Experiment 12

Lewis Dot Structures and Molecular Geometry

Pre-Lab Assignment

Before coming to lab:

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

To determine the Lewis dot structures and VSEPR geometries of a variety of covalently bonded molecules and ions.

Background

While some atomic elements can be found in nature, most combine with other atoms to form larger groups called molecules. Lewis Theory states that atoms will form bonds with their valence electrons in order to fill their outer orbitals to mimic the electron configuration of the noble gases. Since the outer s and p orbitals can hold a total of eight electrons, almost all atoms on the periodic table will follow the Octet Rule, or "rule of eight". A common exceptions to the Octet Rule include H and He that can hold only two electrons in their outer shell (1^{st} shell).

In this activity, we will examine elements that are covalently bonded which involves the sharing of their electrons. To imagine how this occurs, we will draw Lewis structures a which are representations of molecules that show the connections that are holding atoms together. Lewis structures represent the valence electrons present in the molecule as lone pairs (unshared electrons, drawn as dots) or bonds (shared electrons, drawn as lines).

Procedure for Drawing Lewis Structures

1. Add up the total number of valence electrons that each atom contributes to the molecule/polyatomic ion.
    - The quickest way is to find the group number for each atom.
    - For ions with a negative charge (anions) , you must add electrons to the total number of valence electrons. For ions with a. positive charge (cations), you must subtract electrons from the total number of valence electrons.

2. Draw a sketch of the molecule.
    - Most molecules/ consist of one central atom bonded to 2, 3 or 4 other atoms.
    - The least electronegative atom is the central atom. Hydrogen is the only exception to this, as it is never the central atom and forms only 1 bond.
    - Arranged the other atoms around the central atom, and attach them to the central atom with single bonds.

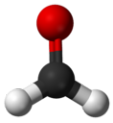
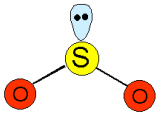
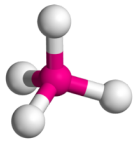
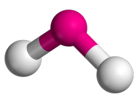
3. Place the remaining electrons around each atom until they have a total of 8 electrons (except hydrogen – it only requires 2 electrons).
    - If there are not enough electrons available to obey the octet rule using single bonds, this indicates that double or triple bonds between two atoms are required in your structure. If short by two electrons, try a double bond, and if short by four electrons, try a triple bond or two double bonds.

Procedure for Determining Geometry

Once the Lewis structure of a molecule or ion is determined, the 3-D shape of the molecule can be determined. The **Valence Shell Electron Pair Repulsion theory or VSEPR theory** is one useful theory for predicting the geometries of molecules. The fundamental premise of the theory is that electron pairs whether contained within bonds or in lone pairs repel each other because of their like charges. This causes the electrons to arrange themselves as far apart around the central atom as possible.

We describe the shape using the electron domain geometry which is based on the total number of areas around the central atom containing electrons and the molecular geometry which is based on how many lone pairs of electrons and atoms are around the central atom. Common shapes of molecules and ions are summarized in the table on the following page.

Common Geometries of Molecules and Ions

Total Number of Areas with electrons around the central atom	**Electron Pair Geometry**	**Areas around the central atom with shared Electrons**	**Areas around the central atom with lone pairs**	**Molecular Geometry**	**Example**
2	Linear	2	0	Linear	 CO_2
3	Trigonal Planar	3	0	Trigonal Planar	 H_2CO
3	Trigonal Planar	2	1	Angular (Bent)	 SO_2
4	Tetrahedral	4	0	Tetrahedral	 CH_4
4	Tetrahedral	3	1	Trigonal Pyramidal	 NH_3
4	Tetrahedral	2	2	Angular (Bent)	 H_2O

In addition to determining the Lewis structure and shape of molecules or ions, we will also build the molecules or ions using model kits.

Procedure for Using Model Kits

1. Each colored ball in your kit corresponds to different atom or different group of atoms
   - White (1 hole) = Hydrogen
   - Black 4 hole) = Carbon, Silicon
   - Blue (4 hole) = Nitrogen, Phosphorous
   - Red (2 hole) = Oxygen
   - Green (1 hole) = Chlorine, Fluorine or Iodine
   - Orange (1 hole) = Bromine
   - Yellow (4 hole) = Sulfur

2. Use the **short sticks** to represent single bonds.

3. Use **two long flexible sticks** for a double bond and **three long flexible sticks** for a triple bond.

Procedure for Determining Polarity of Molecules

After drawing the Lewis structure and determining the geometry of molecules on the last two pages of the report, we will determine if the molecules are polar are nonpolar. Molecular polarity results when the entire molecule *(not just a bond in the molecule)* ends up with an unequal distribution of electrons.

To be a polar molecule, the molecule must:

1. Contain at least one polar bond (electronegativity difference of 0.5 -1.9)
2. Also contain <u>either</u>

   - At least one lone polar on the central atom
     OR
   - Different kinds of atoms attached to the central atom.

   This is called being asymmetrical.

Electronegativity values of the elements (Pauling scale)

H 2.1																	He
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr 3.0
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe 2.6
Cs 0.7	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Ti 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2	Rn 2.4
Fr 0.7	Ra 0.7	Ac 1.1															

Ce 1.1	Pr 1.1	Nd 1.1	Pm 1.1	Sm 1.1	Eu 1.1	Gd 1.1	Tb 1.1	Dy 1.1	Ho 1.1	Er 1.1	Tm 1.1	Yb 1.1	Lu 1.2
Th 1.3	Pa 1.5	U 1.7	Np 1.3	Pu 1.3	Am 1.3	Cm 1.3	Bk 1.3	Cf 1.3	Es 1.3	Fm 1.3	Md 1.3	No 1.3	Lr

Name _____

Molecular Models Report Sheet

1. CCl_4

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

2. PH_3

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

3. $COCl_2$

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

4. Br_2

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

5. OF_2

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

6. N_2

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

7. NCl_3

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

8. SO_2

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

9. CO_3^{2-}

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

10. NO_2^{1-}

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

11. NF_2^{1-}

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	

12. ClO_3^{1-}

Total Number of Valence Electrons :	EDG: MG	Model Checked: DO NOT BUILD
Lewis Structure:	3-D Model Sketch:	

13. SiI_4

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

14. CS_2

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

15. CH_3F

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

16. H_2S

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

17. HCN

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

18. SO_3

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

19. NI_3

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

20. H_2O

Total Number of Valence Electrons :	EDG: MG	Model Checked:
Lewis Structure:	3-D Model Sketch:	Any Polar Bonds in Molecule? **Yes** or **No** Overall Molecular Polarity **Polar** or **Nonpolar**

Name _____

Pre-Lab Assignment for Lewis Dot Structures and Molecular Geometry

1. Write the number of valence electrons *for each atom,* total number of valence electrons as well as the Lewis electron dot structure and the name of the molecular geometry (shape) of the following molecules.

	Valence electrons	Lewis Structure	Name of electron geometry	Name of molecular geometry
a. PCl_3				
b. CS_2				
c. NCl_4^{1+}				

2. One of the goals of this lab is to become familiar with different shapes of simple molecules.

a. What is the name of the theory used to predict molecular geometries?

b. Suppose a molecule consists of a central atom bonded to 2 outer atoms. There are two lone pairs on the central atom. What is the name of the molecular shape of this molecule?

c. Suppose a molecule consists of a central atom bonded to 4 outer atoms. There are no lone pairs on the central atom. What is the name of the molecular shape of this molecule?