Unit 2: Atomic Structure and Bonding

Chapter 5: The Periodic Table and Chemical Trends

# Lesson 1: The Development of the Periodic Table

Big Idea:  
The periodic table was developed through the contributions of several scientists, and it organizes elements based on atomic structure and repeating chemical properties.  
  
Essential Questions:  
1. **How has the periodic table evolved into a powerful tool for understanding elements and their properties?**   
 - The periodic table has evolved from early attempts to organize elements based on their atomic weights to a modern table that arranges elements by atomic number. This organization allows us to predict the properties of elements, understand their relationships, and even anticipate the behavior of elements that were not yet discovered at the time.  
  
2. **Why did early versions of the periodic table have limitations?**   
 - Early versions, like Mendeleev's, were based on atomic mass, which led to some inconsistencies. For example, some elements appeared to be out of order when their properties were considered. The discovery of atomic numbers by Moseley corrected these issues, giving us the modern periodic table.  
  
3. **How does the modern periodic table help predict the behavior of elements?**   
 - The modern table is arranged so that elements with similar properties are in the same column, or group. This means we can predict how an element will react chemically based on its position.  
  
  
  
Phenomenon-Based Learning:  
- **Phenomenon**:   
In northern countries, during freezing winters, roads are covered in ice. Salt is spread to melt the ice, making it safer. But why do we use different salts, like sodium chloride, magnesium chloride, or calcium chloride? How are they different? What makes these elements behave similarly or differently?  
  
- **Connection to Lesson**:   
The salts used for de-icing share a common “chloride” part, but they differ in the metal element (sodium, magnesium, or calcium). These metals have different properties because they belong to different groups in the periodic table. By understanding the periodic table’s structure, we can predict why these elements behave differently when combined with chloride.  
  
  
  
 Vocabulary:  
1. **Atomic Mass**: The mass of an atom, typically measured in atomic mass units (amu), which is roughly equal to the sum of protons and neutrons in the nucleus.  
2. **Atomic Weight**: The average mass of atoms of an element, taking into account the different isotopes and their abundance.  
3. **Mendeleev**: A Russian chemist who created one of the first periodic tables and arranged elements by atomic mass.  
4. **Modern Periodic Table**: The current version of the periodic table, which arranges elements by atomic number instead of atomic mass.  
5. **Moseley**: An English physicist who discovered that elements should be ordered by atomic number, not atomic mass, leading to the modern periodic table.  
  
  
  
SMART Objectives:  
By the end of this lesson, students will be able to:  
1. Name key scientists who contributed to the development of the periodic table, such as Mendeleev and Moseley.  
2. Outline the principles behind the organization of the periodic table, including atomic mass, atomic number, and periodic trends.  
3. Compare and contrast early periodic tables with the modern periodic table, understanding the limitations of early models and how Moseley’s work led to improvements.  
4. Apply their knowledge of the periodic table to predict the properties of elements based on their position.  
  
  
  
Engage (Ignite):  
**Phenomenon-Related Question to Ignite Curiosity**:   
- If sodium chloride, magnesium chloride, and calcium chloride all contain chloride, why do they behave differently when spread on roads? How can we predict which one will work best in different conditions?  
  
Hands-On Experiment:   
**Title: Simple Salt Melting Test   
Materials:**- Sodium chloride (table salt)   
- Magnesium chloride   
- Calcium chloride   
- Ice   
- 3 small bowls  
  
**Procedure:**1. Place an equal amount of ice in each of the three bowls.  
2. Add 1 teaspoon of sodium chloride to the first bowl, 1 teaspoon of magnesium chloride to the second, and 1 teaspoon of calcium chloride to the third.  
3. Observe which bowl of ice melts the fastest over 10 minutes.  
  
**Follow-up Questions:**1. Which salt melted the ice the fastest?   
2. How do the elements in each salt influence its ability to melt ice?   
3. Based on what you know about the periodic table, why do you think these elements behave differently?  
  
