

Introduction

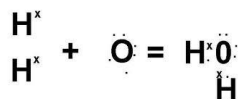
Molecules have shape! The structure and shape of a molecule influences its physical properties and affects its chemical behavior as well. Lewis structures and VSEPR theory offer useful models for visualizing the structures of covalent compounds.

Concepts

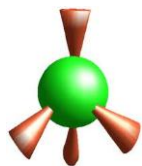
- Valence electrons
- Lewis Dot structures
- Covalent bonding
- VSEPR theory

Background

Covalent bonds are defined as the net attractive forces between nonmetal atoms that share one, two, or three pairs of electrons. In general, only the *valence electrons*, those in the highest energy levels that are the farthest away from the nucleus, are available for bonding. The number of valence electrons influences the number of bonds that an atom will form. The periodic table offers a convenient shortcut for determining the number of valence electrons in an atom. Remember that the position of an element in the modern periodic table reflects its electrons configuration. When the elements are arranged in columns from IA to VIIIA, the number of valence electrons for an element is equal to its group number. Thus, potassium in Group IA has one valence electron, carbon in Group IVA has four valence electrons, and chlorine in Group VIIA has seven valence electrons. In 1916, G.N. Lewis, an American chemist, proposed arranging dots around the symbols of the elements to represent the valence electrons. *Lewis dot symbols* remain the most popular way to picture the valence electrons that are available for bonding.



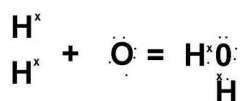
Lewis dot structures for molecules build on the Lewis dot symbols of the elements to show the bonding arrangement of atoms in a molecule and the distribution of all valence electrons. The Lewis structure of a molecule thus shows all of the atoms and how they are connected. A single covalent bond between two atoms is represented using two dots. Sometimes atoms share more than one pair of electrons between them. Four dots are used to represent a double



Dot & VSEPR Lab

CLASS SET!

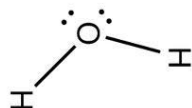
bond, while six dots are used to represent a triple bond. According to Lewis, nonmetals may share electrons in order to achieve a valence shell electron “count” similar to that of the noble gases, with eight valence electrons. The Octet Rule assumes that atoms form molecules to achieve this stable, noble gas electron configuration. In counting valence electrons to build the structure of a covalent molecule, we will distinguish between two kinds of electron pairs. *Bonding pairs* are electrons that are shared between the two atoms. *Nonbonding pairs* are electrons that are not shared between atoms.



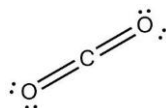
Molecular Geometry (Shape)

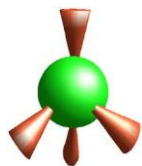
According to the **Valence Shell Electron Pair Repulsion (VSEPR)** theory, the valence electron pairs that surround an atom repel each other due to their like negative charges. In order to minimize this repulsion, the electron pairs should be positioned around the atom so that they are as far apart as possible. The resulting arrangement of electron pairs around atoms can be used to predict the shape of molecules.

The shape of a molecule is affected by the arrangement of *all* the electron pairs- both bonding and nonbonding- around the central atom. This is best illustrated using an example. In the Lewis dot structure of the water molecule, there are four pairs of valence electrons around the central oxygen atom. Two pairs of electrons are involved in bonding to hydrogen atoms, while the other two electrons pairs are unshared pairs. The four pairs of electrons around an atom will adopt a tetrahedral arrangement to be as far apart in space as possible. As a result, the two hydrogen atoms and the oxygen atom occupy a “bent” shape.



When two atoms are linked via a double or triple bond, the multiple electron pairs between the atoms must be considered together when determining the shape of the molecule. Carbon dioxide provides a good example. The central atom is linked to two oxygen atoms by two double bonds. The resulting arrangement of atoms is linear in shape.





Dot & VSEPR Lab

CLASS SET!

Experiment Overview

The purpose of this activity is to practice drawing Lewis dot structures of molecules and to use these structures to predict their molecular geometry. Molecular models will be studied to visualize the shapes of molecules and to sketch their three-dimensional structures.

Pre-Lab Questions

1. Write the Lewis dot structures for each of the following atoms: hydrogen, nitrogen, silicon, sulfur, and bromine.
2. What information about a molecule does its Lewis dot structure provide?
3. What is the Octet Rule? Which element is the exception?

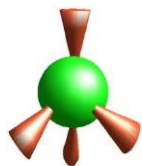
Procedure

Part A

1. Write the formula for each molecule or polyatomic ion listed in Data Table A. Some of the formulas have been filled in for you. (**Use your Elementary Knowledge sheet and your knowledge of naming covalent compounds to help you!**)
2. Count the number of number of valence electrons supplied by each atom in the formula. Determine the *total number* of valence electrons for the molecule and record this number in Data Table A. In the case of polyatomic ions, *add* one electron for each unit of *negative* charge or *subtract* one electron for each unit of *positive* charge to determine the total number of valence electrons.
3. Draw the Lewis dot structure for each molecule or ion. Remember to use the Octet Rule, HONC 1234 rule, and the total number of valence electrons to check if the structure is correct!
4. Describe the molecular shape as one of the following: linear, trigonal planar, bent, tetrahedral, or pyramidal.

Part B

1. Examine the molecular models A-K. For each model, identify the number of bonding pairs, the number of unshared (lone) pairs, and the total number of electron domains around the *central atom*. Record this information in Data Table B.
2. Sketch the ball-and-stick model in Data Table B and describe the molecular shape as one of the following: linear, trigonal planar, bent, tetrahedral, or pyramidal.
3. Determine the bond angle for the atoms in the molecule and record in Data Table B.



Dot & VSEPR Lab

CLASS SET!

Data Table A

Name	Molecular Formula	Total # of Valence electrons	Lewis Dot Structure	Molecular Shape
Phosphorous trichloride				
Methane				
Ethylene	C ₂ H ₄			
Ammonia				
Ammonium Ion				
Dihydrogen sulfide				
Carbon tetrafluoride				
Carbonate Ion				
Carbon disulfide				
Formaldehyde	H ₂ CO			

Data Table B

Model	# of Bonded Pairs	# of Unshared (Lone) Pairs	Total # of electron domains	Ball-and-stick drawing AND Shape	Bond Angle
A					
B					
C					
D					
E					
F					