Unit 2: Atomic Structure and Bonding

Chapter 3: Unlocking the Atom

# Lesson 1: The Evolution of Atomic Models and Structure

1. Big Idea:  
- The structure of the atom has been understood through a series of discoveries by different scientists, each building upon the work of their predecessors.  
  
  
  
 2. Essential Questions:  
- **How have discoveries over time influenced our current understanding of atomic structure?**  
  
 Answer:  
- Over time, scientists such as Democritus, Dalton, Thomson, Rutherford, Bohr, and Schrodinger contributed to the development of atomic theory. Each scientist’s discoveries helped to build a clearer picture of the atom. From early ideas of indivisible particles to complex quantum mechanical models, our understanding of atomic structure has evolved significantly.  
  
  
  
 3. Phenomenon-Based Learning:  
  
**Phenomenon:**  
- **Unit Phenomenon:** In northern countries, road salt is used to make streets safer in winter by melting ice. However, street signs and lampposts do not "vanish" like the ice does.

- **Chapter 3 Phenomenon:** Is salting the road a magic trick? When salt is added to icy roads, the ice seems to disappear. To understand this, you must explore the structure of the substances involved—like water, salt, and metals—all of which are made of atoms. But are all atoms the same? No, and understanding the atomic structure is key to explaining these differences.  
  
  
  
 4. Vocabulary:  
- **Bohr:** A scientist who introduced the idea of electrons orbiting the nucleus in fixed energy levels.  
- **Dalton:** Proposed the first modern atomic theory stating that atoms are indivisible particles.  
- **Democritus:** An ancient philosopher who first suggested that all matter is made of tiny, indivisible particles called atoms.  
- **Electrons:** Negatively charged particles that orbit the nucleus of an atom.  
- **Nuclear model:** Rutherford's model of the atom, where a dense nucleus is surrounded by orbiting electrons.  
- **Neutrons:** Particles in the nucleus of an atom with no charge.  
- **Plum-pudding model:** J.J. Thomson's model of the atom, where electrons are scattered within a positive "soup."  
- **Protons:** Positively charged particles in the nucleus of an atom.  
- **Rutherford:** Discovered the nucleus and proposed the nuclear model of the atom.  
- **Schrodinger:** Developed the quantum mechanical model of the atom, where electrons are found in probability clouds rather than fixed orbits.  
- **Thomson:** Discovered the electron and proposed the plum-pudding model.  
- **Quantum mechanical model:** The modern theory of the atom where electrons are found in orbitals as probability clouds rather than fixed paths.  
  
  
  
 5. SMART Objectives:  
1. **Name key scientists** who contributed to the development of atomic theory, including Democritus, Dalton, Thomson, Rutherford, Bohr, and Schrodinger.  
2. **Trace the evolution of atomic models** from Democritus’s indivisible atoms to the modern quantum mechanical model.  
3. **Compare and contrast the contributions** of different scientists to the understanding of atomic structure by identifying key differences and similarities in their atomic models.  
4. **Explain how discoveries in atomic structure** have influenced modern technology, using road salt and ice melting as a real-world example.  
  
  
  
 6. Engage (Ignite):  
  
**Phenomenon-Related Question:** Why does road salt make ice on roads disappear without affecting metal street signs?   
  
Hands-On Experiment:   
- **Objective:** Understand the molecular structure of salt and water, and how salt dissolves in water to lower the freezing point.  
   
 Procedure:  
1. **Materials:** Two small bowls, water, salt, a freezer, and a thermometer.  
2. **Step 1:** Fill each bowl halfway with water. Add a tablespoon of salt to one bowl and stir until dissolved, leaving the other bowl as plain water.  
3. **Step 2:** Place both bowls in the freezer.  
4. **Step 3:** After 30 minutes, check the bowls. Measure the temperature and observe which one freezes first.  
   
 Follow-Up Questions:  
1. **What difference did you observe in the freezing of the salty water compared to the plain water**?  
2. **Why do you think the salt caused a change in the freezing process**?  
3. **How does this relate to the phenomenon of road salt melting ice?**  
  
  
  
 7. Pre-Explore (Direct Instruction):  
  
**Background Information:**  
- The atom has not always been understood as it is today. Early philosophers like Democritus proposed that all matter is made up of tiny, indivisible particles called atoms. However, it wasn’t until the 19th and 20th centuries that scientists began to develop models that explained atomic properties and behavior.  
   
