

CARBON COMPOUNDS AND CHEMICAL BONDS

General Chemistry is a required prerequisite for Organic Chemistry, and many concepts you will need for Organic you have already seen there. Much of this first module is a review of these concepts.

A STUDENT WHO HAS MASTERED THIS MATERIAL SHOULD BE ABLE TO:

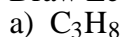
1. Draw Lewis (electron dot and line) structural formulas for simple compounds and ions from molecular formulas and other structures. Correct structures should:
 - Have the skeleton arranged correctly (this will become more and more important later in the course).
 - Have the correct number of electrons (no exceptions).
 - Obey the octet rule (exceptions: hydrogen, which can only have two electrons in its valence shell; some reactive intermediates such as carbocations, free radicals, and carbenes; some compounds containing elements with available d orbitals; some electron-deficient species such as BH_3).
 - Show the correct formal and total charges, if any.
2. Given a Lewis (dash or dot), condensed, or bond-line structural formula of a compound, draw the other representations.
3. Draw resonance structures (hint: move electrons, nonbonded electrons, and charges only), and draw the structures of isomers (hint: most real organic compounds don't contain atoms that have formal charges).
4. Given a structure, predict the shape of the molecule and the approximate bond angles in it, and give the hybridization of central atoms. The following table may be useful.

Example	Valence No.	Atoms on Central At.	Hyb.	Bond Angle	Molecular Shape
CH_4	4	4	sp^3	109.5°	tetrahedral
NH_3	4	3	sp^3	109.5°	trigonal pyramid
H_2O	4	2	sp^3	109.5°	bent
BF_3	3	3	sp^2	120°	trigonal planar
ClNO	3	2	sp^2	120°	bent
HCN	2	2	sp	180°	linear

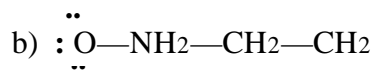
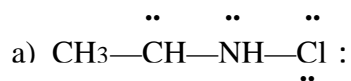
5. Define, recognize, and give examples of geometric isomers (*cis* and *trans*). Also, predict whether a compound will have *cis-trans* isomers.
6. Predict relative strengths and lengths of carbon-carbon and carbon-hydrogen bonds in hydrocarbons.
7. Draw pictures given the name, and name given the picture, of atomic orbitals, including s, p, and hybrid (sp , sp^2 , sp^3), and molecular orbitals, including sigma and pi. Also, distinguish between atomic and molecular orbitals. Also, given a structural formula, identify the molecular orbitals (sigma, pi) present, and indicate what atomic orbitals (s, p, sp , sp^2 , sp^3) are used to form them.

A STUDENT WHO HAS MASTERED THE OBJECTIVES ON THE PREVIOUS PAGE SHOULD BE ABLE TO SOLVE THE FOLLOWING PROBLEMS AND RELATED ONES:

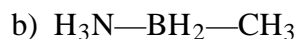
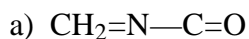
1.1 Draw Lewis structures for the following:



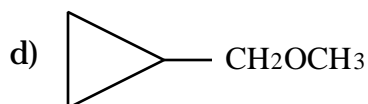
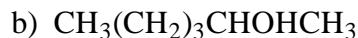
1.2 Show the formal charges on all the atoms, other than hydrogens, of the following species. (The unshared electrons are shown)



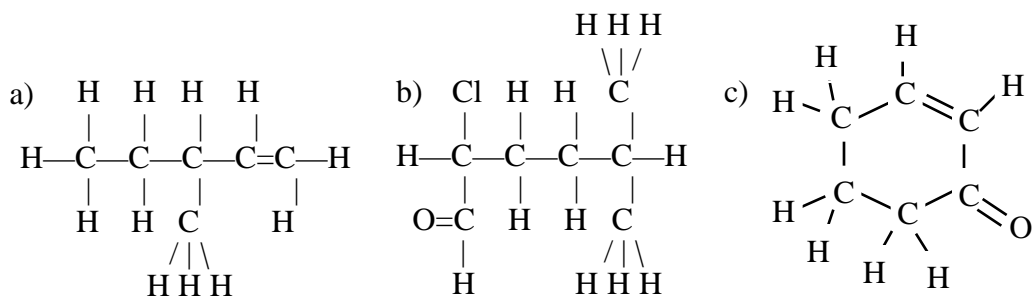
1.3 Show the formal charges on all the atoms, other than hydrogens, of the following compounds. (The unshared electrons are not shown; you must determine their locations. Hint: octet rule.)



