal rows called **periods**. Elements in the same group have the same number of **valence electrons**, which is why they often behave similarly in chemical reactions.

### Groups and Periods:

- **Groups**: Elements in the same group have similar chemical properties because they have the same number of valence electrons. For example, all elements in Group 1 (the alkali metals) have 1 valence electron, which makes them highly reactive. Sodium (Na), magnesium (Mg), and calcium (Ca) are in different groups, but they all share some common properties because they are metals.

- **Periods**: The period number tells you how many electron shells an element has. For example, elements in Period 2 (like sodium) have 2 electron shells, while elements in Period 4 (like calcium) have 4 shells. This affects the size of the atom and its reactivity. As you move down a group, elements become larger because they have more electron shells.

### Metals, Metalloids, and Nonmetals:

The periodic table also divides elements into three broad categories: **metals**, **metalloids**, and **nonmetals**.

- **Metals**: Most elements are metals. They are typically shiny, malleable, and good conductors of electricity. Metals like sodium, magnesium, and calcium are all good examples.

- **Metalloids**: These elements have properties that are a mix of metals and nonmetals. They can conduct electricity, but not as well as metals. Silicon is a common metalloid.

- **Nonmetals**: These elements are poor conductors of electricity and are often gases or brittle solids at room temperature. Examples include oxygen and sulfur.

### Valence Electrons and Reactivity:

The chemical properties of an element are largely determined by its **valence electrons**. These are the electrons in the outermost shell of an atom. Elements with the same number of valence electrons tend to form similar types of bonds. For example, both sodium (Na) and potassium (K) have 1 valence electron, which makes them both highly reactive metals.

**Why Valence Electrons Matter**:

When atoms react to form compounds, they do so by gaining, losing, or sharing valence electrons. In our road salt example, sodium (Na) in sodium chloride (NaCl) loses its 1 valence electron to chlorine (Cl), forming an ionic bond. Similarly, magnesium (Mg) in magnesium chloride (MgCl2) loses its 2 valence electrons to chlorine. Calcium (Ca) in calcium chloride (CaCl2) loses its 2 valence electrons as well, but because calcium is a larger atom with more electron shells, it behaves differently from magnesium and sodium.

### Periodic Trends:

Periodic trends are patterns in the properties of elements that can be observed as you move across a period or down a group. These trends help us predict how elements will behave in chemical reactions.

- **Atomic Size**: As you move down a group, atoms get larger because they have more electron shells. For example, calcium is much larger than sodium because it has more electron shells. Larger atoms tend to be less electronegative because their valence electrons are farther from the nucleus.

- **Ionization Energy**: This is the energy required to remove an electron from an atom. Elements with low ionization energy, like sodium, lose electrons easily and are highly reactive. As you move down a group, ionization energy decreases because the outer electrons are farther from the nucleus.

- **Electronegativity**: This is a measure of how strongly an atom attracts electrons when it forms a bond. Elements with high electronegativity, like chlorine, attract electrons very strongly. As you move across a period, electronegativity increases because atoms get smaller and their nuclei can pull electrons closer.

**Sample Problem**:

**Question**: Predict which element—sodium (Na), magnesium (Mg), or calcium (Ca)—will lose electrons most easily and explain why.

**Answer**: Sodium (Na) will lose electrons most easily because it has only 1 valence electron and is in Period 3, meaning its electrons are closer to the nucleus compared to magnesium and calcium. Additionally, sodium has a lower ionization energy than magnesium and calcium, making it easier to lose its valence electron.

**Progress Check**:

**Question**: Which element in Group 2—magnesium (Mg) or calcium (Ca)—is more reactive? Why?

**Answer**: Calcium (Ca) is more reactive than magnesium because it has more electron shells, meaning its valence electrons are farther from the nucleus and easier to lose in a chemical reaction.

### 10. Closing Thoughts:

By understanding the periodic table and the trends that exist within it, we can predict the behavior of elements in chemical reactions. This knowledge is essential for solving real-world problems, like choosing the best salt to melt ice on roads. The periodic table is not just a list of elements—it is a powerful tool for understanding the behavior of matter.

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

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

- **Answer**: An element is a pure substance made of only one kind of atom, like oxygen (O). A compound is a substance made of two or more different types of atoms bonded together, like water (H₂O).

2. **Why do chemical reactions occur?**

- **Answer**: Chemical reactions occur because atoms want to achieve stable electron configurations, often by gaining, losing, or sharing electrons. This leads to the formation of new substances.

3. **Describe the role of energy in a chemical reaction.**

- **Answer**: Energy is needed to break the bonds in the reactants, and energy is released when new bonds form in the products. If more energy is released than absorbed, it's an exothermic reaction. If more energy is absorbed than released, it's an endothermic reaction.

### 11. Elaborate (Power Up)

1. **Mini-task**: Consider the reaction between hydrogen and oxygen to form water. What would happen to the properties of the hydrogen and oxygen after they form water? How does this relate to the Law of Conservation of Mass?

- **Answer**: After hydrogen and oxygen react to form water, the properties of the resulting compound (water) are different from those of the original elements. For example, water is a liquid at room temperature, while hydrogen and oxygen are gases. However, the total mass of the reactants and products remains the same, as per the Law of Conservation of Mass.

