A REVIEW OF GENERAL CHEMISTRY: ELECTRONS, BONDS AND MOLECULAR PROPERTIES

A STUDENT SHOULD BE ABLE TO:

1. Draw Lewis (electron dot and line) structural formulas for simple compounds and ions from molecular formulas. Correct structures should:
   - Have the skeleton arranged correctly.
   - Have the correct number of electrons.
   - Have an octet of electrons on second-row atoms. Some high-energy, reactive species have an atom with 6 or 7 valence electrons.
   - Show the correct formal and total charges, if any.

2. Define, recognize and give examples of constitutional isomers (same formula, different connectivity) for compounds having 4 carbons or fewer.

3. Identify bonds as non-polar covalent, polar covalent or ionic, based on electronegativity. Draw bond dipoles for polar covalent bonds. Determine whether molecules are polar or nonpolar, and draw the direction of the dipole moment for polar compounds.

4. Given a structure, predict the shape of the molecule and the approximate bond angles in it, and give the hybridization of central atoms.

Ex.	Atoms on Central At.	+ Lone Pairs =	Steric No.	Hyb.	Bond Angle	Molecular Shape
CH_4	4	0	4	sp^3	109.5^o	tetrahedral
NH_3	3	1	4	sp^3	109.5^o	trigonal pyramid
H_2O	2	2	4	sp^3	109.5^o	bent
BF_3	3	0	3	sp^2	120^o	trigonal planar
HN=O	2	1	3	sp^2	120^o	bent
HC≡N	2	0	2	sp	180^o	linear

5. Predict relative strengths and lengths of carbon-carbon bonds, and lengths of carbon-hydrogen bonds in hydrocarbons.

6. 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.

7. Determine how intermolecular forces and size/surface area (including branching) influence boiling point and solubility. The forces are: ionic, hydrogen bonds (in protic compounds with F, O, N), dipole-dipole interactions, and van der Waals/fleeting dipole-dipole interactions. Solubility: H-bonding compounds will be soluble with 4 C or less; may be soluble with 5-6 C, and will not be soluble with more than 6 carbons.

To best prepare for this module, please work Chapter 1 Skill Builder problems in the textbook.

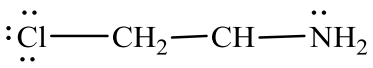
A STUDENT WHO HAS MASTERED THE OBJECTIVES ON THE PREVIOUS PAGE SHOULD BE ABLE TO SOLVE THE FOLLOWING PROBLEMS AND RELATED ONES:

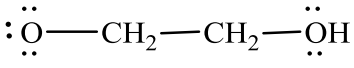
1.1 Draw Lewis structures for the following:

a) C_3H_8 b) C_2H_5F c) NH_3

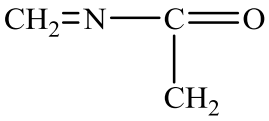
d) CH_3^+ e) CH_3^- f) CNO^-

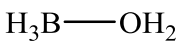
1.2 Show the formal charges on all the atoms, other than hydrogens, of the following species. (The unshared electrons are shown)

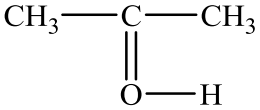
a) 

b) 

1.3 Show the formal charges on all the atoms, other than hydrogens, of the following compounds. Unshared electrons are not shown; determine locations using the octet rule.

a) 

b) 

c) 

Overall charge: anion neutral cation

2.1 Draw two constitutional isomers for the molecular formulae given in parts (a) and (b).

a) C_2H_7N b) C_2H_4O

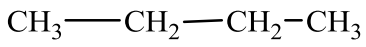
c) Draw 4 constitutional isomers for C_4H_9Br. There are two ways to arrange the carbons.

2.2 Determine the relationship between the structures in each pair, choosing from: same compound, constitutional isomers, unrelated.

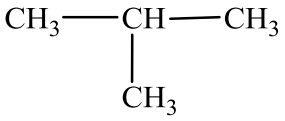
a) $CH_3\text{-}CH_2\text{-}CH_2\text{-}Cl$ versus $Cl\text{-}CH_2\text{-}CH_2\text{-}CH_3$

2.2 b) CH_3-CH_2-CH_3 versus CH_2=CH-CH_3

c)



versus



3.1 Draw bond dipoles for all polar covalent bonds. Show positive and negative charges for ionic bonds.

a) Cl-CH_3 b) H-O-CH_3 c) CH_3-O-Na

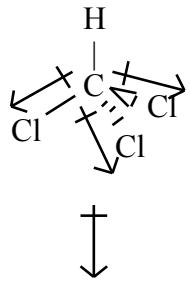
d) Li-CH_3 e) NH_3 f) CH_3-CH=O

3.2 a) For 3.1a, draw an arrow pointing to the atom that would attract an anion.

