

Chemistry 104, Dr. Batterton
 Help Sheet #1 – Review Material; Chapters 8 and 9, and a little from Chapter 4
 Tony Jacob

CHAPTER 8: Lewis dot structures, VSEPR, bond angles

BOND ORDER (BO): Single bond = sharing 1 pair e^- ; **BO** = 1; Double bond = sharing 2 pairs e^- ; **BO** = 2

Triple bond = sharing 3 pairs e^- ; **BO** = 3; Multiple Bonds = Double or Triple bonds.

BO \uparrow \Rightarrow bond strength \uparrow bond length \downarrow

With resonance structures: **Bond Order** = $\frac{\text{\# bonds}}{\text{\# locations bonds are distributed}}$

LEWIS DOT STRUCTURES

1. Count valence electrons
2. Draw skeleton structure
3. Build octets
4. Check number of electrons drawn
5. Too many e^- \rightarrow Step 2 & add a multiple bond; Too few e^- \rightarrow add electron pairs to central atom.

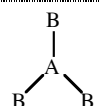

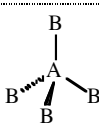


Resonance and Resonance Structures: Usually has double bonds; must have a location to move bond.

Important organic structure: benzene, C_6H_6 , alternating single/double C–C bonds with resonance; **BO** = 1.5

VSEPR (Valence Shell Electron Pair Repulsion)

1. Draw correct Lewis Structure.
2. Add: $\#$ lone pairs of electrons around central atom + $\#$ atoms bonded to central atom
3. Compare to table below.

VSEPR GEOMETRIES

Total = #atoms + #lone pairs on central atom	#atoms bonded to central atom	# lone pairs on central atom	Electron pair arrangement	Molecular geometry	Picture	Angles	Ex	Polar	HO
2	2	0	Linear	Linear	B—A—B	180°	BeCl ₂	NP*	sp
3	3	0	Trigonal planar	Trigonal planar		120°	BF ₃	NP*	sp ²
	2	1	"	Bent			AlF ₂ ⁻	P	sp ²
4	4	0	Tetrahedral	Tetrahedral		109.5°	CH ₄	NP*	sp ³
	3	1	"	Trigonal pyramid		107.5	NH ₃	P	sp ³
	2	2	"	Bent		104.5	H ₂ O	P	sp ³

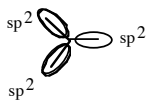
P = polar molecule; NP = nonpolar molecule

* = these nonpolar molecules assume that the B atoms are the same atoms; if not, the molecule will be polar

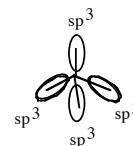
CHAPTER 9 - Hybridization



2 pairs of e⁻ → sp hybridization
(s orbital + p orbital); 2 sp orbitals, linear shape



3 pairs → sp² (s orbital + 2p orbitals); 3 sp² orbitals, trigonal planar shape



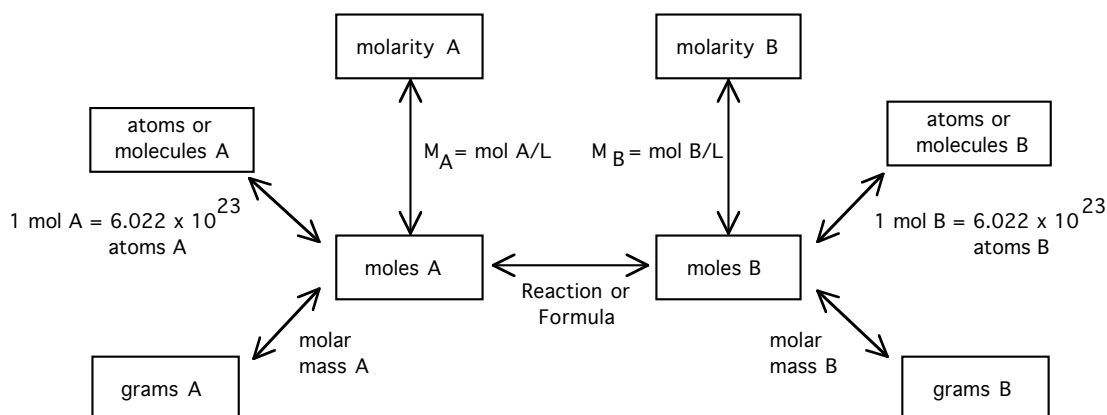
4 pairs → sp³ (s orbital + 3p orbitals); 4 sp³ orbitals, tetrahedral shape

Sigma (σ) Bonds: These bonds/electrons lie between the nuclei of the two atom. All bonds (single, double, triple) contain a σ bond. *Sigma (σ) bonds are made from hybrid orbitals overlapping (e.g., sp²-sp³) or hybrid orbital-1s overlap.*

Pi (π) Bonds: Bonds/electrons don't lie on internuclear axis; occur with double or triple bonds. *Pi (π) bonds are made from p-p atomic orbitals overlapping.*

Single bond = σ bond; Double bond = σ bond + π bond; Triple bond = σ bond + 2π bonds

MOLES



1. Draw Lewis dot (electron-dot) structures for each of the following:

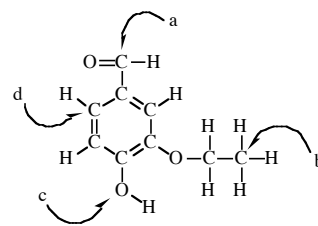
a. C₂H₆ b. C₂H₄ c. CH₃CH₂OH d. CH₃CH₂-O-CH₂CH₃

2. What is the electron arrangement and hybridization around the **bold underlined** atom of the molecules below? (Hint: First draw the Lewis dot structure for each molecule.)

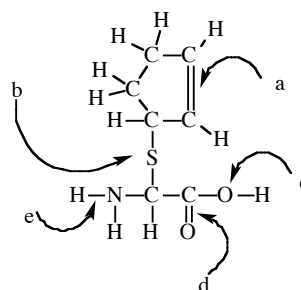
a. CH₄ b. CH₃CH₃ c. C₂H₄ d. HC≡CH e. CO₃⁻² f. SO₂

3. A structure is drawn below. Answer the questions below about the structure and bonding in this molecule. The letters refer to the questions. (Hint: First start by adding lone pairs to build octets.)

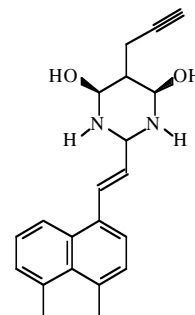
- What is the angle between the H-C-O marked with an "a"?
- What is the electron pair geometry around the carbon atom marked "b"?
- What is the molecular geometry around the oxygen atom labeled "c"?
- What is the hybridization of the carbon atom labeled "a"?
- What orbitals overlap to make the bond between the carbon atom labeled "d" and the attached hydrogen atom?
- What orbitals make up the pi (π) bond between the carbon atom labeled "a" and the oxygen atom attached to it?
- What is the electron pair geometry around the carbon atom labeled "d"?
- How many lone pairs of electrons are there in the molecule?



- Draw in the lone pairs of electrons in the structure.
 - What is the bond order for the bond marked "a"?
 - What is the hybridization on the S marked "b"?
 - What is the angle for the C-O-H on the O labeled "c"?
 - What orbitals are used to form the bond labeled "e"?
 - How many σ and π bonds are in the molecule?
 - What is the electron pair geometry around the S atom marked "b"?
 - What orbitals are used to form the π bond labeled "a"?
 - What orbitals are used to make the σ bond labeled "d"?



- A fused-ring molecule is shown at the right:
 - What is the chemical formula for this chemical?
 - How many sp hybrid **C atoms** are there? (ignore N and O atoms)
 - How many sp² hybrid **C atoms** are there? (ignore N and O atoms)
 - How many sp³ hybrid **C atoms** are there? (ignore N and O atoms)



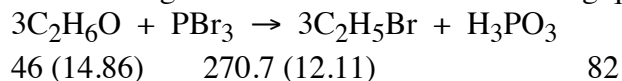
- Copper metal reacts with nitric acid. Assume that the reaction is

$$3\text{Cu(s)} + 8\text{HNO}_3\text{(aq)} \rightarrow 3\text{Cu(NO}_3)_2\text{(aq)} + 2\text{NO(g)} + 4\text{H}_2\text{O(l)}$$
 - If 10.00 g Cu(NO₃)₂ is obtained, how many grams of nitrogen monoxide, NO, would have also formed?
 - How many grams of water would also have formed?

- Nitric acid, HNO₃, is manufactured by the Oswald process, in which nitrogen dioxide, NO₂, reacts with H₂O.

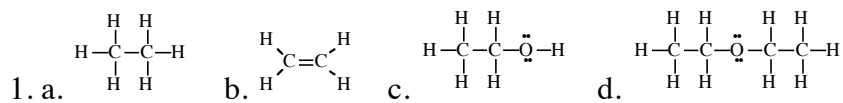
$$3\text{NO}_2\text{(g)} + \text{H}_2\text{O(l)} \rightarrow 2\text{HNO}_3\text{(aq)} + \text{NO(g)}$$
 How many grams of nitrogen dioxide are required in this reaction to produce 5.00 g HNO₃.

- Use the following reaction to answer the following questions



- 25g of C₂H₆O and 40.0 grams of PBr₃ are combined. How many grams of phosphorous acid can theoretically be produced in this reaction?
- Which is the limiting reagent?

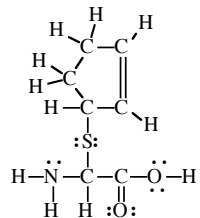
ANSWERS

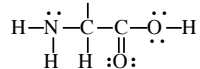


2. d. tetrahedral, sp^3 e. tetrahedral, sp^3 f. trigonal planar, sp^2 g. linear, sp a. trigonal planar, sp^2

b. trigonal planar, sp^2

3. a. 120° b. tetrahedral c. bent d. sp^2 e. sp^2-s f. p orbital + p orbital g. trigonal planar h. 6



4. a.  b. 2 c. sp^3 d. 109.5 e. $s-sp^3$ f. $22\sigma, 2\pi$ g. tetrahedral h. $p + p$; one from each C

5. a. $C_{21}H_{24}N_2O_2$ b. 2 c. 12 d. 7

6. a. 1.06 g NO b. 1.28 g H_2O

7. 5.48

8. a. 12.1g H_3PO_3 b. PBr_3