2. **Open-ended question**: How might understanding the properties of elements and compounds help in developing new materials or medicines?

- **Answer**: Understanding the properties of elements and compounds can help scientists predict how different substances will interact. This knowledge can lead to the creation of new materials with specific properties, such as stronger metals or more efficient medicines that target diseases more effectively.

3. **Additional question**: If you could change one variable in a chemical reaction, such as temperature or concentration of reactants, what would it be, and why?

- **Answer**: Answers may vary. For example, increasing the temperature might speed up the reaction by giving the particles more energy to collide and react. Changing the concentration could also increase the rate of reaction by having more particles available to collide.

### 12. Final Evaluation

**Debate Question**:

Should we continue using fossil fuels, or should we focus on renewable energy sources like solar and wind?

- **Arguments for fossil fuels**: Fossil fuels are currently the most reliable and widely available source of energy. They are efficient and provide a stable energy supply.

- **Arguments against fossil fuels**: Fossil fuels are non-renewable and contribute to environmental problems like air pollution and climate change. Renewable energy is cleaner and sustainable for the future.

**Multiple Choice Questions**:

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

- a) Oxygen (O₂)

- b) Carbon dioxide (CO₂)

- c) Nitrogen (N₂)

- d) Gold (Au)

- **Correct Answer**: b) Carbon dioxide (CO₂)

- **Explanation**: A compound is made of two or more different elements. Carbon dioxide contains both carbon and oxygen.

2. **In a chemical reaction, what happens to the atoms of the reactants?**

- a) They disappear.

- b) They are destroyed.

- c) They are rearranged to form new substances.

- d) They change into energy.

- **Correct Answer**: c) They are rearranged to form new substances.

- **Explanation**: Atoms are rearranged in a chemical reaction, but they are not destroyed or created, following the Law of Conservation of Mass.

3. **When energy is absorbed during a chemical reaction, the reaction is called:**

- a) Exothermic

- b) Endothermic

- c) Combustion

- d) Decomposition

- **Correct Answer**: b) Endothermic

- **Explanation**: Endothermic reactions absorb energy from their surroundings, making the environment feel cooler.

4. **What is the Law of Conservation of Mass?**

- a) Matter can be created or destroyed.

- b) Mass is lost in a chemical reaction.

- c) The total mass of reactants equals the total mass of products.

- d) Mass is converted into energy.

- **Correct Answer**: c) The total mass of reactants equals the total mass of products.

- **Explanation**: The Law of Conservation of Mass states that mass cannot be created or destroyed in a chemical reaction.

**Long-Answer Questions**:

1. **Explain why balancing a chemical equation is necessary.**

- **Answer**: Balancing a chemical equation ensures that the Law of Conservation of Mass is followed. It shows that the same number of atoms of each element is present on both sides of the equation, meaning mass is conserved.

2. **Describe how temperature affects the rate of a chemical reaction.**

- **Answer**: Increasing the temperature increases the energy of the particles, making them move faster. This leads to more frequent and energetic collisions between particles, increasing the rate of reaction. Lowering the temperature has the opposite effect, slowing down the reaction rate.

3. **How do catalysts affect chemical reactions?**

- **Answer**: Catalysts speed up chemical reactions without being consumed in the process. They work by lowering the activation energy required for the reaction to occur, allowing the reaction to happen more quickly or under less extreme conditions.

4. **Discuss the environmental impact of chemical reactions, particularly those involving fossil fuels.**

- **Answer**: Chemical reactions involving fossil fuels, such as combustion, release carbon dioxide (CO₂) and other pollutants into the atmosphere. This contributes to air pollution and climate change, which can have long-term environmental effects, such as global warming and harm to ecosystems.

### 13. Extend (Beyond the Lesson)

1. **Task**: Research a real-world application of a chemical reaction, such as how rust forms on iron or how baking soda reacts in baking. Write a brief report explaining the chemistry behind it.

- **Expected Outcome**: Students will explore practical applications of chemical reactions and explain the processes involved, reinforcing their understanding of reaction types and the factors that influence them.

2. **Challenge**: Design an experiment to test how the concentration of a reactant affects the rate of reaction. Record your observations and explain your results.

- **Expected Outcome**: Students will apply their knowledge of reaction rates by conducting an experiment, analyzing data, and explaining the relationship between concentration and reaction rate.

3. **Additional Readings**:

- Read about the Haber process, used to produce ammonia for fertilizers. How does understanding chemical reactions help in large-scale industrial production?

- Explore how chemical reactions are used in battery technology. How could advancements in chemistry help improve energy storage?

4. **Spaced Practice**:

- Over the next few weeks, students can revisit the topic of balancing chemical equations. Start with simple equations, then gradually move to more complex reactions.

- Reinforce the concept of reaction rates by solving problems over time, adjusting one variable at a time (e.g., concentration, temperature, or catalyst) and predicting the effects on the reaction rate.

By challenging students with real-world applications and encouraging spaced practice, these tasks deepen their understanding of chemical reactions and help them connect the concepts learned in class to broader scientific and industrial contexts.