Chem 1045 **General Chemistry by Ebbing and Gammon, 8th Edition**
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Chapter 10 Molecular Geometry and Chemical Bonding Theory

These Notes are to SUPPLIMENT the Text, They do NOT Replace reading the Text Material. Additional material that is in the Text will be on your tests! To get the most information, READ THE CHAPTER prior to the Lecture, bring in these lecture notes and make comments on these notes. These notes alone are NOT enough to pass any test!

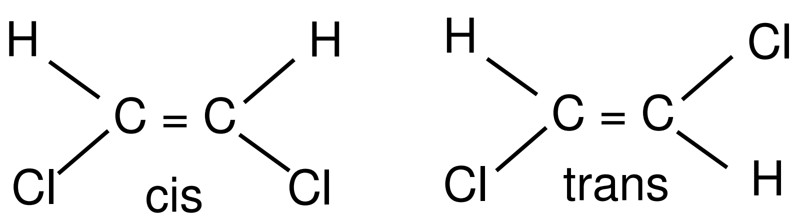
The author is providing these notes as an addition to the students reading the text book and listening to the lecture. Although the author tries to keep errors to a minimum, the student is responsible for correcting any errors in these notes.

Total Electron Pair	Shape	Example	
2	Linear	BeF_2	
3	Trigonal Planar	BF_3	
	Tragonal Planar Bent	SO_2	[Sulfur has one lone pair of electrons]
4	Tetrahedral	CH_4	
	Trigonal Pyramidal	NH_3	[Nitrogen has one lone pair of electrons]
	Tetrahedral Bent	H2O	[Oxygen has 2 lone pair of electrons]

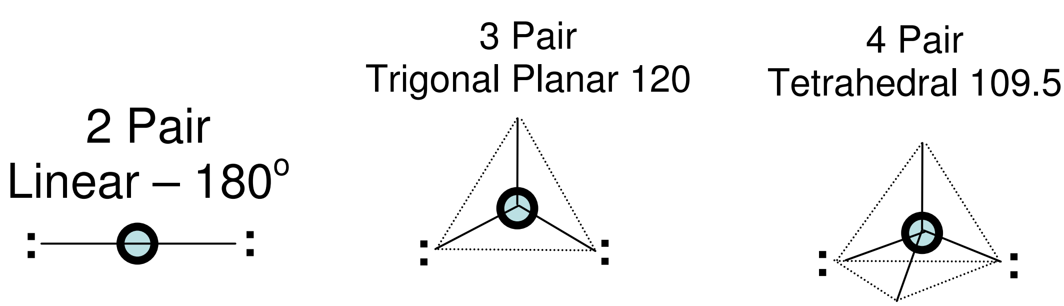
Boron Trifluoride, BF_3 is flat planar with 120^o angle between the bonds

Phosphorous Trifluoride, PF_3 Tetrahedral, 3 Fluorine bonds and one electron lone pair, the P-F bonds are 96^o.

Structures tell more than molecular formulae. Look at the difference between cis and trans di-chloroethane
Cis has a bp of 60 ^oC and trans 48 ^oC.



Valence Shell Electron Pair Repulsion (VSEPR) Model predicts the shapes of molecules and ions by assuming that the valence shell electron pairs are arranged about each atom so that electron pairs are kept as far away from one another as possible, thus minimizing electron-pari repulsions.



See also the Trigonal Bipyramidal [5 bonds] and Octahedral [6 bonds].

To determine the geometry, locate the direction in space of the bonding pair of electrons.

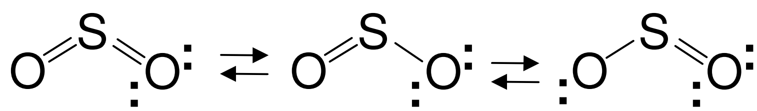
Two Electron Pair: BeF_2 : F : Be : F : This is a linear arrangement

CO_2 : O :: C :: O : -or- O = C = O

Three Electron Pair BF_3 Trigonal Planar – 120° between bonds

: F :
: F : B : F :

Error on above pic, F should have 8 electrons around it!



Sulfur Dioxide SO_2

With 3 atoms, you can only arrange it as Trigonal Planer

Four Electron Pair

CH_4 Tetrahederal

NH_3 Trigonal Pyramidal, sort of Tetrahedral, the nitrogen lone pair pushes the H down

H_2O Bent

Steps to predict the Geometry by the VSEPR Model

1. Write the electron dot formula
2. Determine the number of electron pair, include bonding and non-bonding pair
3. Determine the arrangement of electrons per Fig 10.2 p 374 or the table above
4. Obtain the molecular geometry from the directions of the bonding pair.