  
  
Pre-Explore (Direct Instruction):  
**Background Information:**   
The periodic table is a powerful tool that organizes all known elements. It evolved over time as scientists discovered more about atomic structure. Early attempts to arrange elements were based on their atomic mass, but this led to some inconsistencies. The modern table is based on atomic number, a more accurate way to order elements. Elements in the same group (vertical columns) have similar properties, which helps us predict how they will behave chemically.  
  
**Interactive Elements:**- **Class Discussion**: Ask students to think about why different salts behave differently. Guide the conversation to the idea that the elements in these salts belong to different groups on the periodic table, which explains their different behaviors.  
- **Scaffolded Questions:**   
 - What is the difference between atomic mass and atomic number?   
 - How did Mendeleev organize his periodic table?   
 - What did Moseley discover that corrected Mendeleev’s table?  
  
  
  
Evaluate (Progress Check) - Pre-Explore:  
**Scaffolded Questions:**1. Why was Mendeleev’s periodic table considered revolutionary at the time, even though it wasn’t perfect?  
2. How did Moseley improve the periodic table?  
3. How does the modern periodic table help us predict the properties of elements like sodium, magnesium, and calcium?  
  
  
  
Explain (Lightbulb):  
The development of the periodic table involved many scientists and spanned several decades. Here’s a breakdown of how it happened and why it’s important.  
  
 **1. Mendeleev’s Contribution:**In 1869, Dmitri Mendeleev, a Russian chemist, was trying to organize the known elements in a way that made sense. At the time, about 63 elements were known, and their properties were often puzzling. Mendeleev arranged the elements by increasing atomic mass. He noticed that elements with similar properties appeared at regular intervals, and this led him to create the first version of the periodic table.   
  
Mendeleev’s table had some gaps, but he was bold enough to predict that these gaps represented elements that hadn’t been discovered yet. When these elements were later found, they fit perfectly into Mendeleev’s table, proving that his system worked well — for the most part.  
  
However, there were some issues. A few elements didn’t seem to fit properly when ordered by atomic mass. For example, iodine and tellurium appeared to be in the wrong order based on their masses, but their properties suggested they were in the right place.  
  
**Sample Problem:**   
Suppose we arrange the elements lithium (Li), beryllium (Be), and boron (B) based on atomic mass. Predict the element that would come next based on Mendeleev’s arrangement.  
  
Progress Check:   
Given the following elements arranged by atomic mass: lithium (Li), potassium (K), and rubidium (Rb), predict which element might come next.  
  
  
  
 **2. Moseley’s Contribution:**  
In 1913, Henry Moseley, an English physicist, discovered that the periodic table should be arranged according to atomic number, not atomic mass. Moseley used X-ray experiments to show that each element has a unique number of protons in its nucleus. This number, called the atomic number, is a more accurate way to organize the elements.  
  
When the elements were arranged by atomic number, the inconsistencies in Mendeleev’s table disappeared. Elements that seemed out of order based on mass, like iodine and tellurium, were now in the correct positions when ordered by atomic number.  
  
**Sample Problem:**   
Explain why iodine (atomic number 53) and tellurium (atomic number 52) were placed in the wrong order when arranged by atomic mass but are correctly ordered by atomic number.  
  
Progress Check:   
Given the atomic numbers of sulfur (16) and chlorine (17), predict which element comes next in the periodic table when arranged by atomic number.  
  
  
  
 **3. The Modern Periodic Table:**Today, the periodic table is arranged by atomic number, which reflects the number of protons in an atom’s nucleus. The elements are arranged in rows called periods and columns called groups. Elements in the same group have similar chemical properties because they have the same number of electrons in their outer shell.  
  
For example, sodium (Na), magnesium (Mg), and calcium (Ca) are all in different groups. This explains why the salts they form behave differently. Sodium is in Group 1, magnesium is in Group 2, and calcium is also in Group 2 but lower down. These differences in group position explain why magnesium chloride and calcium chloride are more effective at melting ice than sodium chloride.  
  
