Chem 103, Section F0F
Unit VI - Compounds Part II: Covalent Compounds
Lecture 17

- Using the Valence-Shell Electron-Pair Repulsion (VSEPR) Theory to predict molecular shapes
- Molecular shape and polarity

Lecture 17 - Covalent Bonding

Reading in Silberberg

- Chapter 10, Section 2
  - *Valance-Shell Electron-Pair Repulsion (VSEPR) Theory and Molecular Shape*
- Chapter 10, Section 3
  - *Molecular Shape and Molecular Polarity*

Lecture 17 - Introduction

In this lecture we will look into predicting molecular shapes and polarity

- Using a simply theory called the **V**alence-**S**hell **E**lectron-**P**air **R**epulsion (VSEPR) Theory it is possible to predict the shape of a molecule starting with its Lewis structure.
- The molecular structure can then be coupled with electronegativity to predict molecular polarity.
- Molecular shape and polarity have a marked influence on a molecule's physical properties.
  - This is particularly the case for biological molecules.

Lecture 17 - VSEPR and Molecular Shape

The main principle of VSEPR is

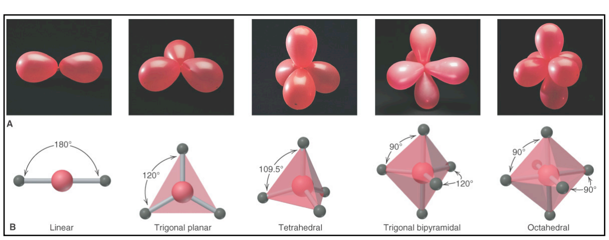
- *Each group of valence electrons (VSEP) around a central atoms is located as far away as possible from the other groups (R).*

A "group" is any number of electrons that are located near to one another:

- A non bonded pair of electrons (2 e^-'s)
- A single bond (2 e^-'s)
- A double bond (4 e^-'s)
- A triple bond (6 e^-'s)
- A lone free radical electron (1 e^-)

Lecture 17 - VSEPR and Molecular Shape

Placing the groups as far apart as possible favors a limited set of electron-group geometries.

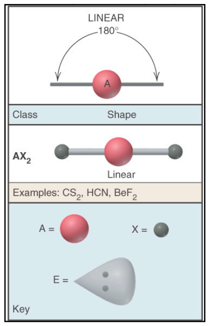


Lecture 17 - VSEPR and Molecular Shape

Once the electron group geometry is established, the **molecular shape** is determined by the resulting arrangement of the surrounding atoms about the central atom.

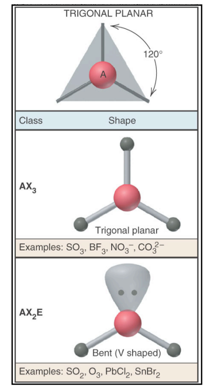
Lecture 17 - VSEPR and Molecular Shape

Two electron-groups
(Linear electron-group geometry):



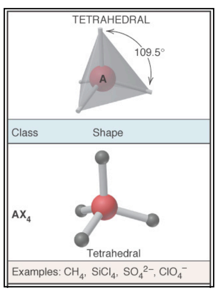
Lecture 17 - VSEPR and Molecular Shape

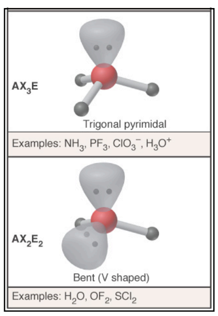
Three electron-groups
(Trigonal electron-group geometry):



Lecture 17 - VSEPR and Molecular Shape

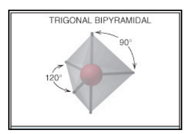
Four electron-groups
(Tetrahedral electron-group geometry):

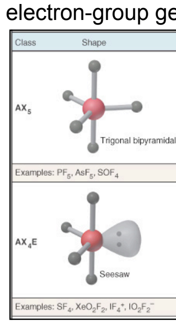


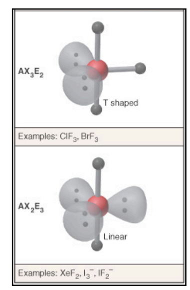


Lecture 17 - VSEPR and Molecular Shape

Five electron-groups
(Trigonal bipyramidal electron-group geometry):

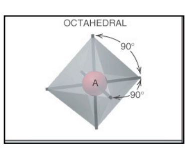


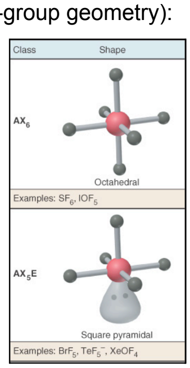


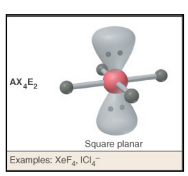


Lecture 17 - VSEPR and Molecular Shape

Six electron-groups
(Octahedral electron-group geometry):



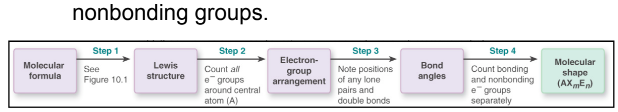




Lecture 17 - VSEPR and Molecular Shape

The 4-step approach to determining molecular shape with VSEPR:

