Unit 2: Atomic Structure and Bonding

Chapter 5: The Periodic Table and Chemical Trends

# Lesson 1: The Development of the Periodic Table

### 1. Big Idea:

- The periodic table is a tool that helps scientists classify, organize, and predict the properties of elements based on their atomic structure.

### 2. Essential Questions:

- How has the periodic table evolved into a powerful tool for understanding elements and their properties?

**Answer**:

The periodic table has evolved over time due to the contributions of key scientists like Dmitri Mendeleev and Henry Moseley. Originally, Mendeleev organized the elements by their atomic weight and properties, predicting the existence of elements not yet discovered. Later, Moseley refined the table by arranging elements by their atomic number, which is the number of protons in an atom. This organization allows us to predict chemical properties and behaviors of elements based on their position in the table.

### 3.1 Phenomenon-Based Learning

**Phenomenon**:

In northern countries, where winter brings extremely cold weather, roads are often covered in ice and snow. Salt, such as sodium chloride, is spread on the roads to melt the ice. Metal objects like street signs and lampposts do not melt the ice. The question arises: Why do only certain materials seem to affect the ice? How are the properties of these salts related to the elements they contain? What are the differences between salts like sodium chloride, magnesium chloride, and calcium chloride?

**Chapter Phenomenon**:

The salts used on icy roads contain different elements: sodium, magnesium, and calcium. How can we predict the properties of these elements? How do these elements’ positions on the periodic table help us understand their similarities and differences?

### 3.2 Lesson Phenomenon

**Lesson Phenomenon**:

The periodic table helps us predict the behavior of elements, such as those found in common salts used to melt ice. Sodium, magnesium, and calcium are different elements, but they share certain properties because they are located in specific groups on the periodic table. How does the organization of the periodic table help us understand the behavior of elements in these salts?

### 4. Vocabulary

- **Atomic Mass**: The average mass of an atom of an element, usually measured in atomic mass units (amu).

- **Atomic Weight**: The weighted average of the atomic masses of the naturally occurring isotopes of an element.

- **Mendeleev**: A Russian chemist who created one of the first versions of the periodic table by organizing elements based on atomic weight and properties.

- **Modern Periodic Table**: The current arrangement of elements by increasing atomic number, with elements grouped by similar chemical properties.

- **Moseley**: An English physicist who refined the periodic table by organizing elements by their atomic number instead of atomic weight.

### 5. SMART Objectives

- Name key scientists who contributed to the development of the periodic table.

- Outline the principles behind the organization of the periodic table.

- Compare and contrast early periodic tables with the modern periodic table.

### 6. Engage (Ignite)

**Phenomenon-Based Question**:

Begin by asking: “Why does salt melt ice on roads, but metal objects like lampposts do not?”

**Hands-On Experiment**:

Students can conduct a simple experiment to investigate the effects of different salts on ice.

**Materials Needed**:

- Ice cubes

- Table salt (sodium chloride)

- Epsom salt (magnesium sulfate)

- Calcium chloride

- Three small bowls

**Procedure**:

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

2. Sprinkle a teaspoon of table salt on one ice cube, Epsom salt on another, and calcium chloride on the third.

3. Observe the melting rate of each ice cube over time.

**Follow-Up Questions**:

1. Which salt melted the ice the fastest?

- **Answer**: Calcium chloride typically melts ice the fastest because it can lower the freezing point of water more than sodium chloride or magnesium sulfate.

2. What differences did you observe in how each salt behaves with the ice?

- **Answer**: Calcium chloride may cause the ice to melt much faster because it dissolves and releases heat. Sodium chloride will also melt the ice but at a slower rate. Magnesium sulfate may have the least noticeable effect.

3. Why do you think different salts affect the ice in different ways?

- **Answer**: The differences in the salts' effectiveness are due to the chemical properties of the elements in each salt, such as their ability to dissolve in water and produce heat.

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

**Background Information**:

Elements are organized on the periodic table in a way that reflects their properties. The periodic table has not always looked as it does today. Early scientists tried different ways to organize elements, but it wasn’t until Dmitri Mendeleev’s work that a clear pattern emerged. Mendeleev arranged elements by increasing atomic weight and grouped them by similar chemical properties. He even left spaces for elements that hadn’t been discovered yet, predicting their properties based on their position.

Later, Henry Moseley discovered that organizing elements by atomic number, rather than atomic weight, made more sense. Atomic number is the number of protons in an atom, and this arrangement corrected some inconsistencies in Mendeleev’s table. Today, the modern periodic table is organized by atomic number, and elements with similar properties are placed in vertical columns called groups.

**Discussion Questions**:

1. Why do you think Mendeleev left gaps in his periodic table?

- **Answer**: Mendeleev left gaps because he predicted that elements with certain properties had yet to be discovered. He used the patterns he observed to forecast the properties of these missing elements.

2. How did Moseley’s discovery change the way the periodic table was organized?

- **Answer**: Moseley discovered that organizing elements by atomic number, rather than atomic weight, solved many of the problems with Mendeleev’s table. This reorganization made the periodic table more accurate.