  
  
Elaborate (Extend):  
**Extension Activity:**Students can research other elements that were predicted by Mendeleev before they were discovered. What properties did Mendeleev predict, and how accurate were his predictions?  
  
**Discussion Prompts:**- How does the organization of the periodic table by atomic number help us understand the properties of elements?   
- Why do elements in the same group have similar properties?  
  
  
  
Evaluate (Summative Assessment):  
**Final Assessment Questions:**  
1. Name two key scientists who contributed to the development of the periodic table and explain their contributions.  
2. Describe how the modern periodic table is organized and why this organization is useful.  
3. Compare and contrast Mendeleev’s periodic table with the modern periodic table in terms of arrangement and predictions.  
  
**Sample Problem for Final Assessment:**   
Given the elements potassium (K), calcium (Ca), and scandium (Sc), predict the behavior of a compound formed with chloride.  
  
Evaluate (Progress Check) - Explain  
  
In this section, we'll pose three scaffolded questions to confirm your understanding of key concepts. These questions will follow varying levels of Depth of Knowledge (DOK), helping you to deepen your learning.  
  
 Question 1 (DOK 1 - Recall):  
**What is the chemical symbol for water, and what elements make up this compound?**  
- Answer: The chemical symbol for water is H₂O. It is made up of two hydrogen atoms and one oxygen atom.  
  
 Question 2 (DOK 2 - Skill/Concept):  
**Explain why water is considered a polar molecule.**  
- Answer: Water is a polar molecule because oxygen has a higher electronegativity than hydrogen. This means oxygen pulls the electrons in the bond closer to itself, creating a partial negative charge on the oxygen atom and a partial positive charge on the hydrogen atoms. This uneven distribution of charge makes water polar.  
  
 Question 3 (DOK 3 - Strategic Thinking):  
**How does the polarity of water contribute to its ability to dissolve many substances?**  
- **Answer**: Water's polarity allows it to interact with and surround charged or polar molecules. The partially negative oxygen side of water can attract positive ions, while the partially positive hydrogen side can attract negative ions or other polar molecules. This helps to break apart substances, making water an excellent solvent.  
  
  
  
Elaborate (Power Up)  
  
Let's dive deeper into the concepts to expand your thinking!  
  
 Mini-task 1:  
**Compare and contrast the solubility of polar and nonpolar substances in water. What can you infer about how substances mix based on their polarity?**  
- **Answer**: Polar substances, like salt (NaCl), dissolve well in water because water is polar and can surround and separate the charged ions. Nonpolar substances, like oil, do not dissolve in water because there is no attraction between the nonpolar molecules and the polar water molecules. This is why oil and water don’t mix.  
  
 Mini-task 2:  
**Water has a high specific heat capacity. How does this property affect the environment, particularly in coastal regions?**  
- **Answer**: Water’s high specific heat capacity means it can absorb or release large amounts of heat without changing its temperature drastically. Coastal regions experience milder climates because the nearby ocean absorbs heat in the summer and releases it in the winter, moderating the temperatures.  
  
 Mini-task 3:  
**Design an experiment to test how temperature affects the solubility of sugar in water. What would be your hypothesis and method?**  
- **Answer**: Hypothesis: The solubility of sugar increases as the water temperature rises. Method: Heat water to different temperatures (e.g., 10°C, 30°C, 50°C, 70°C, and 90°C) and measure how much sugar can dissolve in each sample. Record the amount of sugar dissolved at each temperature.  
  
  
  
Final Evaluation  
  
Debate Question:  
**Should the use of chemical solvents in industry be reduced in favor of “greener” solvents like water?**  
- **Arguments For**: Water is non-toxic, readily available, and environmentally friendly. Using water as a solvent reduces harmful chemical waste and pollution.  
- **Arguments Against**: Water cannot dissolve all substances, especially nonpolar compounds like oils. Chemical solvents are sometimes necessary for manufacturing processes that water cannot achieve.  
  