 Key Concepts:  
- **Democritus (450 BCE):** First proposed that matter is made of small, indivisible particles called atoms.  
- **John Dalton (1803):** Developed the modern atomic theory, stating that all matter is composed of atoms, which cannot be created or destroyed.  
- **J.J. Thomson (1897):** Discovered the electron and proposed the **plum-pudding model**, where atoms are made of electrons scattered within a positively charged “soup.”  
- **Ernest Rutherford (1911):** Conducted the gold foil experiment and discovered the nucleus, leading to the **nuclear model** of the atom.  
- **Niels Bohr (1913):** Proposed that electrons orbit the nucleus in fixed energy levels, creating the **Bohr model** of the atom.  
- **Erwin Schrodinger (1926):** Developed the **quantum mechanical model**, where electrons exist in probability clouds called orbitals.  
  
**Interactive Elements:**  
- Discussion prompts to compare the atomic models of Dalton, Thomson, Rutherford, Bohr, and Schrodinger.  
   
  
  
 8. Evaluate (Progress Check) - Pre-Explore:  
  
**Scaffolded Questions:**1. Which scientist first discovered the electron? (DOK 1)  
2. How did Rutherford’s model of the atom differ from Thomson’s plum-pudding model? (DOK 2)  
3. Why is Schrodinger’s quantum mechanical model more accurate than Bohr’s model? (DOK 3)  
  
  
  
 9. Explain (Lightbulb):  
  
 The Evolution of Atomic Models:  
  
1. **Democritus (450 BCE):**  
 - Democritus was a Greek philosopher who first suggested the idea of atoms. He believed that all matter was composed of small, indivisible particles. However, his idea was purely philosophical and lacked experimental evidence. Despite this, his concept of atoms laid the foundation for future scientists.  
  
2. **John Dalton (1803):**  
 - In the early 1800s, John Dalton revisited the idea of atoms and developed the first modern atomic theory. Dalton proposed that atoms were tiny, indivisible spheres, much like billiard balls. He suggested that all atoms of a given element are identical and that atoms combine in simple ratios to form compounds. Dalton's theory explained many chemical reactions but did not account for subatomic particles, like electrons, protons, or neutrons.  
  
3. **J.J. Thomson (1897):**  
 - J.J. Thomson discovered the electron, a tiny particle with a negative charge. His discovery led to the plum-pudding model of the atom. In this model, electrons are scattered like raisins in a positively charged “pudding.” While this model introduced the idea of subatomic particles, it didn’t explain how electrons were arranged within the atom.  
  
4. **Ernest Rutherford (1911):**  
 - Rutherford's famous gold foil experiment revealed that atoms have a small, dense, positively charged nucleus at their center. This discovery led to the nuclear model of the atom. In this model, electrons orbit the nucleus, but it was unclear how they stayed in orbit without falling into the nucleus. This question would be answered by later models.  
  
5. **Niels Bohr (1913):** - Niels Bohr built upon Rutherford's model by introducing the idea that electrons orbit the nucleus in fixed energy levels or shells. Electrons can jump from one energy level to another, but they cannot exist between levels. This explained why atoms emit light at specific wavelengths, as electrons lose energy when they drop to lower levels.  
  
6. **Erwin Schrodinger (1926):** - Schrodinger developed the quantum mechanical model of the atom, which is the most accurate model we have today. Instead of fixed orbits, electrons exist in regions of probability called orbitals. These orbitals are like clouds surrounding the nucleus, where electrons are likely to be found. Schrodinger’s model explains the complex behavior of electrons and laid the groundwork for modern quantum physics.  
  
  
  
 Hands-On Activity Reflection:  
  
- **Understanding Salt and Water at the Atomic Level:**  
 - Salt (NaCl) dissolves in water because the positive and negative charges of the water molecules pull apart the sodium and chloride ions. This disrupts the freezing process by lowering the temperature at which ice forms, which is why salty water freezes more slowly than fresh water. So when you put salt on icy roads, it lowers the freezing point of the ice, causing it to melt.  
   