Example 10.1 Predict the geometry of the following: $BeCl_2$ NO_2^- $SiCl_4$

See page 379 for the answer

Cl : Be : Cl Linear

[O - N = O]$^-$ Has resonance of double bond. Trigonal Planar Bent

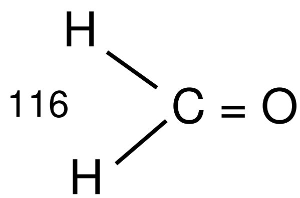
$SiCl_4$ is like Carbon Tetrahedral

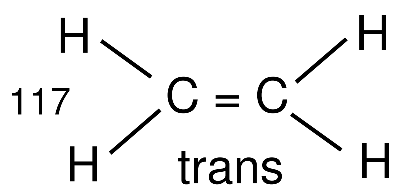
Bond Angles and Lone Electron Pair

A lone pair tends to require more space than a corresponding bonding pair: See pg 380

CH_4	109.5°	CH_3Cl	110° between H
NH_3	107° between H	H_2O	105° between H

Bond Angles with C-C double bonds





Central Atom with 5 or 6 Valence Shell Electrons **Examples BSOC**

5	Trigonal Bipyramidal
6	Octahedral

Left and Right handed Molecules. Carbon molecules that have 4 different groups on a central Carbon atom are optically active and have L & R shapes. This is very important in biochemistry. Build two molecular models of carbon with 4 different groups on it. It's just like your left and right hand are mirror images of each other.

Dipole Moment is a quantitative measure of the degree of charge separation in a molecule. Upper right side of the Periodic Table is most electronegative. Example is water – it's a polar molecule

H-Cl	Electronegative Chlorine pulls the electron from hydrogen HCl has a large dipole moment.	
NF_3	with a lone pair has a small dipole moment.	
CO2	O = C = O Linear	Net Zero Dipole Moment
H_2O	109° angle for Hydrogen	Large Dipole Moment

Formula	**Molec Geom**	**Dipole Moment**
AX	Linear	Can be non-zero [H-Cl]
AX_2	Linear	Zero
	Bent	Can be non-zero
AX_3	Trigonal Planer	Zero
	Trigonal Pyramidal	Can be non-zero
	Trigonal T-Shaped	Can be non-zero
AX4 – 6	BSOC	

Cis and Trans DiChloroEthane above. The Cis, with both Chlorine on the same side has a dipole moment. The Trans does not.
Hybrid Orbitals:
Chloride

Chlorine

1s	2s	2p -1	2p 0	2p +1	3s	3p -1	3p 0	3p +1
↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↑

Oxygen

Oxygen

1s	2s	2p -1	2p 0	2p +1	3s	3p -1	3p 0	3p +1
↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↑	↑

Carbon and its **Hybrid Orbital**

Carbon

1s	2s	2p -1	2p 0	2p +1	3s	3p -1	3p 0	3p +1	
↓↑	↓↑	↓↑	↓↑	↓↑	↓↑	↑	↑		
↓↑	↓↑	↓↑	↓↑	↓↑	↑	↑	↑	↑	Hybrid Orbital

A Hybrid Orbital describes bonding that is obtained by taking combinations of atomic orbitals of the isolated atoms.

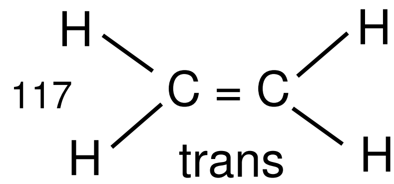
The shapes of the Carbon Orbital actually changes from the expected 3s beach ball shapped and the 3 dumball shapped Px, Py, and Pz.

The shape of the hybrid orbitals also changes. It is not the normal round S and 3 figure 8 ps. It forms a tetrahedral – see page 390.

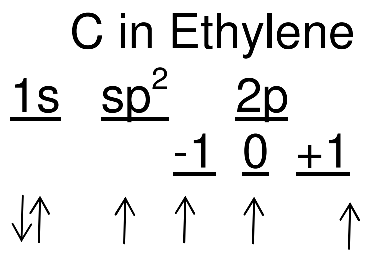
Sp^3 forms 4 bonds	Tetrahedral, 109.5 degrees	CH_4
Sp^2 forms 3 bonds	Trigonal Planer, 120 degrees	BF_3 or ethylene
Sp forms 2 bonds	Linear, 180 degrees	Be in BeF_2 or acetylene

H_2O Oxygen has 2 lone pair of electrons and 2 bonds. 4 Bonds = Tetrahederal or Sp^3 hybrid instead of a 2s and 2p.

Multiple Bonds Ethylene



Ethylene has 3 bonding pair. It Is hybridized to Sp2 with a 2p electron available for the double bond.

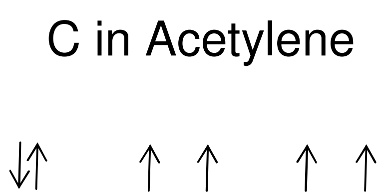


Sigma Bond: The Carbon to Hydrogen bond in ethylene is the cylindrical shaped electron cloud.

Pi Bond: is an electron distribution above and below the C-C bond axis.

The triple bond is Acetylene is

$$H - C \equiv C - H$$



Practice Questions:

Review Questions: All Example Problems in the chapter

Concept Questions:

Practice Problems: