Announcements

Monday, December 14, 2009

Today:

- Chapter 10 (Final exam grading may be adjusted based on material we don't cover).
- Project presentations start at 3:30 in the lab. I have timeslot signup on the board in the lab.

Wednesday:

- Chapter 10 MasteringChemistry is due before class, will be for up to 5 points extra credit.
- ACS standardized final exam from 1:30-3:30. Non-programmable calculators only! See webpage for study guide and scoring info.

Friday:

- Lab project formal report is due to dropbox by 5pm. See lab project page, formal report guidelines, and Andy's addendum, all linked from course webpage. D2L will remain open until Dec 30 to check scores.

Weekend:

- Scores and course letter grades will be posted to D2L gradebook. An email will be sent out when they are up. No grades by email.

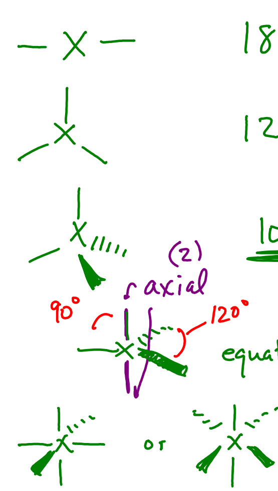
Chapter 10: Chemical bonding II: Molecular shapes and bonding

VSEPR Theory: Valence shell electron pair repulsion

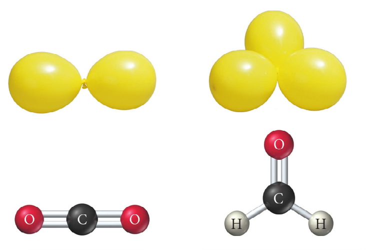
- Electron groups repel one another through coulombic forces
- They will spread as far apart as possible on a molecule's central atom
- 1 electron group: e^- clouds, e^- domains
  - 1 single bond
  - 1 double bond
  - 1 triple bond
  - 1 lone (unshared) pair of electrons

The five major electron group geometries:

# e^- groups	Geometry	Structure	Ideal bond angle
2	Linear		180°
3	Trigonal planar		120°
4	Tetrahedral		109.5°
5	Trigonal bipyramidal		90°, 120°
6	Octahedral		all 90°

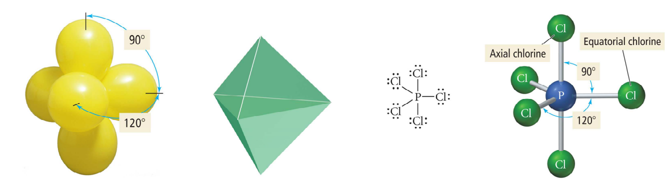


Electron group geometries

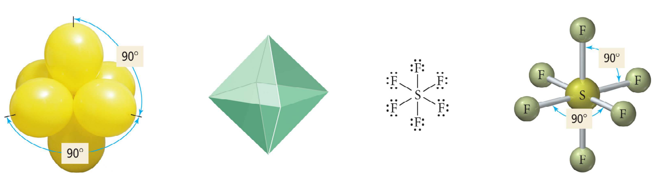


(a) Linear geometry (b) Trigonal planar geometry

Tetrahedral geometry Tetrahedron Tetrahedral geometry



Trigonal bipyramidal geometry Trigonal bipyramid Trigonal bipyramidal geometry



Octahedral geometry Octahedron Octahedral geometry

Lone pairs and molecular geometry

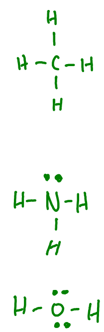
Electron group geometry is the arrangement of the electron groups

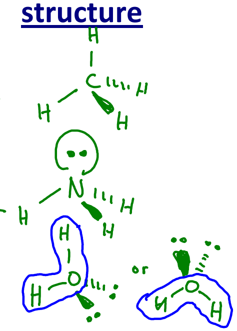
Molecular geometry is the arrangement of the atoms

These are the same if only **bonding** electron groups are attached to the central atom.

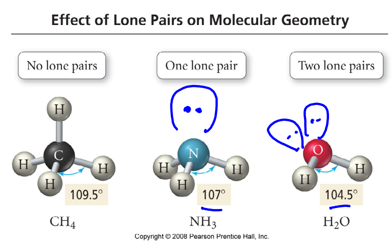
Nonbonding electrons (lone pairs) on the central atom will change the **molecular geometry**.