3. What information can we predict about an element based on its position on the periodic table?

- **Answer**: We can predict an element’s reactivity, its state of matter at room temperature, and whether it is a metal, nonmetal, or metalloid. We can also predict how it will combine with other elements to form compounds.

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

**Scaffolded Questions**:

1. What key discovery did Henry Moseley contribute to the periodic table’s development?

- **Answer**: Moseley discovered that elements should be arranged by their atomic number, not atomic weight.

2. How did Mendeleev’s organization of the periodic table predict the properties of undiscovered elements?

- **Answer**: Mendeleev organized elements by their atomic weight and observed patterns in their properties. He left gaps for elements that had not yet been discovered and predicted their properties based on the trends he saw.

3. Why is the modern periodic table more accurate than earlier versions?

- **Answer**: The modern periodic table is more accurate because it is organized by atomic number, which reflects the actual structure of atoms, rather than atomic weight, which can vary among isotopes.

### 9. Explain (Lightbulb)

**Full Explanation of the Lesson's Concept**:

### The Early Development of the Periodic Table

During the 1800s, scientists had discovered many elements, but there was no clear system to organize them. They knew that certain elements had similar properties, but they didn’t understand why. Several attempts were made to organize the elements, but none of them worked well until Dmitri Mendeleev, a Russian chemist, made his breakthrough.

Mendeleev created a table by arranging elements in order of increasing **atomic mass**. He noticed that when elements were arranged in this way, certain properties repeated at regular intervals, or “periods.” This repeating pattern is called **periodicity**. Mendeleev’s table was revolutionary because it not only grouped elements with similar properties together, but it also predicted the existence of elements that hadn’t yet been discovered. For example, he predicted the properties of elements like gallium and germanium before they were found.

### Mendeleev’s Predictions

Mendeleev’s predictions were based on the gaps he left in his table. He knew that if elements followed a repeating pattern, then there must be elements missing from the known list. When gallium and germanium were discovered, their properties matched Mendeleev’s predictions almost perfectly, which confirmed the accuracy of his table.

### Moseley’s Contribution

Though Mendeleev’s table was groundbreaking, it wasn’t perfect. Some elements didn’t fit well when ordered by atomic mass. For example, iodine has a lower atomic mass than tellurium, but its chemical properties are more similar to fluorine, chlorine, and bromine, so it should be placed with those elements.

In 1913, Henry Moseley, an English physicist, solved this problem by discovering the concept of **atomic number**. He found that elements are better organized by their atomic number, which is the number of protons in the nucleus of an atom. This discovery led to the **modern periodic table** that we use today, where elements are arranged by increasing atomic number. This fixed the problems with Mendeleev’s table and created an accurate, reliable way to organize the elements.

### Modern Periodic Table

The modern periodic table is organized into 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 energy levels. This is why sodium, magnesium, and calcium, which are all used in road salts, belong to different groups but still show related behaviors.

The periodic table helps scientists understand the properties of elements and predict how they will react with others. It is a powerful tool because it organizes elements in a way that reflects their atomic structure and properties.

### Solved Example Problem:

**Problem**:

The element with atomic number 19 is potassium (K). Based on its position on the periodic table, predict whether potassium is a metal or a nonmetal, and explain why.

**Solution**:

Potassium is located in Group 1 of the periodic table, which contains the alkali metals. Elements in this group are highly reactive metals. Therefore, potassium is a metal. Its position in Group 1 indicates that it has one electron in its outer energy level, which it readily loses in chemical reactions.

**Progress Check**:

- **Question**:

The element with atomic number 17 is chlorine (Cl). Based on its position on the periodic table, predict whether chlorine is more likely to gain or lose electrons in reactions. Why?

- **Answer**:

Chlorine is located in Group 17, also known as the halogens. Elements in this group are more likely to gain one electron to achieve a full outer energy level. Therefore, chlorine is more likely to gain an electron in reactions.

This concludes the detailed lesson plan for "The Development of the Periodic Table."

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

To confirm your understanding of the key concepts covered in the "Explain" section, here are three scaffolded questions. Answer them to check your progress!

**Question 1**: What is an element?

Answer: An element is a pure substance that cannot be broken down into simpler substances by chemical means. It consists of only one type of atom.

**Question 2**: How do you differentiate between a compound and a mixture?

Answer: A compound is made up of two or more elements chemically combined in a fixed ratio, while a mixture is a combination of two or more substances that are not chemically bonded and can be separated by physical methods.

**Question 3**: If you are given a sample of saltwater, how would you separate the salt from the water?

Answer: You can separate salt from water through evaporation. By heating the saltwater solution, the water will evaporate, leaving the salt behind.

### 11. Elaborate (Power Up)

Let’s take your understanding further! Try these mini-tasks and open-ended questions to deepen your thinking.

**Mini-Task 1**: How would life on Earth be different if water was a compound made of three hydrogen atoms and one oxygen atom (H3O instead of H2O)?

