

NAME \_\_\_\_\_

SECTION \_\_\_\_\_

PARTNER(S) \_\_\_\_\_

DATE \_\_\_\_\_

**IT'S ALL IN THE SHAPE:  
Covalent Bonding and Molecular Geometry**

This activity explores covalent bonding and how interactions among electron pairs affect the geometry of a molecule.

**PRE-LAB QUERIES**

**Some Preliminary Information Gathering**

Before we can uncover the molecular geometry of a molecule we need to gather information about the composition and covalent bonding in the molecule. Useful information will be the Lewis dot structure (or diagram) and a structural formula. The Lewis dot structure shows the arrangement of electrons around a central atom and the atoms attached to it. The structural formula supplies the same information but uses lines to represent pairs of bonded electrons. Here are two examples of molecules with Lewis dot structures and the structural formulas.

Molecule	Chemical Formula	Lewis Dot Structure	Structural Formula
hydrogen sulfide	H <sub>2</sub> S	$\text{H} : \overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{S}}} : \text{H}$	$\text{H} \text{---} \text{S} \text{---} \text{H}$
ethene	C <sub>2</sub> H <sub>4</sub>	$\begin{array}{c} \text{H} \quad \text{H} \\ \cdot\cdot \quad \cdot\cdot \\ \text{H} : \text{C} : : \text{C} : \text{H} \\ \cdot\cdot \quad \cdot\cdot \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H} \text{---} \text{C} = \text{C} \text{---} \text{H} \end{array}$

**Answer Questions 1-3 before coming to class for this activity.**

1. Draw the Lewis dot structures and the structural formulas for the following molecules. Keep in mind the "octet" rule and its exceptions.



2. When an electron cloud of one atom is in the vicinity of the nucleus of another atom, is the tendency to move closer together or farther apart? Why? Is this movement stabilizing or destabilizing for the atoms?

3. If two clouds of electrons were in the same vicinity, would the tendency be for them to move closer together or farther apart? Why?

### PROCEDURE

Think about your responses to the question above as you complete this activity in class.

1. Suppose there was a large empty ball or sphere and two people who did not like each other were trapped inside the sphere. Where would they go to be as far apart as possible?

If you drew a line between the two people, what angle would be made between them?  
(Remember that a circle has  $360^\circ$ .)

2. Now suppose that three disgruntled people were in the sphere. Where would they go to be as far apart as possible? To help you visualize this situation, take one styrofoam ball to represent the center of the sphere and smaller balls to represent the people. Stick a toothpick in each smaller ball and arrange them around the larger ball (center of the sphere). What is the angle between each of the people (small balls)?
3. Now imagine four incompatible people in the sphere. Imagine that they can go anywhere inside the sphere. What angle would be formed between them? (Use the balls if needed).

What angle(s) will form between five people? six people?

**Stop here and show the models to your instructor before proceeding.**

Now for the rest of this activity, imagine that the people are atomic nuclei with their electron clouds. They are confined in the sphere because they are held together by covalent bonds, shared electrons.

They must remain close but have the freedom to arrange themselves in three dimensional space.

4. The following table contains a number of compounds. You drew the Lewis dot structures and structural formulas for these compounds in the preliminary section of this activity. For each of these compounds:
- Use the styrofoam balls and toothpicks to construct realistic models of the molecules (remember that electron pairs repel);
  - Imagine that you draped material over the model that stretched from point to point tightly to form sides. Determine the resulting molecular geometry for the model (linear, trigonal planar, tetrahedral, trigonal bipyramidal, octahedral). There are solid models of some of these shapes on the instructor's desk.

Molecule	Structural Formula	Molecular Geometry
HF		
BeCl <sub>2</sub>		
BCl <sub>3</sub>		
CH <sub>4</sub>		
PCl <sub>5</sub>		
SF <sub>6</sub>		

5. Locate the Lewis dot structures and make models of  $\text{PF}_3$  and  $\text{BCl}_3$  (which each have three atoms surrounding the central atom). Do you think the geometries (shapes) are the same? Explain. What is different about the two molecules? What effect might this difference have on the shape?

Locate the dot structures and make models of  $\text{CS}_2$  and  $\text{H}_2\text{O}$  (which each have two atoms around the central one). Do you think the geometries the same? Why or why not?

Electron pairs, whether they are shared between two nuclei in a bond or are **lone pairs**, will repel and arrange themselves as far away from each other as possible in three dimensional space. A central atom with two shared and two lone pairs will have the same electron pair geometry as a central atom with four shared pairs. However, the geometry of the molecule as we "sense" it is determined by the nuclei. We do not "see" lone pairs. Therefore the geometry of molecules with lone pairs will be different than those with just shared electron pair.

A multiple bond between two atoms means that there is more electron density between those nuclei. For geometric considerations, the double or triple bond is treated like a single bond. A central atom with two single and one double bond will arrange the electron pairs as if it has three electron pairs associated with it.

6. Complete Table 2 as you did for Table 1 keeping in mind lone pairs and multiple bonds. Determine the geometry of all electron pairs, called the electron pair geometry. We cannot see lone pairs when we image a molecule (we see nuclei by x-ray diffraction techniques) so the molecular geometry is determined by taking the electron geometry and removing the lone pairs

on the central atom without rearranging the remaining bonds in space (since the electron pairs are really still there). If you cannot put a name to any new molecular geometries, ask your instructor. NOTE: If a person asks for a geometry and does not specify molecular or electron pair, they mean molecular.

**Table 2**

<b>Molecule</b>	<b>Structural Formula</b>	<b>Electron Geometry</b>	<b>Molecular Geometry</b>
CO <sub>2</sub>			
SO <sub>2</sub>			
H <sub>2</sub> O			
NH <sub>3</sub>			
TeCl <sub>4</sub>			
ClF <sub>3</sub>			
I <sub>3</sub> <sup>1-</sup>			

7. Go back in this activity and find the geometries you predicted for  $\text{CH}_4$  and  $\text{H}_2\text{O}$ . Draw the structure and predict the molecular geometry for  $\text{NH}_3$ .

What do the geometries of these molecules have in common? How would the bond angles compare?

The bond angles in  $\text{CH}_4$  are  $109.5^\circ$ , the bond angle for a tetrahedral arrangement of electron pairs. The bond angles in ammonia are  $107^\circ$  and the bond angles in water are about  $105^\circ$ . Can you think of a reason why?

The lone pairs are spread out further in space than pairs that are bound up in covalent bonds. Their negative charge repels the bonded pairs of electrons and effectively forces atoms attached to the central atom closer together, distorting the bond angles of the molecule.

**To manipulate models of molecules with the various geometries uncovered in this activity using Chime go to:**

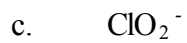
[http://academic.pgcc.edu/~bgage/vsepr/Molecular\\_Geometry.html](http://academic.pgcc.edu/~bgage/vsepr/Molecular_Geometry.html)

[http://academic.pgcc.edu/~ssinex/geometry/geometry\\_LP.htm](http://academic.pgcc.edu/~ssinex/geometry/geometry_LP.htm)

<http://academic.pgcc.edu/~ssinex/polarity/polarity.htm>

## POST-LAB QUESTIONS

1. Determine the molecular geometries of the following molecules and ions:



2. Draw the dot structure for the ionic compound  $\text{MgF}_2$ . Can you make a model of this substance? Explain your answer.