	# e⁻ groups	# lone pairs	e⁻ group geom.	molec. geom.	3-D structure
CH_4	4	0	tetrahedral	tetrahedral	
NH_3	4	1	tetrahedral	trigonal pyramidal	
H_2O	4	2	tetrahedral	bent	



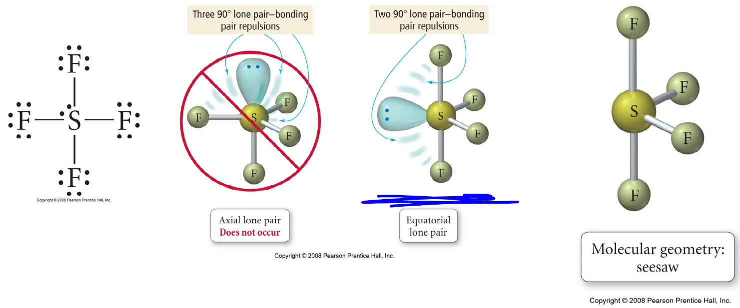


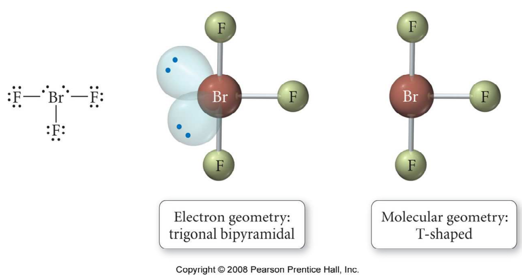
Lone pairs will actually repel the bonds a little more than a bond would, decreasing bond angles slightly.

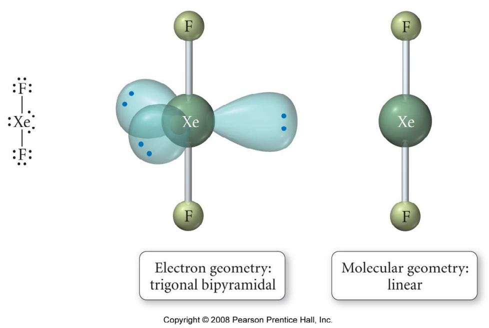


5 electron groups with lone pairs

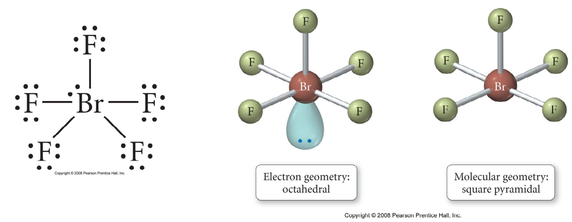
Lone pairs will **only** be placed in equatorial positions in the trigonal bipyramidal electron group geometry.



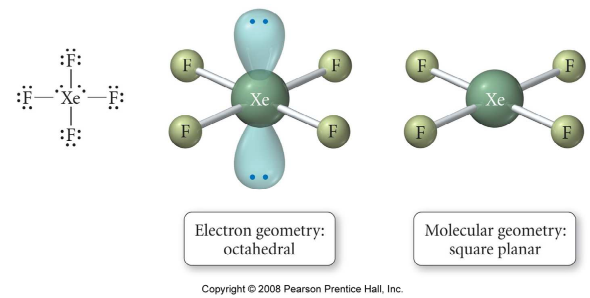




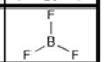
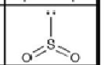
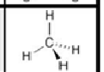
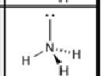
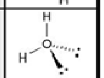
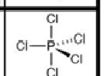
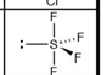
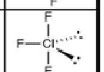
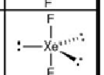
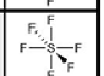
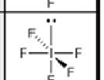
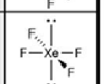
6 electron groups with lone pairs



Two lone pairs in an octahedral electron group geometry will add across from each other to minimize lone pair-lone par repulsions.

