# Unit: Unit 2: Atomic Structure and Bonding

## Chapter: Chapter 7: Covalent Bonding

### Lesson: Lesson 1: Covalent Bonding and Molecular Structure

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### Essential Questions:   
- \*\*How do covalent bonds form, and how do they differ from ionic bonds?\*\*  
  
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### 1. Big Idea   
Atoms share electrons to form \*\*covalent bonds\*\*, creating molecules with specific structures and properties.  
  
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### 2. Essential Questions  
  
- \*\*How do covalent bonds form, and how do they differ from ionic bonds?\*\*  
  
### Answer:  
Covalent bonds form when two atoms share electrons to achieve a full outer shell (also called a stable electron configuration). This is different from ionic bonds, where atoms transfer electrons, leading to a bond between positively and negatively charged ions. In covalent bonding, no ions are formed—just shared electrons.  
  
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### 3. Phenomenon-Based Learning  
  
- \*\*Unit Phenomenon:\*\*  
 In northern countries, streets and roads are often covered in ice during the winter. To make these surfaces safer, road salt is spread to melt the ice. The ice seems to disappear, but metal street signs and lampposts do not undergo the same change. How is this possible?  
  
- \*\*Chapter Phenomenon:\*\*  
 Water is unique—when it melts, it changes from solid ice to liquid water, but its molecular structure remains the same. The shape of the water molecule is crucial to its properties. How can we predict the shape of molecules like water?  
  
 The focus of this lesson will be to understand how atoms bond to form molecules like water and how these bonds affect the properties of the molecules.  
  
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### 4. Vocabulary  
  
- \*\*Covalent bond:\*\* A type of chemical bond where two atoms share one or more pairs of electrons.  
- \*\*Single bond:\*\* A bond where two atoms share one pair of electrons.  
- \*\*Double bond:\*\* A bond where two atoms share two pairs of electrons.  
- \*\*Triple bond:\*\* A bond where two atoms share three pairs of electrons.  
  
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### 5. SMART Objectives  
  
By the end of this lesson, students will be able to:  
  
1. \*\*Describe\*\* the formation of covalent bonds between atoms.  
2. \*\*Identify\*\* the basic properties of covalent compounds, such as low melting points and poor electrical conductivity.  
3. \*\*Construct\*\* Lewis structures for simple covalent molecules (e.g., H₂, O₂, H₂O).  
4. \*\*Differentiate\*\* between single, double, and triple bonds using examples.  
  
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### 6. Engage (Ignite)  
  
\*\*Phenomenon-Related Question:\*\*   
- "Why does road salt melt ice but not metal objects like street signs?"  
  
\*\*Hands-On Experiment:\*\*   
\*\*"Building Covalent Bonds with Ball-and-Stick Models"\*\*  
  
#### Materials:  
- Ball-and-stick molecular model kits (or toothpicks and marshmallows as an alternative)  
- Periodic table  
- Paper and pencil for notes  
  
#### Procedure:  
1. \*\*Modeling Single Bonds:\*\*  
 - Use two hydrogen atoms (represented by balls) and connect them with one stick (representing a single pair of shared electrons).  
 - This models a \*\*single bond\*\* (H₂ molecule).  
  
2. \*\*Modeling Double Bonds:\*\*  
 - Use two oxygen atoms and connect them with two sticks (representing two pairs of shared electrons).  
 - This models a \*\*double bond\*\* (O₂ molecule).  
  
3. \*\*Modeling Triple Bonds:\*\*  
 - Use two nitrogen atoms and connect them with three sticks (representing three pairs of shared electrons).  
 - This models a \*\*triple bond\*\* (N₂ molecule).  
  
#### Follow-Up Questions:  
1. What do the sticks between the atoms represent?  
2. How does the number of sticks (single, double, or triple bonds) relate to the strength and length of the bond?  
3. How do the structures of H₂, O₂, and N₂ compare in terms of bond strength and stability?  
  
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### 7. Pre-Explore (Direct Instruction)  
  
#### Background Information:  
Atoms form \*\*covalent bonds\*\* by sharing electrons. This occurs because atoms want to achieve a stable electron configuration, often similar to the noble gases. For most atoms, this means having eight electrons in their outer shell (the \*\*octet rule\*\*). Hydrogen, however, only needs two electrons.  
  
Covalent bonds can differ in strength and length depending on how many pairs of electrons are shared:  
- \*\*Single Bonds:\*\* One pair of electrons shared (e.g., H₂).  
- \*\*Double Bonds:\*\* Two pairs of electrons shared (e.g., O₂).  
- \*\*Triple Bonds:\*\* Three pairs of electrons shared (e.g., N₂).  
  
Covalent compounds have distinct properties:  
- \*\*Low melting and boiling points\*\* compared to ionic compounds.  
- They are often \*\*poor conductors of electricity\*\* because they don’t have free-moving charged particles (like ions).  
  
#### Interactive Notes:  
- Use the ball-and-stick model to visualize how atoms share electrons.  
- Have students discuss with a partner the differences between single, double, and triple bonds.  
  
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### 8. Evaluate (Progress Check) - Pre-Explore  
  
\*\*Scaffolded Questions:\*\*  
  
1. What is the main difference between covalent and ionic bonds?   
 \*(DOK 1: Recall and Comprehension)\*  
  
2. Why do atoms form covalent bonds instead of ionic bonds in some cases?   
 \*(DOK 2: Cause and Effect)\*  
  
3. How would you compare the bond strength in single, double, and triple bonds?   
 \*(DOK 3: Application and Analysis)\*  
  
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### 9. Explain (Lightbulb)  
  
#### Introduction to Covalent Bonding:  
  
\*\*Formation of Covalent Bonds:\*\*  
  
Unlike ionic bonds, which occur when atoms transfer electrons, covalent bonds form when two atoms \*\*share electrons\*\*. The sharing of electrons allows each atom to achieve a full outer electron shell, which makes the atom more stable. For example, in a hydrogen molecule (H₂), each hydrogen atom has just one electron, but both atoms want two electrons to fill their outer shell. By sharing one pair of electrons, both hydrogen atoms achieve a stable configuration.  
  
\*\*Example:\*\*   
Consider the water molecule (H₂O). Oxygen needs two more electrons to complete its outer shell, and each hydrogen atom needs one more electron. By sharing electrons, oxygen forms two single bonds—one with each hydrogen atom. This sharing arrangement allows all three atoms to achieve stable configurations.  
  
\*\*Properties of Covalent Compounds:\*\*  
  
Covalent bonds create molecules, and these molecules behave differently from ionic compounds. Some key properties of covalent compounds include:  
- \*\*Low melting and boiling points:\*\* Covalent molecules are held together by relatively weak forces, so it doesn’t take much energy to separate them.  
- \*\*Poor conductivity:\*\* Since covalent compounds do not have charged particles (ions) that can move around, they typically do not conduct electricity.  
- \*\*Dissolving in water:\*\* Some covalent compounds can dissolve in water (like sugar), but others cannot (like oil). This depends on whether the molecule can interact with water molecules.  
  
#### Lewis Structures:  
  
Lewis structures are simple diagrams that show how atoms share electrons in covalent bonds. In a Lewis structure, we use dots to represent electrons and lines to represent bonds.  
  
\*\*Steps to draw a Lewis structure:\*\*  
1. \*\*Count the total number of valence electrons.\*\*   
 For example, for H₂O, hydrogen has 1 valence electron, and oxygen has 6. So, H₂O has 8 valence electrons in total.  
  
2. \*\*Place the least electronegative atom in the center.\*\*   
 In H₂O, oxygen is placed in the center, with the hydrogen atoms on either side.  
  
3. \*\*Use single lines to represent bonds and assign remaining electrons as lone pairs.\*\*   
 The oxygen atom forms two single bonds with the two hydrogen atoms. The remaining four electrons stay on oxygen as lone pairs.  
  
\*\*Example: Drawing the Lewis Structure for O₂\*\*  
- Oxygen has 6 valence electrons. Two oxygen atoms = 12 total valence electrons.  
- Place the atoms next to each other and connect them with a single bond.  
- Use the remaining electrons to satisfy the octet rule. You’ll find that oxygen needs to form a \*\*double bond\*\* to satisfy the octet rule for both atoms.  
  
\*\*Solved Example:\*\*  
- \*\*Draw the Lewis structure for CO₂ (carbon dioxide).\*\*  
 1. Count valence electrons: Carbon has 4, and oxygen has 6. Total = 16 electrons.  
 2. Place carbon in the center, with one oxygen on each side.  
 3. Create double bonds between carbon and each oxygen. Use remaining electrons to form lone pairs on oxygen.  
  
\*\*Progress Check:\*\*  
- Draw the Lewis structure for methane (CH₄). How many single bonds does it have?  
  
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### 10. Elaborate (Deep Dive)  
  
#### How Covalent Bonds Connect to the Phenomenon:  
  
In the chapter phenomenon, we talked about how water molecules change their state from solid (ice) to liquid (water) when road salt is applied. The \*\*covalent bonds\*\* between hydrogen and oxygen in water molecules do not break during this change. The water molecules remain intact, but the forces between the molecules weaken, allowing the solid to turn into a liquid. The covalent bonds define the \*\*molecular structure\*\* of water, which determines many of its properties, like its ability to dissolve substances (like salt) or its unique behavior when freezing.  
  
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### 11. Evaluate (Post-Lesson):  
  
\*\*Final Questions:\*\*  
1. How do covalent bonds allow atoms to achieve stable electron configurations?  
2. Why do covalent compounds tend to have low melting and boiling points compared to ionic compounds?  
3. Draw the Lewis structure for nitrogen (N₂). How many bonds do the nitrogen atoms share?  
  
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This lesson plan provides a structured approach to understanding covalent bonding, with various interactive elements and hands-on activities to ensure students can relate the content back to real-world phenomena like melting ice on roads.  
  
### 10. Evaluate (Progress Check) - Explain  
  
#### Scaffolded Questions:  
Scaffolded questions are designed to gradually increase in complexity according to Depth of Knowledge (DOK) levels, ensuring a clear understanding of the material.  
  
1. \*\*DOK Level 1: Recall and Reproduction\*\*  
 - \*\*Question\*\*: What is the chemical symbol for water?  
 - \*\*Answer\*\*: The chemical symbol for water is \*\*H₂O\*\*. This is because water is made up of two hydrogen (H) atoms and one oxygen (O) atom.  
  
2. \*\*DOK Level 2: Skill/Concept\*\*  
 - \*\*Question\*\*: Why does water have a bent molecular shape instead of a linear one?  
 - \*\*Answer\*\*: Water has a bent shape because of the two lone pairs of electrons on the oxygen atom. These lone pairs push the hydrogen atoms closer together, creating a bent shape rather than a straight line.  
  
3. \*\*DOK Level 3: Strategic Thinking\*\*  
 - \*\*Question\*\*: Explain how the polarity of water molecules contributes to its ability to dissolve many substances.  
 - \*\*Answer\*\*: Water molecules are polar, meaning they have a positive and negative side. The oxygen atom has a slight negative charge, while the hydrogen atoms have a slight positive charge. This polarity allows water molecules to surround and interact with various ions and molecules, helping to break them apart and dissolve them.  
  
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### 11. Elaborate (Power Up)  
  
#### Mini-Tasks and Open-Ended Questions:  
These tasks encourage deeper thinking and exploration of the concepts.  
  
1. \*\*Mini-Task 1:\*\*  
 - \*\*Question\*\*: Design an experiment to test how temperature affects the solubility of table salt in water.  
 - \*\*Answer\*\*: You could heat water to different temperatures (e.g., 20°C, 40°C, 60°C, etc.) and add a fixed amount of table salt to each sample. Stir the solutions until no more salt can dissolve. Then, measure how much salt was dissolved at each temperature.  
  
2. \*\*Mini-Task 2:\*\*  
 - \*\*Question\*\*: Water is often called the “universal solvent.” Can you think of any substances that water cannot dissolve? Why might this be the case?  
 - \*\*Answer\*\*: Water cannot dissolve non-polar substances like oil. This is because water is polar, and non-polar molecules do not have charges for the water molecules to interact with. As a result, oil and water do not mix.  
  
3. \*\*Open-Ended Question:\*\*  
 - \*\*Question\*\*: How could you use what you know about water's properties to help clean up an oil spill in the ocean?  
 - \*\*Answer\*\*: To clean up an oil spill, you could use substances that attract oil but repel water, such as oil-absorbing materials. You could also use barriers to contain the oil on the surface of the water, since oil is less dense and floats.  
  
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### 12. Final Evaluation  
  
#### Debate Question:  
- \*\*Debate Topic\*\*: Should we use chemical dispersants to break up oil spills in the ocean?  
 - \*\*Arguments For\*\*: Chemical dispersants can break up the oil into smaller droplets, which can make it easier for natural bacteria to degrade the oil. This can speed up the cleanup process.  
 - \*\*Arguments Against\*\*: Dispersants themselves can be harmful to marine life. Additionally, while they break up oil, they don't remove it from the environment, which might still cause long-term damage.  
  