 Multiple-Choice Questions:  
  
1. **Which of the following best explains why water is a good solvent?**  
 - a) Water is a gas at room temperature.  
 - b) Water has a high boiling point.  
 - c) Water is a polar molecule.  
 - d) Water has a low density.  
 - **Answer**: c) Water is a polar molecule.   
 **Explanation**: Water's polarity allows it to dissolve many substances, especially ionic and polar compounds.  
  
2. **What happens to water’s boiling point when salt is added?** - a) It increases.  
 - b) It decreases.  
 - c) It stays the same.  
 - d) It boils instantly.  
 - **Answer**: a) It increases.   
 **Explanation**: Salt increases the boiling point because the dissolved ions interfere with water molecules escaping into gas form.  
  
3. **Which term describes a substance that does not dissolve in water?** - a) Solvent  
 - b) Polar  
 - c) Insoluble  
 - d) Soluble  
 - **Answer**: c) Insoluble.   
 **Explanation**: Insoluble substances cannot dissolve in a solvent like water.  
  
4. **Why is water considered a polar molecule?** - a) It has equal sharing of electrons between hydrogen and oxygen.  
 - b) It has an uneven distribution of charges across the molecule.  
 - c) It has a neutral pH.  
 - d) It is always a liquid at room temperature.  
 - **Answer**: b) It has an uneven distribution of charges across the molecule.   
 **Explanation**: The oxygen atom is partially negative and the hydrogen atoms are partially positive, making water polar.  
  
Long-Answer Questions:  
  
1. **Explain how hydrogen bonding contributes to water’s unique properties, such as its high boiling point and surface tension**.  
 - **Answer**: Hydrogen bonds form between the partially positive hydrogen atoms of one water molecule and the partially negative oxygen atoms of another. These bonds are strong enough to keep water molecules close together, which contributes to water’s high boiling point. They also cause high surface tension, as the water molecules at the surface are pulled together more strongly.  
  
2. **Describe why ice floats on water, and explain the importance of this property to aquatic life**.  
 - Answer: Ice floats because it is less dense than liquid water. As water freezes, its molecules form a crystalline structure that takes up more space, making ice less dense. This property is crucial for aquatic life because it insulates the water below, allowing organisms to survive in cold temperatures.  
  
3. **How does water’s high heat capacity affect the climate of coastal areas?** - **Answer**: Water’s high heat capacity allows it to absorb and release large amounts of heat without significant temperature changes. This moderates the climate in coastal areas, leading to cooler summers and warmer winters compared to inland regions.  
  
4. **Compare the solubility of table salt (NaCl) in water to that of oil. Discuss why you observe these differences**.  
 - **Answer**: Table salt (NaCl) is highly soluble in water because it is an ionic compound, and water can surround and dissolve the charged ions. Oil, being nonpolar, does not dissolve in water because there are no attractions between the nonpolar oil molecules and the polar water molecules.  
  
  
  
Extend (Beyond the Lesson)  
  
 Additional Tasks and Readings:  
  
1. Task: Research and write a short essay on how water is used as a solvent in the pharmaceutical industry. How does water’s polarity benefit this field?  
2. Reading: Explore articles on "The Role of Water in Climate Regulation" and summarize how water's properties help maintain the Earth's temperature.  
3. Challenge: Investigate alternative solvents that are environmentally friendly. Compare their effectiveness to water in dissolving substances.  
  
 Spaced Practice:  
  
- **Activity**: Over the next week, revisit the concept of solubility by experimenting with different household substances (sugar, salt, oil, vinegar). Record the solubility of each in water and other liquids like alcohol or vinegar.  
- **Question**: How might the solubility of these substances change if the temperature or pressure is altered?  
  
By continuing to apply these concepts in new contexts, you'll strengthen your understanding and be able to explain and use these chemical properties in real-world situations!