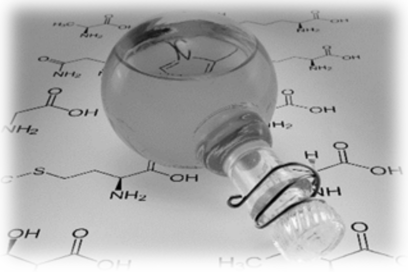
9—Molecular Models & Covalent Bonding



Name: ______________________________

Date: ______________________________

Section: ______________________________

Objectives

- Learn to draw Lewis structures for covalent molecules containing only single bonds
- Learn to draw Lewis structures for covalent molecules containing double and triple bonds
- Learn to draw resonance structures for Lewis structures containing multiple bonds
- Learn to use VSEPR theory to determine molecular shape of covalent molecules
- Predict polarity of covalent molecules from their molecular shape
- Learn to identify the hybridization of central atoms in covalent molecules

Pre-Laboratory Requirements

- Read chapter 10 in Silberberg
- Pre-lab questions (if required by your instructor)
- Laboratory notebook—prepared before lab (if required by your instructor)

Safety Notes

- No hazardous chemicals are used in this experiment. Eye protection is not required

Discussion

Gilbert N. Lewis was a physical chemist at the University of California Berkeley for most of his professional career. He developed the first successful theory of bonding in covalent molecules and we still use many of his ideas today to understand the structure of chemical substances. Lewis postulated that a covalent bond involves the sharing of an electron pair between two atoms, and that eight electrons (i.e., 4 electron pairs) in the valence shell for most atoms has special significance. This last observation is known as the "octet" rule.

By applying these two postulates too many of the elements in the periodic table Lewis was able to explain the formulas for many covalent compounds and to predict their properties and chemical reactivity. As you will learn in today's lab experiment, the first step in understanding the properties of any the molecule is to construct its "Lewis" structure. Before you start today's lab it is essential that you read chapter 10 in Silberberg. Pay particular attention to pages 303-312.

Lewis structures give us a way to identify the bonds that form in covalent molecules and to account for how electrons are shared between atoms. However, Lewis structures do not tell us anything about molecular shape and molecular structure. Valence Shell Electron Pair Repulsion (VSEPR) theory was developed to deal with this problem. Section 10.2 in your textbook explains the background for VSEPR theory and gives many examples to show how one can predict molecular structure using VSEPR. You should understand the material in section 10.2 before attempting this laboratory experiment.

Although Lewis structures and VSEPR theory are powerful tools enabling us to predict many properties of covalent molecules, they suffer from a weakness of treating electrons as particles, requiring a new theory using the wave model for electrons to explain covalent bonding. Linus Pauling developed the concept of hybridization in an attempt to explain how orbitals, an outcome from quantum mechanics, could be used to explain covalent bonding and molecular structure. Modern covalent bonding theories use hybrid orbitals to describe molecular structure and molecular orbitals to describe bonding between atoms. In terms of molecular shape, reactivity, and polarity, modern bonding theories yield results that are in good agreement with the predictions from Lewis structures and VSEPR theory. The advantage of the modern approach is that the underlying concepts are consistent with our understanding of the properties of electrons.

Procedure

1. Begin this experiment by drawing the Lewis structure for each molecule shown in the third column of the answer sheet. You may want to use a piece of scratch paper or your notebook for your trial sketches before you enter the correct Lewis structure into the space on the answer sheet.
2. After you have drawn a successful Lewis structure for each molecule, sketch a 3-D representation of the molecule using the convention where a covalent bond in the plane of the paper is represented by a thin line, a covalent bond projecting from the plane of the paper is represented with a wedged line, and a covalent bond that projects behind the plane of the paper is represented by a dashed.
3. Enter the hybridization of the central atom in the fifth column for each structure (SP, SP^2, or SP^3).
4. The sixth column of your answer sheet should contain the geometric arrangement for all electron pairs around the central atom of your molecule (linear, trigonal planar, or tetrahedral).
5. Molecular shape should be entered into the space in the seventh column (linear, trigonal planar, angular or bent, tetrahedral, or trigonal pyramid).
6. Use the information provided for each molecule to predict whether or not each molecule will have a dipole moment and indicate in the last column if it will be polar or nonpolar.

References

Kenney, T.; Molecular models in general chemistry. *J. Chem. Ed.,* **1992***, 69*, 67. doi:10.1021/ed069p67

Malerich, C. J.; Lewis structures for compounds with expanded octets. *J. Chem. Ed.,***1987***, 64*, 403. doi:10.1021/ed064p403

Pardo, J. Q.; Teaching a model for writing Lewis structures. *J.Chem. Ed.* **1989***, 66*(6), 456. doi:10.1021/ed066p456

No.	Formula	Lewis Structure	Sketch	Central Atom Hybridization	Electron Group Arrangement	Shape	Polarity
1	CH_4						
2	NH_3						
3	NO_3^-						
4	H_2S						
5	C_2H_2						
6	CO_2						

No.	Formula	Lewis Structure	Sketch	Central Atom Hybridization	Electron Group Arrangement	Shape	Polarity
7	$C_2H_3Br_3$						
8	HCO_2^-						
9	SO_3^{2-}						
10	C_4H_{10}						

Electron Group Arrangements, Molecular Shapes, and Central Atom Hybridization for Covalent Compounds With One Central Atom

Number of Electron Group Repulsions Determined from Lewis Strectures	Hybridization of Central Atom	Repulsion Angles	Shape Class	Bonding Electron Repulsions	Lone Electron Pairs	Electron Group Arrangement of all Repulsions	Molecular Shape
2	sp	180°	AX_2	2	0	Linear	Linear
3	sp^2	120°	AX_3	3	0	Trigonal Planar	Trigonal Planar
3	sp^2	120°	AX_2E	2	1	Trigonal Planar	Bent or V-shaped
4	sp^3	109.5°	AX_4	4	0	Tetrahedral	Tetrahedral
4	sp^3	109.5°	AX_3E	3	1	Tetrahedral	Trigonal Pyramid
4	sp^3	109.5°	AX_2E_2	2	2	Tetrahedral	Bent or V-shaped
5	sp^3d	90°,120°	AX_5	5	0	Trigonal Bipyramid	Trigonal Bipyramid
5	sp^3d	90°,120°	AX_4E	4	1	Trigonal Bipyramid	See-Saw
5	sp^3d	90°,120°	AX_3E_2	3	2	Trigonal Bipyramid	T-shaped
5	sp^3d	90°,120°	AX_2E_3	2	3	Trigonal Bipyramid	Linear
6	sp^3d^2	90°	AX_6	6	0	Octahedral	Octahedral
6	sp^3d^2	90°	AX_5E	5	1	Octahedral	Square Pyramid
6	sp^3d^2	90°	AX_4E_2	4	2	Octahedral	Square Planar