Name:__________
Hour______

Lewis Dot Structure

Information: Valence Electrons

The electrons in the highest s or s and p sublevels that are farthest from the nucleus are called valence electrons. Valence electrons are *always* in the highest energy level. The valence electrons are the most important electrons in an atom because they are the electrons that are involved in chemical reactions and bonding.

The electron configuration for thallium is:

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 \mathbf{6s^2} 4f^{14} 5d^{10} \mathbf{6p^1}$

The outermost energy level is the 6th energy level. How many total s and p electrons does thallium have in the sixth level? There are 3. They are in boldfaced type above. Therefore, thallium has 3 valence electrons.

Critical Thinking Questions:

1. Write the electron configurations for
   a) oxygen:

   b) sulfur:

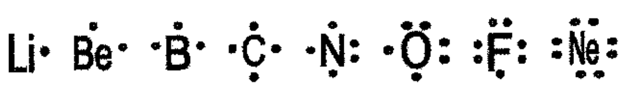
2. How many valence electrons does oxygen have?

3. How many valence electrons does sulfur have?

4. Verify that selenium (atomic number = 34) has six valence electrons by writing an electron configuration and giving a brief explanation.

Information: Electron Dot Diagrams
Below are electron dot diagrams, also known as "Lewis Structures" for atoms #3-10.

FIGURE 1:



Lewis Dot Diagrams are made up of the element symbol and electrons that are represented by dots. The position of the dots is important. We must put one dot on each side of the symbol and then double up. Look at Nitrogen. It has 5 dots. We had to double up on one side. Let's look at another atom that has three dots in its Lewis structure such as aluminum. Aluminum's three dots must be positioned the same way as boron's. Thus, aluminum's Lewis structure is:

Adapted from chemquest

Critical Thinking Questions

5. How does the number of dots relate to the electron configuration? See question 1&2 and figure 1.

6. What relationship exists between an atom's valence electrons and the number of dots in the Lewis structure of the atom?

7. Why does nitrogen's Lewis Structure have five dots around it while nitrogen's electron configuration indicates that it contains 7 electrons?

8. Comparing Figure 1 and Figure 2 we see that boron and aluminum have the same number of dots in their Lewis structures. Notice they are in the same column of the periodic table. Write the Lewis structure for gallium (Ga).

9. Write the Lewis structure for sulfur and selenium. Compare the structures you write with oxygen's Lewis structure from Figure 1.

   a) Sulfur b) Selenium

10. How do the Lewis structures in question 9 compare to the Lewis structure of oxygen in Figure1?

11. Complete this statement: If elements are in the same column of the periodic table, they must have Lewis Structures that are ______________.
    similar or different

12. Draw the Lewis structure for the following elements.
    a) germanium b) bromine c) xenon d) potassium e) arsenic

Adapted from chemquest

Information: Chemical Bonding

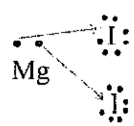
To understand why atoms bond together, we need to understand what "motivates" an atom. (Of course, atoms don't actually have thoughts and feelings, but it is helpful to imagine that they do.) The dream of every atom is to feel complete, and atoms accomplish this by having eight electrons in the valence shell. This "full octet" is very stable, and atoms undergo chemical reactions to obtain it. Noble gases already have a full octet, and therefore rarely react with other atoms.

One way an atom can obtain a full octet is by becoming an ion—by gaining or losing electrons. Atoms in group 17 have 7 valence electrons, so they form a full octet by gaining one more (they become ions with a charge of -1). Atoms in group 16 start with 6 and want two more (they form ions with a charge of -2). Group 15 elements start with 5, and want to gain three (they form -3 ions).

On the other side of the periodic table, elements behave differently. Group 1 atoms only have one valence electron, and the easiest way for them to get a full valence shell is to lose that electron and become ions with a +1 charge. Generally speaking, metals lose electrons to become stable and nonmetals gain electrons to become stable. Thus, when metals encounter nonmetals, the metal will transfer its unwanted electrons to the nonmetals, which eagerly snap them up:

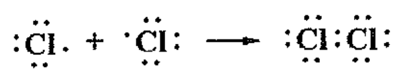
Once the two ions are formed, they stick together because opposite charges attract: this is an ionic bond. The resulting compound is NaCl.