Answer: If water were H3O instead of H2O, its physical and chemical properties would change. The molecular structure would be different, which could affect its boiling point, freezing point, and how it interacts with living organisms. Life as we know it might not exist because many biological processes depend on water's current properties.

**Mini-Task 2**: Research and explain a real-life example where separating mixtures is important.

Answer: One real-life example of separating mixtures is water purification. In water treatment plants, various methods like filtration, sedimentation, and distillation are used to remove impurities and make water safe for drinking. This separation is crucial for providing clean water to communities.

**Mini-Task 3**: Propose a method to separate a mixture of iron filings, sand, and salt. Describe the steps.

Answer: Here’s one way to separate the mixture:

1. Use a magnet to attract and remove the iron filings.

2. Add water to the remaining sand and salt mixture to dissolve the salt.

3. Filter the mixture to separate the sand from the saltwater.

4. Finally, evaporate the water from the saltwater solution to recover the salt.

### 12. Final Evaluation

### Debate Question

**Debate Topic**: Should humans focus more on recycling compounds (e.g., plastics) versus reducing the production of new materials?

**Arguments for Recycling**:

- Recycling reduces waste and conserves natural resources.

- It can prevent harmful chemicals from new material production from entering the environment.

- Reusing materials can save energy compared to creating new products from raw materials.

**Arguments for Reducing Production**:

- By reducing production, we can limit the environmental damage from extraction and manufacturing.

- Focusing on reduction encourages sustainability and lessens dependency on non-renewable resources.

- Reducing production can lead to innovations in creating biodegradable or renewable materials.

### Assessment Questions

**Multiple-Choice Questions**

**Question 1**: Which of the following is a compound?

A) Gold

B) Oxygen

C) Water

D) Helium

**Correct Answer**: C) Water

**Explanation**: Water (H2O) is a compound because it is made up of two hydrogen atoms and one oxygen atom chemically bonded together.

**Question 2**: What method can be used to separate salt from water?

A) Filtration

B) Distillation

C) Chromatography

D) Magnetism

**Correct Answer**: B) Distillation

**Explanation**: Distillation involves heating the saltwater so that the water evaporates, leaving the salt behind.

**Question 3**: A mixture is different from a compound because:

A) Mixtures can only be separated by chemical means.

B) Compounds are physically combined, while mixtures are chemically combined.

C) Mixtures can be separated by physical means.

D) Mixtures always have a fixed ratio of components.

**Correct Answer**: C) Mixtures can be separated by physical means.

**Explanation**: Mixtures are combinations of substances that are not chemically bonded, so they can be separated by methods like filtration or evaporation.

**Question 4**: Which of the following is an example of a physical change?

A) Burning wood

B) Rusting iron

C) Dissolving sugar in water

D) Cooking an egg

**Correct Answer**: C) Dissolving sugar in water

**Explanation**: Dissolving sugar in water is a physical change because no new substance is formed, and the sugar can be recovered by evaporating the water.

**Long-Answer Questions**

**Question 1**: Explain the difference between a homogeneous mixture and a heterogeneous mixture.

Answer: A homogeneous mixture has the same composition throughout, and its components are evenly distributed, like salt dissolved in water. A heterogeneous mixture has visibly different parts and uneven composition, like a salad where you can see the individual ingredients.

**Question 2**: Describe how the periodic table is organized and explain why elements in the same group have similar chemical properties.

Answer: The periodic table is organized by increasing atomic number. Elements are arranged in rows (periods) based on their number of electron shells and in columns (groups) based on similar chemical properties. Elements in the same group have similar properties because they have the same number of valence electrons, which affects how they bond with other elements.

**Question 3**: How can you separate a mixture of oil and water? Explain the process.

Answer: You can separate a mixture of oil and water through decantation or using a separating funnel. Since oil is less dense than water, it will float on top. Using a separating funnel, the water can be drained from the bottom, leaving the oil behind.

**Question 4**: Why is it important to understand the differences between elements, compounds, and mixtures in chemistry?

Answer: Understanding the differences helps us know how substances interact, how to separate them, and how to use them in practical applications. For example, knowing whether a substance is a compound or a mixture tells us what methods we can use to break it down or combine it with other substances.

### 13. Extend (Beyond the Lesson)

Now that you’ve mastered the basics, here are some additional tasks and challenges to take your understanding even further.

**Task 1**: Research the importance of separating mixtures in the food industry. How are mixtures like milk or fruit juices processed to ensure they are safe for consumption?

**Task 2**: Investigate how scientists separate gases from the air to produce products like liquid nitrogen or oxygen for medical purposes. Write a short report on the process used.

**Task 3**: Real-World Application: Imagine you are an environmental scientist tasked with cleaning up an oil spill. Design a method for separating the oil from seawater and explain your process.

**Task 4**: Spaced Practice: Over the next few weeks, revisit the concepts of mixtures and compounds by completing short quizzes or flashcard activities. This will reinforce your understanding and help you retain the information over time.

By engaging in these activities and revisiting the material, you’ll build a deeper understanding of how chemistry affects the world around you!