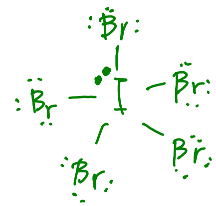


Geometries summary

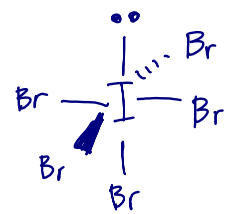
Electron groups	Bonding groups	Nonbonding groups	Molecule shape	Example	Drawing
2	2	0	Linear	BeF_2	F—Be—F
3	3	0	Trigonal planar	BF_3	
	2	1	Bent	SO_2	
4	4	0	Tetrahedral	CH_4	
	3	1	Trigonal pyramid	NH_3	
	2	2	Bent	H_2O	
5	5	0	Trigonal bipyramid	PCl_5	
	4	1	Seesaw	SF_4	
	3	2	T-shaped	ClF_3	
	2	3	Linear	XeF_2	
6	6	0	Octahedral	SF_6	
	5	1	Square pyramid	IF_5	
	4	2	Square planar	XeF4	

Geometry practice

What is the electron group and molecular geometry of IBr_5? Draw its flat Lewis structure and its 3-dimensional structure. 7 + 5(7) = 42 ve

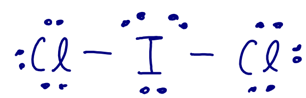


6 e⁻ groups : octahedral e⁻ geometry

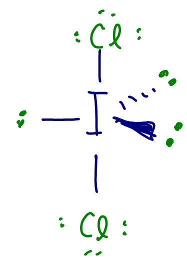


square pyramidal molecular geometry

What is the electron group and molecular geometry of ICl_2^-? Draw its flat Lewis structure and its 3-dimensional structure. 7 + 2(7) + 1 = 22



5 e⁻ groups : trig. bipyramidal

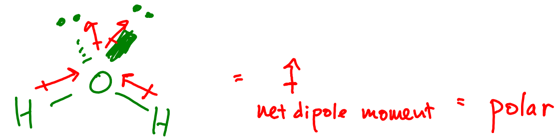


molecular geometry: linear

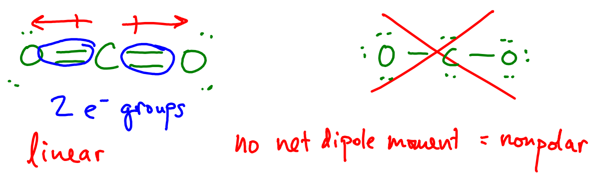
Molecular shape and polarity

The dipoles of polar bonds will add together geometrically to form a **net dipole moment** for the molecule. Molecules with a net dipole moment are **polar**.

H_2O:

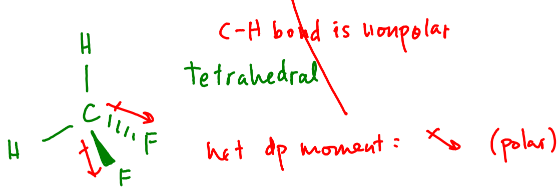


CO_2:

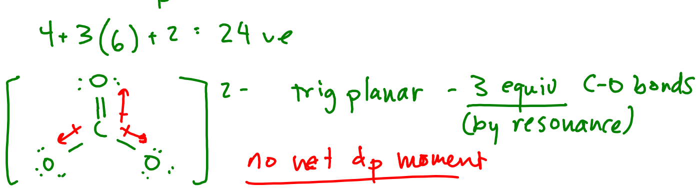


BF_3:

CH_2F_2:



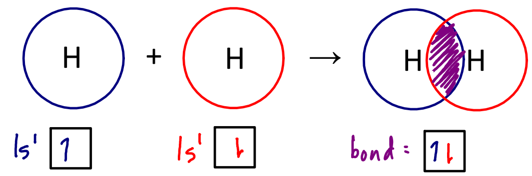
CO_3^{2-}:



Valence bond theory

In valence bond theory, bonds are formed by the orbitals of two atoms overlapping.

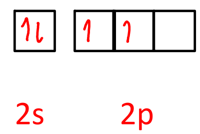
H· + ·H → H—H



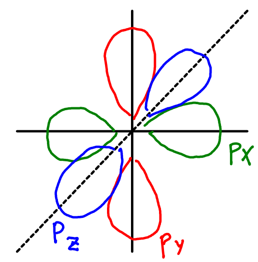
But, many times the orbitals cannot combine as-is.