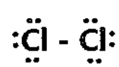
What about magnesium and chlorine? Mg has two unwanted electrons, but chlorine only needs one. So magnesium requires two atoms of chlorine, one for each electron:



And so the resulting compound is $MgCl_2$.

When two nonmetals encounter each other they can bond without forming ions. Instead of transferring electrons from one atom to another, they share valence electrons. When two chlorine atoms come in contact, they share a pair of electrons like this:





The line in this model represents a bond and ONE shared pair

Because only one pair of electrons is shared, this is called a single bond.

Critical Thinking Questions

Below are the electron dot structures for the atoms that make up a water molecule. In this case, notice the valence electrons for each are represented differently to tell them apart.

Hydrogen	Oxygen	Hydrogen
H•	•Ö:	•H

14. In order to have an electron configuration like a noble gas, **hydrogen** needs access to how many *more* valence electrons? ____________ *Note: Hydrogen is an exception to the octet rule as is Helium. So hydrogen will be happy filling only the 1s.

15. In order to have an electron configuration like a noble gas, **oxygen** needs access to how many *more* valence electrons? ____________

16. Each atom attempts to obtain a Noble Gas Electron Configuration. In a molecule of water, the oxygen atom and the hydrogen atoms share electrons to complete their "Octets." Fill in the valence electrons on the symbols shown here. Make bonds to show how oxygen and hydrogen share to get their octets.

H O H

17. The compound NH_3 is made up of one atom of nitrogen and three atoms of hydrogen. Draw the Lewis Dot structures for these four atoms.

Nitrogen	Hydrogen	Hydrogen	Hydrogen
18. To complete their octets these four atoms share valence electrons. Draw this structure in the space provided. *(Hint: the single atom is usually at the center of the molecule.)*			

19. Draw the electron dot structures for the following particles.

Sulfur	Fluorine	Fluorine
SF_2		

STOP Please have these answers checked by your instructor

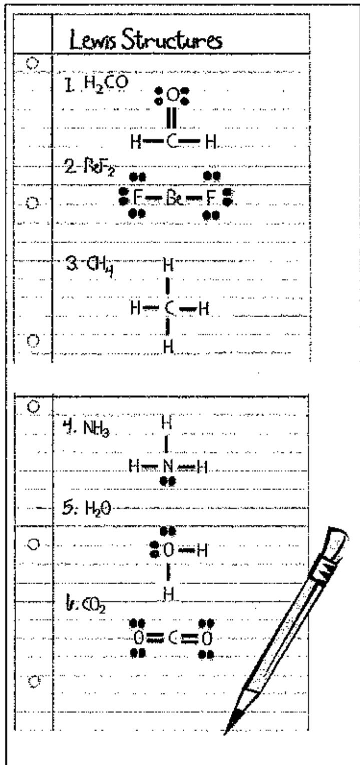
Molecular Geometry

How can molecular shapes be predicted using the VSEPR theory?

Why?

When you draw a Lewis structure for a molecule on paper, you are making a two-dimensional representation of the atoms. In reality however, molecules are not flat—they are *three*-dimensional. The true shape of a molecule is important because it determines many physical and chemical properties for the substance. In this activity you will learn how to predict molecular shapes.

Model 1 – Lewis Structures



Lone pair = ••

	3-D Molecular Shape
H_2CO 3 electron domains (3 bonding, 0 nonbonding)	
BeF_2 2 electron domains (2 bonding, 0 nonbonding)	
CH_4 4 electron domains (4 bonding, 0 nonbonding)	
NH_3 4 electron domains (3 bonding, 1 nonbonding)	
H_2O 4 electron domains (2 bonding, 2 nonbonding)	
CO_2 2 electron domains (2 bonding, 0 nonbonding)	

1. Name the type of structures shown in the left-hand column of Model 1.

2. Examine the drawings in Model 1.
   a. What does a solid line between two element symbols represent in the drawings of the molecules?
   b. What subatomic particles (protons, neutrons or electrons) make up these solid lines?
   c. What does a pair of dots represent in the drawing of the molecules?
   d. What subatomic particle (protons, neutrons or electrons) makes up each dot?