 Expansion Questions:  
1. **How does the atomic structure of water and salt explain the phenomenon of ice melting?**  
2. **Why do metal street signs not "vanish" like ice when exposed to salt and snow?**  
  
  
 Progress Check:  
  
1. **Solved Sample Problem:**  
 **Question:** If electrons are negatively charged, why don’t they fall into the positively charged nucleus according to Rutherford’s model?  
 **Solution:** In Rutherford’s model, the electrons orbit the nucleus, but he didn’t explain why they don’t spiral into the nucleus. Bohr later explained that electrons exist in fixed energy levels, and they can only move between these levels by absorbing or releasing energy.  
  
2. **Student Question:** **Question:** How does the quantum mechanical model differ from Bohr’s model in terms of electron behavior?  
  
  
  
 10. Evaluate (Progress Check) - Explain  
  
Here are three scaffolded questions based on the Depth of Knowledge (DOK) Levels 1-3 to check your understanding.  
  
 Question 1 (DOK 1 - Recall):  
**What is the chemical formula for water?**  
  
**Answer:**   
The chemical formula for water is H₂O.   
This type of question checks your ability to recall basic facts, which is a low-level thinking skill.  
  
  
  
 Question 2 (DOK 2 - Skill/Concept):  
**Explain why water is considered a polar molecule**.  
  
**Answer:**   
Water is considered a polar molecule because it has a partial positive charge on the hydrogen atoms and a partial negative charge on the oxygen atom. This happens because oxygen is more electronegative than hydrogen, pulling the shared electrons closer to itself. As a result, one side of the water molecule is slightly negative, and the other side is slightly positive, creating polarity.  
  
  
  
 Question 3 (DOK 3 - Strategic Thinking):  
**How does the polarity of water affect its ability to dissolve substances like salt (NaCl)**?  
  
**Answer:**   
The polarity of water allows it to dissolve many substances, such as salt (NaCl), because the positive and negative ends of water molecules attract the ions in salt. The positive end of the water molecule (hydrogen) surrounds the negative chloride ions (Cl⁻), and the negative end (oxygen) surrounds the positive sodium ions (Na⁺). This process, known as dissolution, breaks the ionic bonds in salt and disperses the ions throughout the solution.  
  
  
  
 11. Elaborate (Power Up)  
  
Here are some open-ended and mini-tasks to encourage deeper thinking:  
  
 Mini-Task 1:  
**Explore how water's polarity makes it essential for life. Can you think of some biological processes that rely on water's unique properties**?  
  
**Answer:**   
Water's polarity is crucial in biological processes like cellular respiration and photosynthesis. For example, water acts as a solvent inside cells, enabling chemical reactions to take place efficiently. It also plays a role in maintaining the shape of proteins and DNA, which are vital for life functions. Additionally, water's ability to form hydrogen bonds allows it to regulate temperature, which is critical for maintaining stable conditions in living organisms.  
  
  
  
 Mini-Task 2:  
**How would life be different if water were a non-polar molecule?**  
  
**Answer:**   
If water were non-polar, it would not be able to dissolve ionic and polar substances as effectively, and many biological reactions would not occur. For example, nutrients and waste products might not be transported in and out of cells easily. Water's high heat capacity would also be lost, meaning that organisms would struggle to regulate their internal temperatures. Life as we know it would likely not exist, or it would have evolved very differently.  
  
  
  
 Mini-Task 3:  
Compare the role of water in dissolving ionic compounds like salt (NaCl) to its role in dissolving covalent compounds like sugar (C₆H₁₂O₆).  
  
**Answer:**Water dissolves ionic compounds by surrounding the individual ions and breaking their ionic bonds, as explained earlier with salt. For covalent compounds like sugar, water dissolves them through hydrogen bonding. Water molecules form hydrogen bonds with the polar hydroxyl (–OH) groups in sugar, allowing the sugar molecules to disperse throughout the solution. While the process is different, water's polarity plays a key role in dissolving both types of compounds.  
  
  
  
 12. Final Evaluation  
  
 Debate Question:  
**Should water’s unique properties be considered the most important factor for life on Earth? Why or why not?**  
  
**Arguments for Discussion:**- **Yes**: Water’s polarity, high heat capacity, and solvent capabilities make it essential for biochemical reactions, temperature regulation, and nutrient transport, all of which are crucial for life.  
- **No:** While water is important, other factors such as the availability of sunlight (for energy) and the presence of carbon (for building organic molecules) might be equally or more important for life.  
  