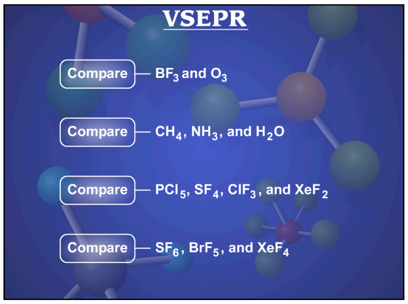
1. *Step 1*: Write the Lewis structure
2. *Step 2*: Assign an electron-group arrangement by counting up the electron-groups
3. *Step 3*: Predict the ideal bond angle from the electron-group arrangment
4. *Step 4*: Draw and name the molecular shape by counting the bonding groups separately from the nonbonding groups.



Lecture 17 - VSEPR and Molecular Shape

Tutorials and animations

- University of Sheffield



Lecture 17 - Clicker Question 1

What is the electron group arrangement for SO_2?

A) Linear
B) Trigonal planar
C) Tetrahedral
D) Trigonal bipyramidal
E) Octahedral

Lecture 17 - Clicker Question 2

What is the molecular shape for SO_2?

A) Linear
B) Trigonal planar
C) Tetrahedral
D) Bent
E) Seesaw

Lecture 17 - Clicker Question 3

What is the ideal O-S-O bond angle?

A) 180°
B) 120°
C) 109.5°
D) 90°
E) 45°

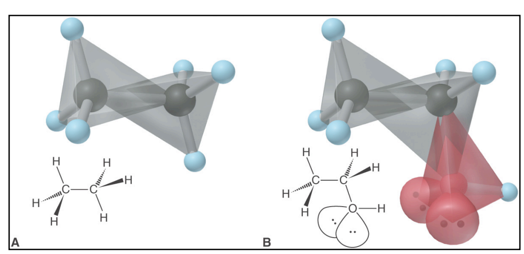
Lecture 17 - Question 4

Determine the electron-group arrangement, molecular shape, and ideal bond angle for N_2O (N is central)?

Using formal charges, which resonance structure for N_2O is the most probable?

Lecture 17 - VSEPR and Molecular Shape

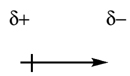
When molecules have more than one central atom, each is treated separately.



Lecture 17 - Molecular Polarity

Molecules containing polar bonds can exhibit molecular polarity.

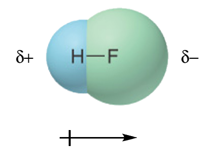
- The polarity is measured in units of debye's (D), which is equal to the magnitude of the partial charges times the distance separating them (1 D = 3.34×10^{-20} C•m).



Lecture 17 - Molecular Polarity

Molecules containing polar bonds can exhibit molecular polarity.

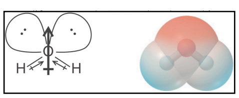
- For diatomic molecules, the molecular dipole is equal to the bond dipole.



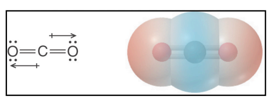
Lecture 17 - Molecular Polarity

Molecules containing polar bonds can exhibit molecular polarity.

- For molecules with more than two atoms, bot the bond dipoles and the molecular shape must be considered in determining the molecular dipole.



- Water has a net dipole moment

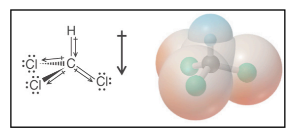


- Carbon dioxide has no net dipole moment

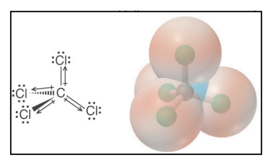
Lecture 17 - Molecular Polarity

Dipole moment

- Chloroform ($CHCl_3$) has a dipole net dipole moment



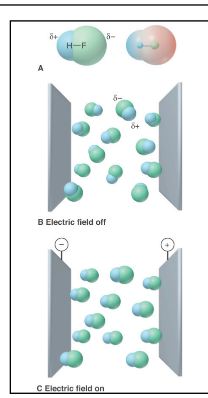
- Carbon tetrachloride does not have a net dipole moment.



Lecture 17 - Molecular Polarity

Molecular polarity can have a marked effect on a molecule's physical properties.

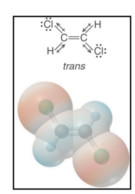
- Polar molecules will align in an electrical field.



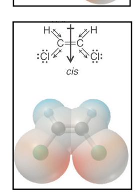
Lecture 17 - Molecular Polarity

Dipole moment and physical properties

- *trans*-Dichloroethene ($C_2H_2Cl_2$) has no net dipole moment and a boiling point of 47.5°C.



- *cis*-Dichloroethene ($C_2H_2Cl_2$) has a net dipole moment and a boiling point of 60.3°C (13°C higher).



Lecture 17 - Clicker Question 5

Which molecule has the *greater* molecular dipole moment?

A) SO_2

B) SO_3

Unit VI - Up Next

Lecture 18 - Theories of Covalent Bonding

- Valence Bond Theory and Orbital Hybridization
- The Mode of Orbital Overlap and the Types of Covalent Bonds.

The End