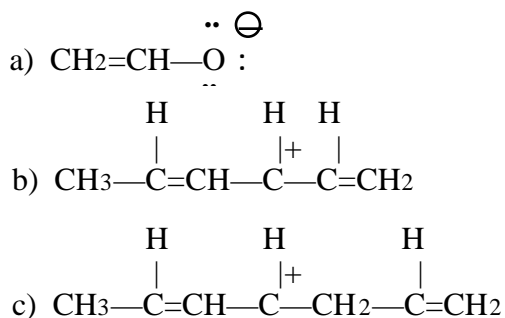
2.1 Draw complete structures (showing bonds as lines, and non-bonding valence electrons as dots) for the following compounds:



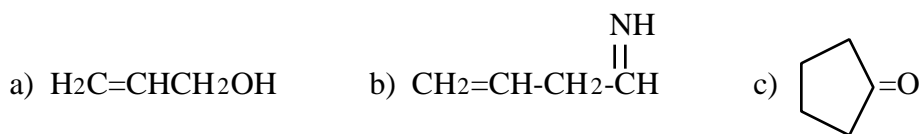
2.2 Draw both condensed and bond-line structures for a and b; draw a bond-line formula for c.



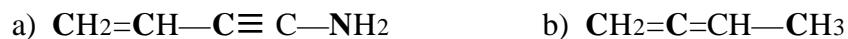
3.1 Draw a resonance structure of each of the following:



3.2. Draw the structure of an isomer of each of the following compounds. No atom should have a formal charge.



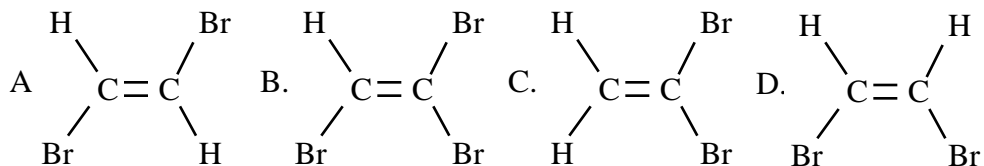
4.1. Provide hybridizations and approximate bond angles around the atoms that are in bold.



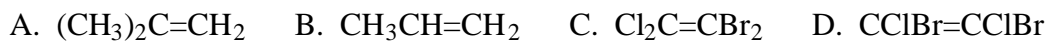
hybridization — — — — — — —

bond angle — — — — — — —

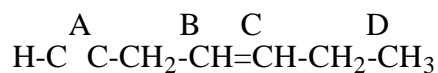
5.1 Which of the following structures is a *cis* isomer? Which is *trans*?



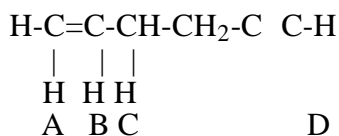
5.2 Which of these alkenes can be drawn in both both *cis* and *trans* configurations?



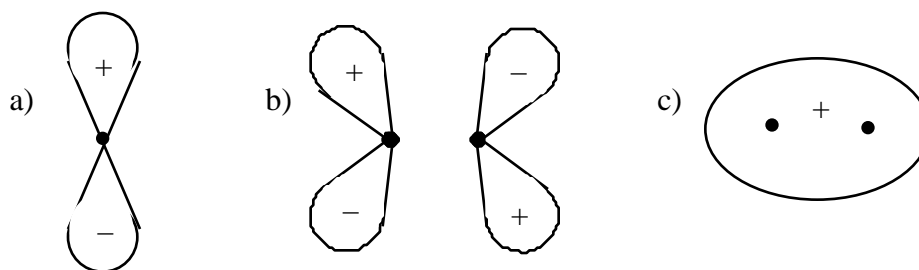
6.1 Which of the carbon-carbon bonds in the structure below is the shortest? Which is the longest? Which is the strongest?