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#### Multiple Choice Questions:  
  
1. \*\*What is the correct chemical formula for carbon dioxide?\*\*  
 a) CO   
 b) CO₂   
 c) C₂O   
 d) C₂O₂   
 - \*\*Answer\*\*: \*\*b) CO₂\*\*   
 \*\*Explanation\*\*: Carbon dioxide consists of one carbon atom and two oxygen atoms.  
  
2. \*\*What type of bond forms between the hydrogen and oxygen atoms in a water molecule?\*\*   
 a) Ionic   
 b) Covalent   
 c) Metallic   
 d) Hydrogen   
 - \*\*Answer\*\*: \*\*b) Covalent\*\*   
 \*\*Explanation\*\*: Water molecules are formed by covalent bonds where hydrogen and oxygen share electrons.  
  
3. \*\*Water is often described as a ‘polar’ molecule. What does this mean?\*\*   
 a) It has an equal distribution of charge.   
 b) It has an unequal distribution of charge.   
 c) It does not have any charge.   
 d) It only dissolves non-polar substances.   
 - \*\*Answer\*\*: \*\*b) It has an unequal distribution of charge.\*\*   
 \*\*Explanation\*\*: Water has a slight positive charge on the hydrogen side and a slight negative charge on the oxygen side, making it polar.  
  
4. \*\*Which property of water allows it to form droplets on surfaces?\*\*   
 a) Surface tension   
 b) Conductivity   
 c) Density   
 d) Polarity   
 - \*\*Answer\*\*: \*\*a) Surface tension\*\*   
 \*\*Explanation\*\*: Surface tension is caused by the cohesive forces between water molecules, leading to the formation of droplets.  
  
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#### Long-Answer Questions:  
  
1. \*\*Explain how the structure of water contributes to its unique properties such as high specific heat and surface tension.\*\*  
 - \*\*Answer\*\*: Water's structure, with two hydrogen atoms and one oxygen atom arranged in a bent shape, leads to its polar nature. The polarity causes water molecules to form hydrogen bonds with each other. These bonds are responsible for water's high specific heat (the ability to absorb a lot of heat without changing temperature) and its surface tension (the tendency of water molecules to stick together at the surface).  
  
2. \*\*Describe a real-world situation where the high specific heat of water is beneficial.\*\*  
 - \*\*Answer\*\*: The high specific heat of water helps regulate temperatures in coastal areas. The ocean absorbs heat during the day and releases it slowly at night, which keeps coastal regions from getting too hot during the day or too cold at night.  
  
3. \*\*How does water’s ability to dissolve many substances affect life on Earth?\*\*  
 - \*\*Answer\*\*: Water's ability to dissolve many substances makes it essential for life. It allows nutrients, minerals, and gases to be transported within organisms. For example, blood, which is mostly water, dissolves and carries oxygen, nutrients, and waste products throughout the body.  
  
4. \*\*Draw and label a diagram of a water molecule, showing its polarity. Then, explain how this polarity leads to hydrogen bonding between water molecules.\*\*  
 - \*\*Answer\*\*: (Students should draw a water molecule with oxygen labeled as slightly negative (δ−) and hydrogens as slightly positive (δ+).) The negative oxygen of one water molecule is attracted to the positive hydrogen of another water molecule, creating a hydrogen bond. These hydrogen bonds are relatively weak individually but collectively give water its unique properties like cohesion and surface tension.  
  
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### 13. Extend (Beyond the Lesson)  
  
#### Suggested Tasks and Challenges:  
  
1. \*\*Real-World Application\*\*: Research how water is used in cooling systems such as in power plants or car engines. Write a report on how water's high specific heat and thermal conductivity make it useful in these situations.  
   
2. \*\*Challenge Activity\*\*: Investigate how different salts affect the freezing point of water (e.g., table salt vs. magnesium chloride). Design and carry out an experiment to compare which salt is more effective at lowering the freezing point.  
  
3. \*\*Spaced Practice\*\*: Over the next week, keep a daily journal of how you observe water’s unique properties in your environment. For example, note where you see droplets forming, water dissolving substances, or water regulating temperature (like ice melting in a drink).  
  
#### Additional Readings:  
- "The Water Cycle" by National Geographic: This article dives into how water moves through the environment, which is essential for understanding water’s impact on Earth.  
- "Water as a Solvent" from Chemistry LibreTexts: This reading explains water’s role as a solvent, with examples of how it interacts with different substances.  
  
By revisiting these ideas and applying them to new contexts, students can deepen their understanding of water’s importance in both chemistry and everyday life.  
  
\*\*Note\*\*: Always encourage students to explore and ask more questions about these properties to fuel curiosity and critical thinking.