3. In the English language, what does the word "domain" mean? (Your group must come to consensus on this question.)

4. Which molecules in Model 1 have four electron domains? Circle or highlight the four electron domains in the Lewis structure for each molecule that you identified.

5. Which molecules in Model 1 have two electron domains? Circle or highlight the two electron domains in the Lewis structure for each molecule that you identified.

6. Which molecule in Model 1 has three electron domains? Circle or highlight the three electron domains in the Lewis structure for the molecule that you identified.

7. When determining the number of electron domains in a Lewis structure, which of the following should you count? Find evidence from Model 1 to support your answers.
   a. Bonds on the center atom
   b. Lone pairs on the center atom
   c. Total number of atoms in the molecule
   d. Lone pairs on peripheral atoms

8. When determining the number of electron domains in a Lewis structure, do you count double bonds as one domain or two domains? Find evidence to support your answer from Model 1.

9. Explain the difference between a **bonding electron domain** and a **nonbonding electron domain** using the examples in Model 1.

10. Circle the correct word or phrase to complete the sentences:

    Pairs of electrons will (attract/repel) each other.

    Two bonds on the same atom will try to get as (close to/far from) each other as possible.

    A lone pair of electrons and a bonded pair of electrons will (push away from/move toward) each other.

STOP

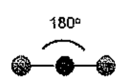
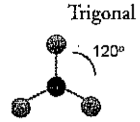
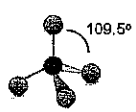
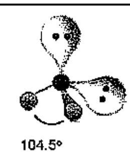
Read This!

The **VSEPR (Valence Shell Electron Pair Repulsion) Theory** helps predict the shapes of molecules and is based on the premise that electrons around a central atom repel each other. **Electron domains** are areas of high electron density such as bonds (single, double or triple) and lone-pairs of electrons. In simple terms VSEPR means that all electron bonding domains and electron nonbonding domains around a central atom need to be positioned as far apart as possible in *three-dimensional* space.

11. VSEPR theory specifies "valence shell" electrons. Explain why these are the most critical electrons for determining molecular shape based on your exploration of Model 1.

12. In the VSEPR theory, what is repelling what?

13. Based on the information in the *Read This!* section, sketch one of the molecular shapes shown below in each of the boxes provided in Model 1.

Three-Dimensional Molecular Shapes	Linear 	Trigonal planar 
Tetrahedral 	Pyramidal 	Bent 

STOP

14. Often we draw Lewis structures with 90° bond angles. Do any of the molecular shapes in Model 1 have 90° bond angles?

15. Are the bond angles in the three-dimensional molecules generally larger or smaller than those shown in the Lewis structures drawn on notebook paper?

16. Why is it possible to get larger angles separating electron domains in three-dimensions versus two-dimensions?

17. Identify the three molecules shown in Model 1 that have four electron domains each.

    a. What happens to the size of the bond angle(s) in a molecule as the number of lone pairs on the central atom increases?

    b. Discuss in your group some possible explanations for the trend in part *a*. Your presenter should be ready to present to the class one or two of your hypotheses for full class discussion.

STOP

18. A student does not "waste" his time drawing a Lewis structure before determining the shape of PF_3. The student thinks that the shape of PF_3 must be trigonal planar because there are three fluorine atoms bonded to the central phosphorus atom.

    a. Draw the Lewis structure for PF_3.

    b. Was the student's answer for the shape of a PF_3 molecule correct? Explain.

    c. Why is it important to draw the Lewis structure for a molecule before identifying the shape of the molecule?

19. Complete the following chart:

Molecule	Lewis Structure	3-D Drawing	Name of 3-D Shape	Bond Angle
H_2S				
PH_3				
CCl_4				
CS_2				

STOP

Extension Question

20. Ozone, O_3, is not a linear molecule. Actually it is bent with an angle that is a little less than 120°.
    a. Draw the Lewis structure of ozone, O_3.

    b. Describe why ozone has a bent shape instead of a linear shape.

    c. Describe why ozone's bond angle is larger than that of water, H_2O.