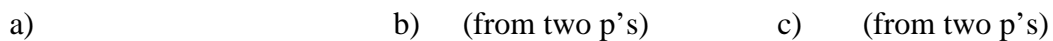
6.2 Which of the indicated carbon-hydrogen bonds in the structure below is the shortest? Which is the longest? Which is the strongest?



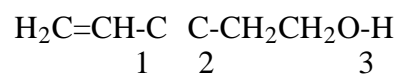
7.1 Identify each of the following orbitals.



7.2 Draw each of the following orbitals.



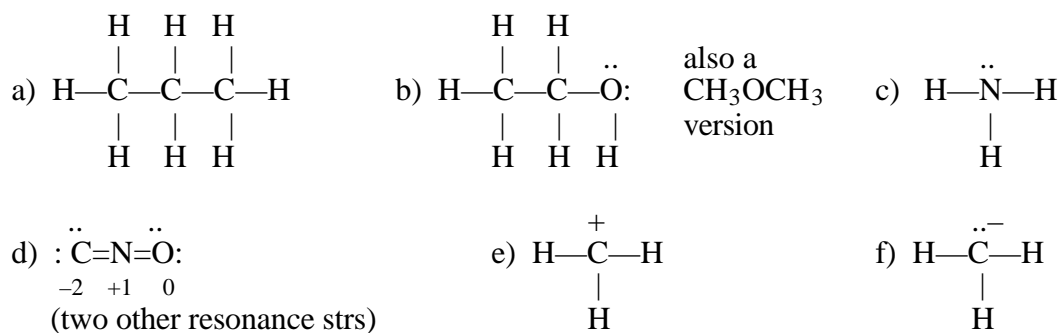
7.3 Fill in the blanks for the following compound.



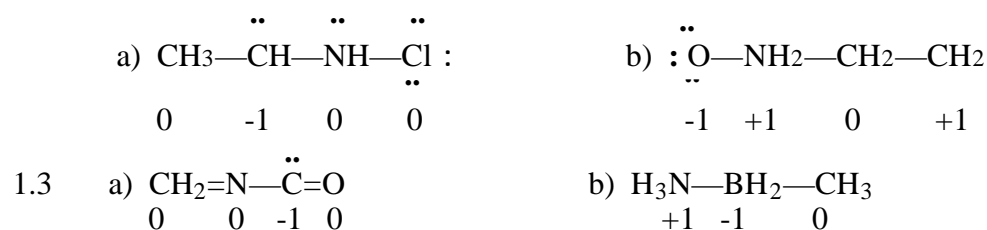
- a) The total number of sigma bonds in the compound is _____
- b) The total number of pi bonds is _____
- c) The total number of electrons in the pi orbitals is _____
- d) The total number of bonds formed by the overlap of two sp^3 orbitals is _____
- e) Bond 1 is formed from the overlap of a(an) _____ orbital with a(an) _____ orbital.
- f) Bond 2 is formed from the overlap of a(an) _____ orbital with a(an) _____ orbital.
- g) Bond 3 is formed from the overlap of a(an) _____ orbital with a(an) _____ orbital.

SOLUTIONS TO SAMPLE PROBLEMS:

1.1

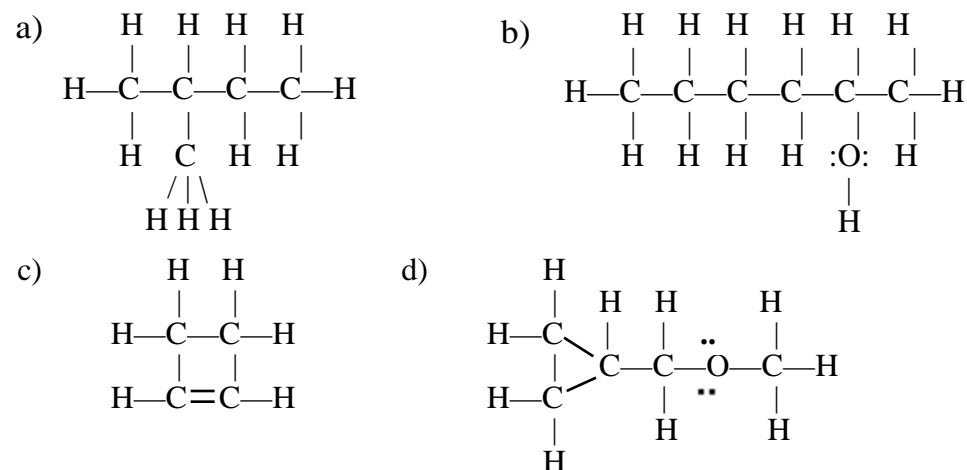


1.2 Formal charges:

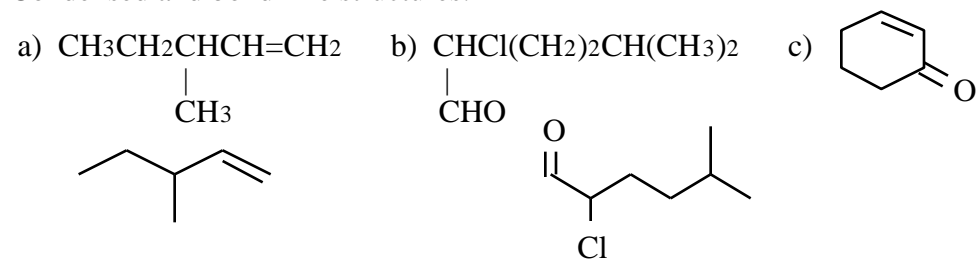


(To locate electron pairs that are not shown, assume that all atoms obey the octet rule.)

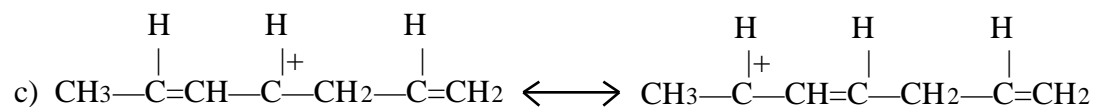
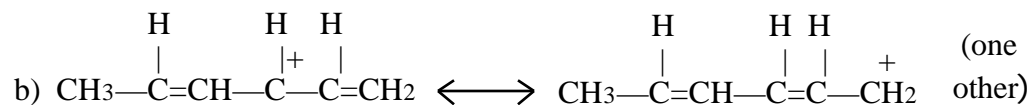
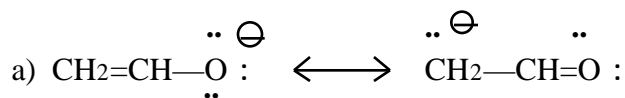
2.1 The Lewis structures are:



2.2 Condensed and bond-line structures:



3.1 Resonance:

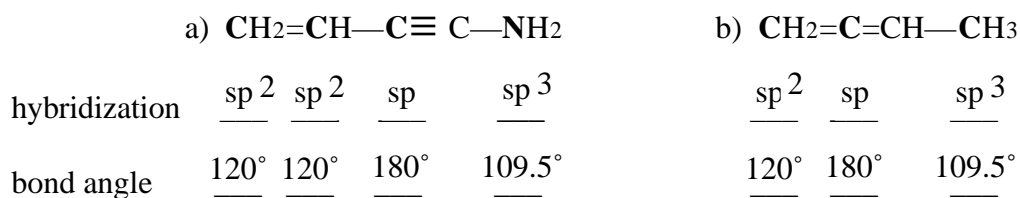


3. Isomers: O



(Note: There are several correct answers for each of these problems. These are examples only.)

4.1. Hybridizations and approximate bond angles:

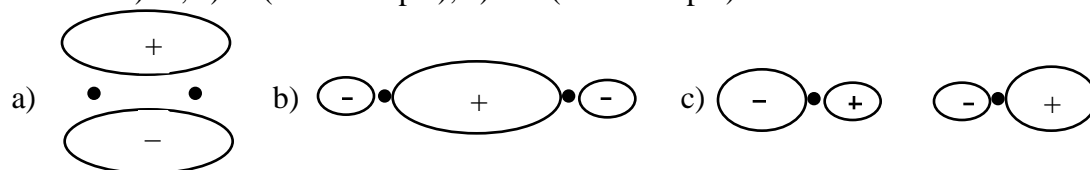


5.1 A is *trans*; D is *cis*. 5.2 D

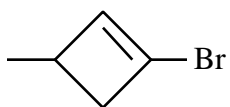
6.1 A is shortest; D is longest; A is strongest. 6.2 D is shortest; C is longest; D is strongest.

7.1 Orbitals: (a) p, (b) *, (c) .

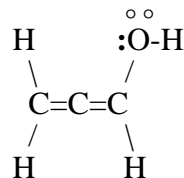
7.2 Orbitals: a) ; b) (from two p's); c) (from two p's)



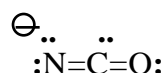
- 7.3
- The total number of sigma bonds in the compound is 14.
 - The total number of pi bonds is 3.
 - The total number of electrons in the pi orbitals is 6.
 - The total number of bonds formed by the overlap of two sp^3 orbitals is 2.
 - Bond 1 is formed from the overlap of a(an) sp^2 orbital with a(an) sp orbital.
 - Bond 2 is formed from the overlap of a(an) sp orbital with a(an) sp^3 orbital.
 - Bond 3 is formed from the overlap of a(an) sp^3 orbital with a(an) s orbital.

1. Draw Lewis structures, showing all electrons, of each of the following.
a)  b) $(\text{CH}_3)_2\text{CH}(\text{CH}_2)_2\text{CH}_3$

c) An ISOMER of

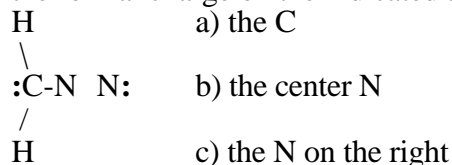


d) Another resonance form of:

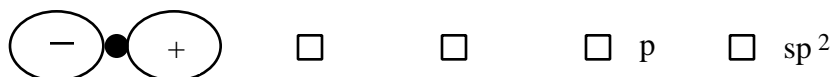


2. Fill in the blanks: The three bonds in the carbon-carbon triple bond in H-C \equiv C-H are:
a) _____ bond formed from _____ orbitals
a) _____ bond formed from _____ orbitals
a) _____ bond formed from _____ orbitals

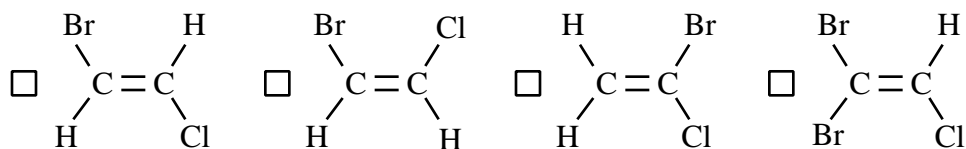
3. What is the formal charge on the indicated atoms? What is the total charge on the species?



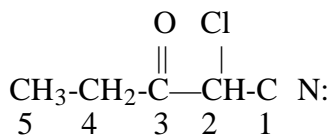
4. What is the orbital shown?



5. Which of the following is a cis isomer?

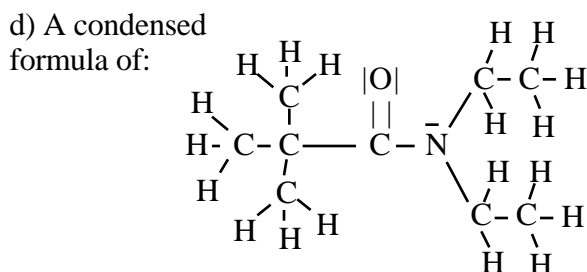
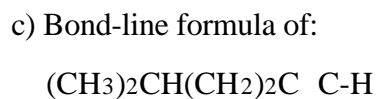
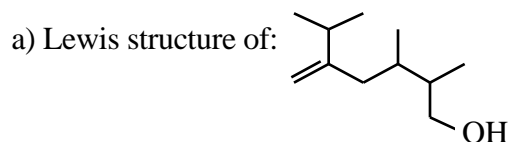


6. Consider the molecule on the left. Give:

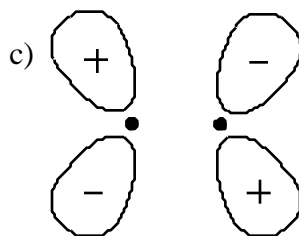
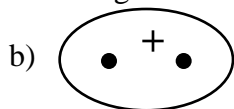
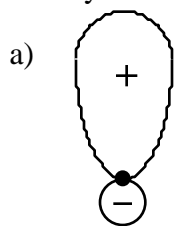


- a) the hybridization of C4 _____
b) the hybridization of C3 _____
c) the C2-C1-N bond angle _____
d) the C2-C3-O bond angle _____
e) the geometry of C5 _____
f) Complete the sentence: The longest carbon-carbon bond in the molecule is between C ____ and C ____ (give numbers).