  
  
 Multiple-Choice Questions:  
  
**Question 1:**What makes water a polar molecule?   
A) It has equal sharing of electrons.   
B) It has an unequal sharing of electrons between hydrogen and oxygen.   
C) It has more protons than neutrons.   
D) It has a linear molecular shape.   
  
**Correct Answer: B   
Explanation:** Water is polar because the oxygen atom pulls the shared electrons closer to itself, leading to an unequal sharing of electrons between the hydrogen and oxygen atoms.  
  
  
  
**Question 2:**   
Which of the following is an example of a substance that is likely to dissolve in water?   
A) Oil   
B) Sand   
C) Sodium chloride (NaCl)   
D) Plastic   
  
**Correct Answer: C**   
**Explanation:** Sodium chloride (NaCl) is an ionic compound, and water, being polar, can dissolve ionic substances by breaking their bonds.  
  
  
  
**Question 3:**   
What property of water allows it to absorb a lot of heat without a large change in temperature?   
A) Low boiling point   
B) High specific heat capacity   
C) Low density   
D) High concentration of hydrogen bonds   
  
**Correct Answer: B   
Explanation:** Water's high specific heat capacity allows it to absorb a large amount of heat energy without a rapid increase in temperature, helping regulate temperatures in environments.  
  
  
  
**Question 4:**   
Why does ice float on water?   
A) Ice is denser than water.   
B) Ice is made of different molecules than liquid water.   
C) Water expands when it freezes, making ice less dense than liquid water.   
D) The hydrogen bonds in ice are weaker than in liquid water.   
  
**Correct Answer: C**   
**Explanation:** When water freezes, it expands, and its density decreases. This is why ice floats on liquid water.  
  
  
  
 Long-Answer Questions:  
  
**Question 1:**   
**Describe how water's ability to form hydrogen bonds affects its role as a solvent in biological systems.**  
**Answer:**   
Water’s ability to form hydrogen bonds makes it an excellent solvent, especially for polar and ionic compounds. In biological systems, this allows water to dissolve essential nutrients, ions, and gases, facilitating their transport and participation in metabolic reactions. For example, water dissolves glucose, enabling it to be transported in the bloodstream to cells for energy production.  
  
  
  
**Question 2:   
Explain the process by which water dissolves sodium chloride (NaCl).**  
  
**Answer:**   
When sodium chloride (NaCl) is added to water, the positive sodium ions (Na⁺) are attracted to the negative part of the water molecules (oxygen), and the negative chloride ions (Cl⁻) are attracted to the positive part of the water molecules (hydrogen). This separates the ions from each other, breaking the ionic bond, and the Na⁺ and Cl⁻ ions become surrounded by water molecules, dissolving the salt.  
  
  
  
**Question 3:**   
**How does water's high specific heat capacity benefit living organisms?**  
**Answer:**   
Water's high specific heat capacity allows it to absorb and retain a large amount of heat without a significant change in temperature. This property helps stabilize temperatures in living organisms and their environments. For example, it prevents rapid temperature changes in oceans, which provides a stable habitat for marine life. In humans, water helps regulate body temperature, preventing overheating.  
  
  
  
**Question 4:**   
**Why is the density of ice important for life in aquatic environments?**  
  
**Answer:**   
When water freezes, it expands and becomes less dense than liquid water. This causes ice to float on the surface of bodies of water, creating an insulating layer. This insulation prevents the entire body of water from freezing solid, allowing aquatic life to survive in the liquid water beneath the ice during cold months.  
  
  
  
 13. Extend (Beyond the Lesson)  
  
Here are some additional tasks and readings to deepen your understanding of water's properties:  
  
 Task 1:  
**Research how water is used in different industries (e.g., agriculture, medicine, manufacturing) and present your findings in a report.**  
  
  
  
 Task 2:  
**Read about the water cycle and explain how water's unique properties (e.g., evaporation, condensation, and surface tension) contribute to this natural process.**  
  
  
  
 Challenge Question:  
How might climate change affect the availability of water in different parts of the world, and what solutions can we consider to address water scarcity?  
  
  
  
 Spaced Practice:  
Over the next few weeks, revisit the concepts of water’s polarity, hydrogen bonding, and its role in biological systems. Create flashcards or summaries to quiz yourself on these key points. Additionally, try to connect what you've learned about water to new topics, such as acids and bases or solutions, as you continue through the course.