Activity: Shapes of Molecules

FOR THE TEACHER

Summary
In this activity, students will investigate the VSEPR geometry of covalent compounds. They will draw Lewis structures, use molecular models, and determine the geometry of covalent compounds. There is a lot of repetition so students gain a lot of practice.

Grade Level
High School

NGSS Alignment
This activity will help prepare your students to meet the following scientific and engineering practices:

- **Scientific and Engineering Practices:**
  - Developing and Using Models

Objectives
By the end of this lesson, students should be able to:

- Draw Lewis structures and apply VSEPR theory to them to identify the molecular geometry of a substance.

Chemistry Topics
This lesson supports students’ understanding of:

- VSEPR theory
- Molecular geometry
- Resonance
- Covalent bonding

Time
**Teacher Preparation:** 10 minutes
**Lesson:** 45 minutes (can be completed for homework)

Materials
- Student handout (per student)
- A set of molecular models (per group)

Safety
No safety considerations need to be observed for this investigation.

Teacher Notes
- It’s helpful to have samples of each geometry at the front of the class so students can familiarize themselves with how to assemble molecular models.
  - Tetrahedral (four atoms around a central atom)
  - Trigonal pyramidal (three atoms, one unbonded pair of electrons around a central atom)
  - Trigonal planar (three atoms and no unbonded electrons around a central atom)
  - Bent (two atoms and two pairs of unbonded electrons around a central atom)
  - Linear (two atoms and no unbonded electrons around a central atom)
- This investigation includes only compounds whose Lewis structures can be drawn to satisfy the octet rule. A possible extension could be to add more complicated molecules that extend past the octet rule. Note that though they all can be drawn to satisfy the octet rule, experimental data shows that in reality some of them violate the octet rule in order to minimize formal charges.
Those structures and further information on formal charges are also included at the end of the answer key. If you wish to go deeper into formal charges, or if your students come across these alternative structures on their own, these substances can be used as a starting point for that discussion.

**FOR THE STUDENT**

**Lesson**

**Shapes of Molecules**

**Background**

The valence shell electron pair repulsion (VSEPR) theory is how the geometry of a molecule is determined. It’s called “vesper” theory for short. The shapes that are possible are tetrahedral, trigonal planar, trigonal pyramidal, bent, and linear. To determine the shape of a molecule, you must look at the central atom. Though only atoms and not unbonded electrons are considered when naming the shape of a molecule, the unbonded electrons are still very important because they do affect the location of the outer atoms around the central atom, and therefore the shape of the molecule. Unbonded electrons around atoms that are not the central atom have little effect on the geometry.

In this activity, you will draw Lewis structures for a number of substances and use them to determine how the molecular models need to be assembled. From the models, you will determine the geometry of the substances. After completing a few examples, you should start to see how the two dimensional drawings really exist in three dimensions.

**Procedure**

Complete each column in order. Compare your model to the samples at the front of the room if you are confused about which geometry your model makes.

<table>
<thead>
<tr>
<th>Substance (write the chemical formula)</th>
<th>Total valence e^-</th>
<th>Lewis structure (check the box if a resonance structure is possible)</th>
<th>Lewis structure with proper geometry (use the models to help here)</th>
<th>VSEPR geometry (the name of the shape)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
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<tr>
<td>Nitrogen</td>
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<tr>
<td>Carbonate</td>
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<tr>
<td>Sulfite</td>
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<tr>
<td>Carbon tetrachloride</td>
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<tr>
<td>Ammonium</td>
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<tr>
<td>Bromine</td>
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<tr>
<td>Substance</td>
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<tr>
<td>Carbon monoxide</td>
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<tr>
<td>Dinitrogen monoxide</td>
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<td>Ozone</td>
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<td>Nitrate</td>
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<tr>
<td>Nitrite</td>
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<td>Bromate</td>
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<td>Chlorite</td>
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<tr>
<td>Phosphate</td>
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<tr>
<td>Acetic Acid (try your best! Both carbons are in the middle.)</td>
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</tbody>
</table>

**Analysis**
Without using the models, determine the geometry of these substances (you can draw Lewis structures to help you):

- \( \text{NF}_3 \)
- \( \text{H}_2\text{S} \)
- \( \text{OCl}_2 \)
- \( \text{HCN} \)
- \( \text{F}_2 \)
- \( \text{SO}_2 \)
- \( \text{SO}_4^{2-} \)
- \( \text{ClO}_3^- \)

- \( \text{SO}_3 \) (not sulfite!)

**Conclusion**
All of the substances in this exercise have what kind of bonds? Explain why this is important.