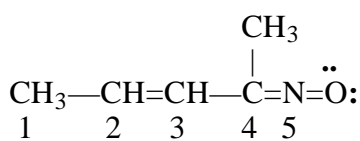
1. Draw structures as indicated.



2. Identify each of the following orbitals.



3. Consider the molecule shown:.. What is:



a) the hybridization of N5 _____

b) the hybridization of C2 _____

c) the C2-C3-C4 bond angle _____

d) the geometry of C4 _____

e) the formal charge on N _____

f) the formal charge on O _____

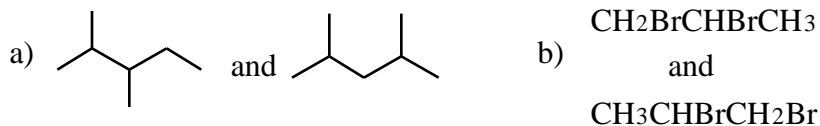
4. Give the information requested about the molecule $\text{CH}_3-\text{CH}=\text{CH}_2$.

a) Which carbon-carbon bond is the longest? _____

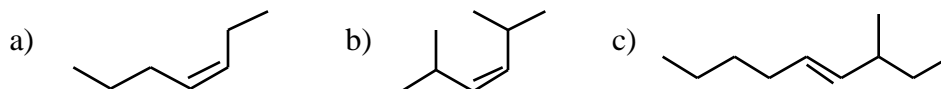
b) Which carbon-carbon bond is the strongest? _____

c) Bond 2 is composed of a _____ bond made from head-to-head overlap of _____ orbitals and a _____ bond made from side-to-side overlap of _____ orbitals.

5. What is the relationship between the structures shown below? (Possible answers: Different compounds that are not isomers, different compounds that are constitutional isomers, the same compound, resonance contributors.)

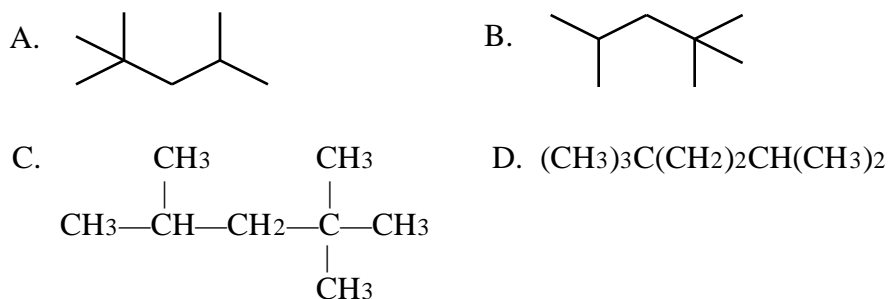


6. Identify each of the following as cis, trans, or neither.

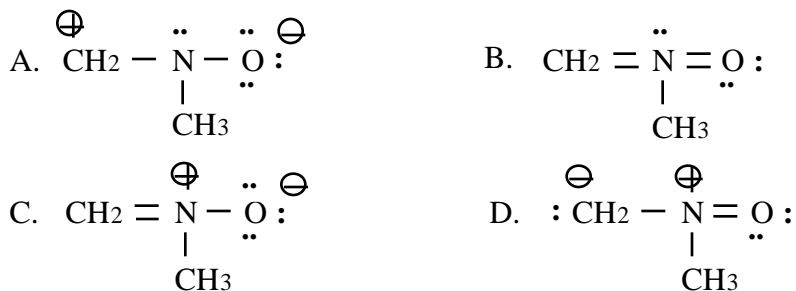


Multiple Choice:

7. Which of these formulas represents a different compound from the others?



8. Which of the following is NOT a permissible resonance form?



9. Which of these molecules is linear? (Hint: draw a Lewis structure before you decide).



10. How many 2p atomic orbitals from boron must be mixed with a 2s atomic orbital to yield the bonding hybrid atomic orbitals in BF_3 ?