4 H· + ·C· → CH_4

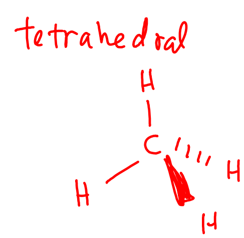
C:



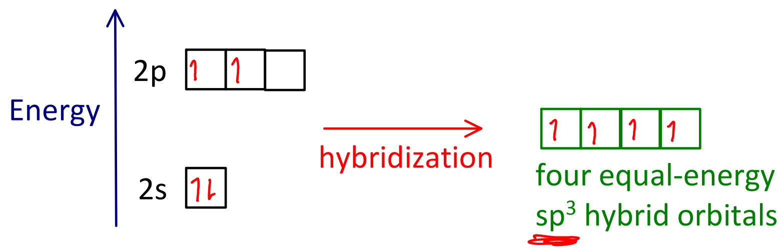
Remember, p orbitals are oriented on the *x*, *y*, and *z* axes:



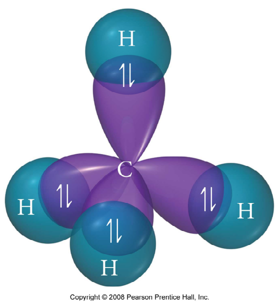
Using VSPER, what is the shape of the CH_4 molecule?



The one s and three p orbitals in carbon's valence shell combine together into 4 equivalent **hybrid orbitals** so carbon can make 4 bonds.

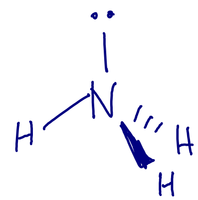


According to VSEPR, four equivalent hybrid orbitals (each containing one electron group) will best fit around a central atom with a tetrahedral geometry.

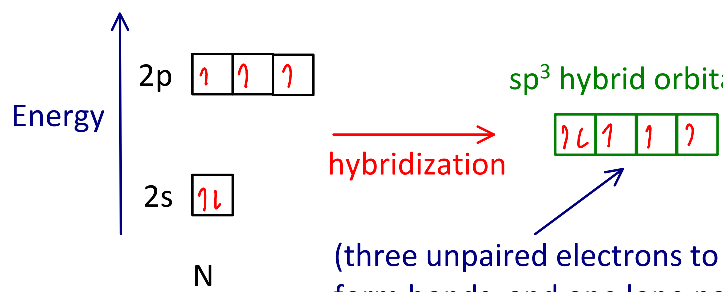


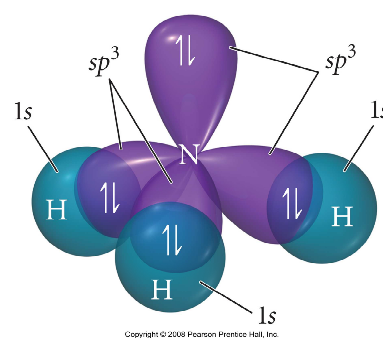
Any time there's a tetrahedral electron group geometry, the hybridization of the central atom is sp^3.

NH_3: electron group geometry: tetrahedral
molecular geometry: trigonal pyramidal
\# electron groups on central atom: 4



(The number of electron groups on the central atom is the number of hybrid orbitals that need to be formed!)

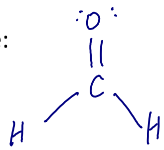


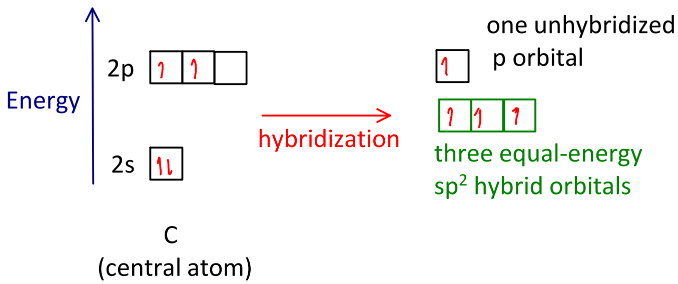


sp² hybrid orbitals

CH_2O: # electron groups on central atom:
hybrid orbitals to be formed:

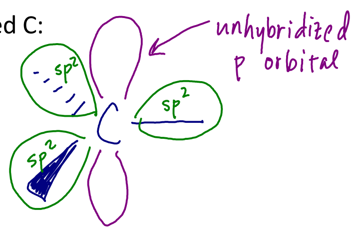
CH_2O Lewis structure:





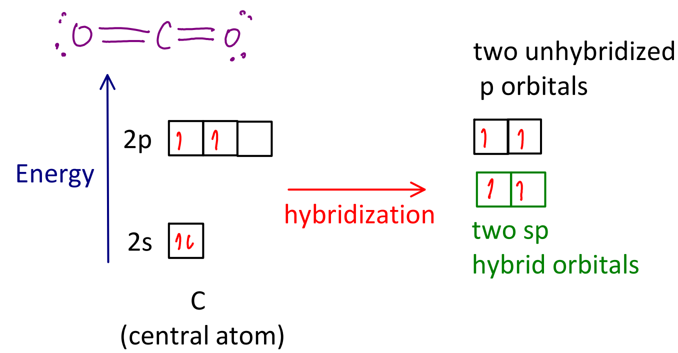
The three sp² hybrid orbitals will be trigonal planar in shape. The unhybridized p orbital is perpendicular.

sp² hybridized C:



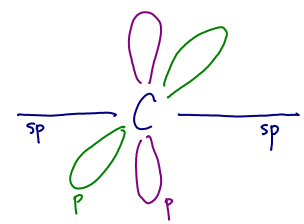
sp hybridization

CO_2: 2 electron groups around C, so 2 hybrid orbitals

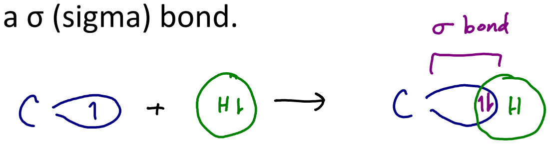


An sp hybridized central atom will be planar in shape.

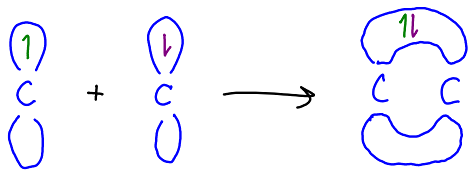
sp hybridized C:



The bonds in valence bond theory are classified by their positions relative to the two bonding atoms. If two half-filled orbitals combine straight between the two atoms, it's called a σ (sigma) bond.

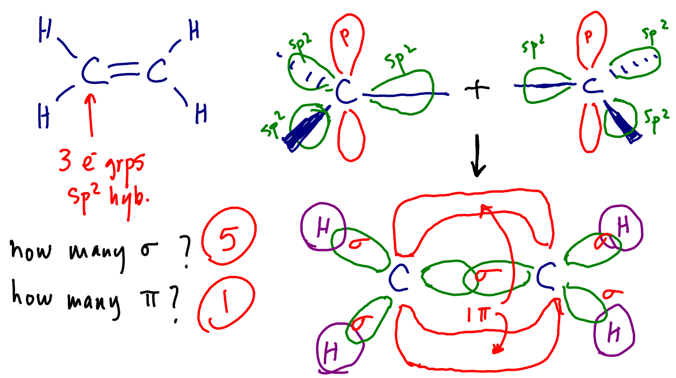


When two half-filled p orbitals combine side-by-side, it's called a π (pi) bond.

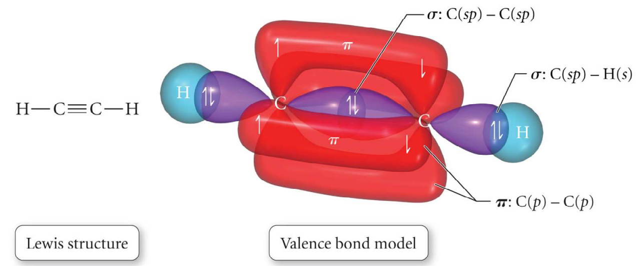


A **single bond** from Lewis theory like the C–H bonds in CH_4 is made of a single σ (sigma) bond.

A **double bond** from Lewis theory like the C=C bond in C_2H_4 is formed by one σ bond and one π bond.



If an atom is sp hybridized, it has 2 hybrid orbitals and 2 unhybridized p orbitals.



Summary of σ and π bonding:

Bond type:	Lewis:	Valence bond theory:
Single	—	1 σ, 0 π
Double	=	1 σ, 1 π
Triple	≡	1 σ, 2 π

Summary of hybrid orbitals

# of electron groups on central atom	hybridization	unhybridized p orbitals
4	sp^3	0
3	sp^2	1
2	sp	2