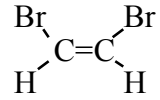
b) For 3.1b, draw an arrow starting at the atom that would attract a proton.

3.3 Indicate directions of individual bond dipoles of the following compounds. Also indicate the directions of the overall dipoles, if appropriate, underneath the structures.

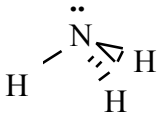
example

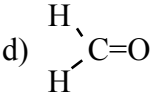


a) Br—C≡C—H



c)





d)

3.4 Draw the molecules in their approximate shapes, and indicate the overall dipoles, if appropriate, underneath the structures.

a) CH_2Cl_2 b) $Br_2C=CH_2$ c) CH_3-O-CH_3 d) CH_3-C(=O)-CH_3

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

a) **C**H$_2$=**C**H—**C**≡C—**N**H$_2$ b) **C**H$_2$=**C**=CH—**C**H$_3$

hybridization	___	___	___	___		___	___	___
bond angle	___	___	___	___		___	___	___

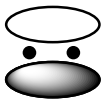
5.1 Which of the carbon-carbon bonds in the structure below is the shortest? Which is the longest? Which is the strongest?

A B C D
H-C≡C-CH$_2$-CH=CH-CH$_2$-CH$_3$

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

H-C=C-CH-CH$_2$-C≡C-H
| | |
H H H
A B C D

6.1 First, identify each of the following orbitals as either an atomic orbital or a molecular orbital. Then, identify each atomic orbital as s, p, d, or hybrid, and each molecular orbital as σ, σ*, π, or π*. Nuclei are shown as large black dots.

a)  b)  c)  d)  e) 

6.2 Fill in the blanks for the following compound.

H$_2$C=CH-C≡C-CH$_2$-CH$_2$-O-H
1 2 3

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 _____

6.2 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.

7.1 Which of these compounds has the highest boiling point? Which has the lowest?

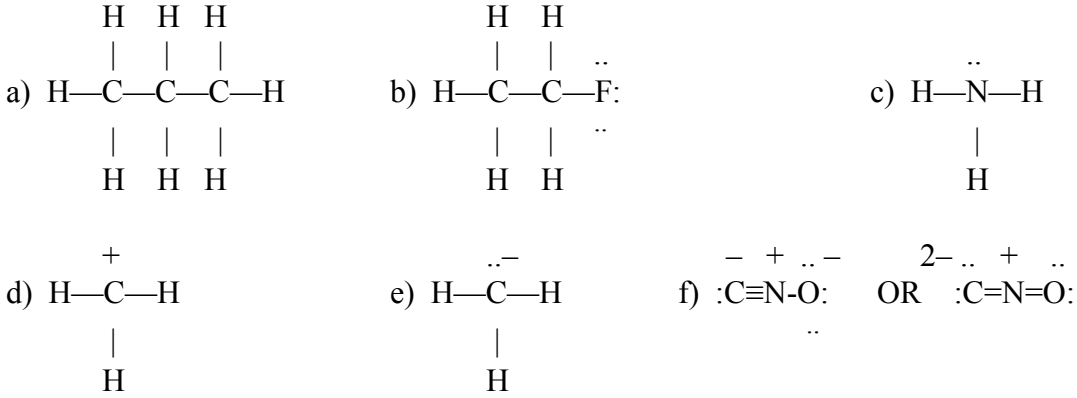
A. $CH_3CH_2CH_3$ B. $CH3CH_2CH_2OH$ C. $CH_3CH_2CH_2Cl$ D. $CH_3\overset{\overset{O}{\|}}{C}CH_3$

7.2 Which of the following compounds is most soluble in water? Which is the most soluble in hexanes ($CH_3CH_2CH_2CH_2CH_2CH_3$)?

A. CH_3CH_2Br B. $CH_3CH_2\overset{\overset{O}{\|}}{C}$-OH C. $CH_3CH_2CH_2CH_2OH$ D. $CH_3CH_2CH_2CH_2CH_3$

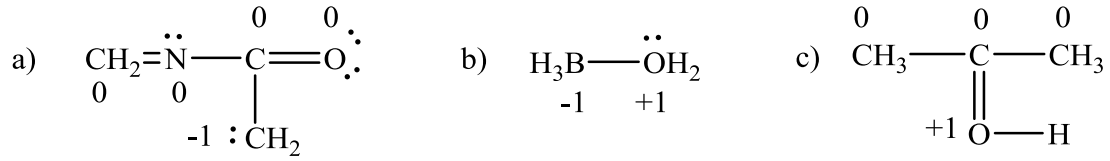
SOLUTIONS TO SAMPLE PROBLEMS:

1.1



1.2 Formal charges:

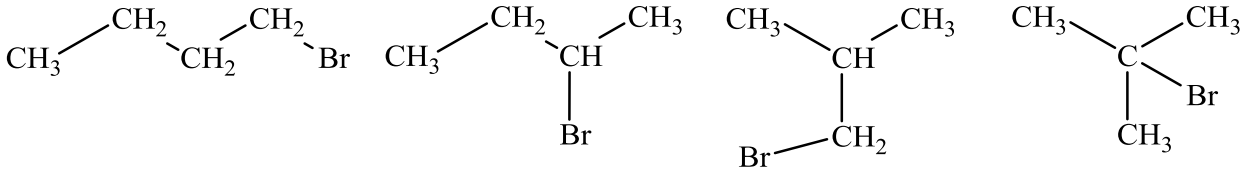
1.3



2.1 a) CH_3-CH_2-NH_2 and CH_3-NH-CH_3

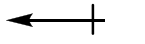
b) CH_3-CH=O and CH_2=CH-OH (this isomer is a lot less stable, and uncommon)

c)

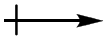


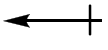
2.2 a) same b) unrelated (different formula) c) constitutional isomers

3.1 a) Cl-CH_3 b) H-O-CH_3 c) CH_3-O^- $^+$Na

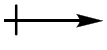


d) Li-CH_3 or Li^+ $^-$:CH_3 e) NH_3 f) CH_3-CH=O



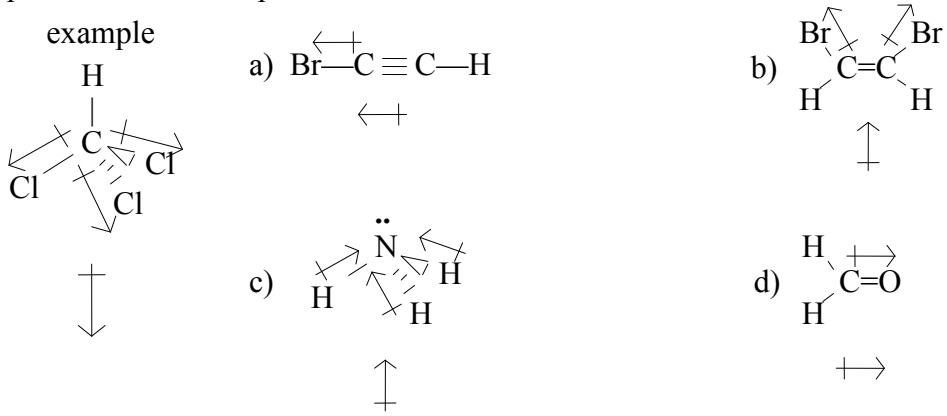


all 3 NH are polar

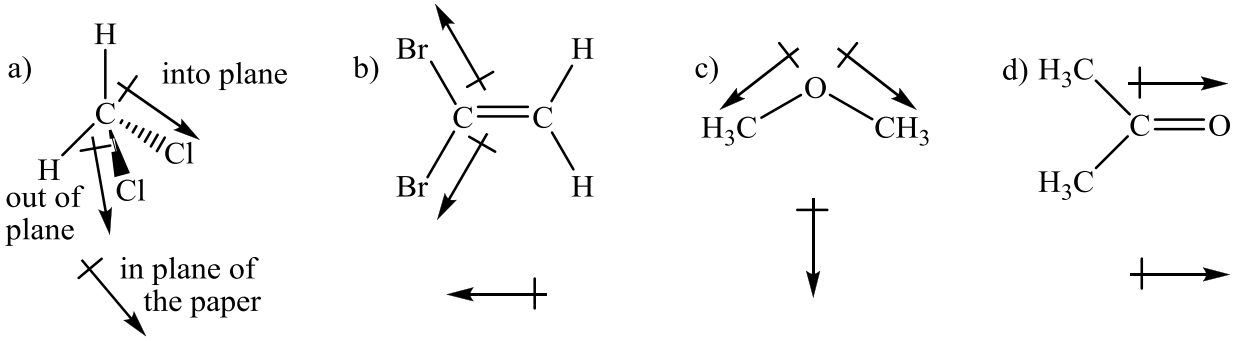


3.2 a) CH_3-Cl (electron poor C) b) CH_3-O-H (electron rich O)

3.3 Bond dipoles and overall dipoles:



3.4 Shapes and overall dipoles:



4.1. Hybridizations and approximate bond angles:

	a) **C**H_2=**C**H—**C**≡ C—**N**H_2				b) **C**H_2=**C**=CH—**C**H_3			
hybridization	sp^2	sp^2	sp	sp^3	sp^2	sp	sp^3	
bond angle	120^o	120^o	180^o	109.5^o	120^o	180^o	109.5^o	

5.1 A is shortest; D is longest; A is strongest. 5.2 D is shortest; C is longest.

6.1

a)	b)	c)	d)	e)
AO	MO	MO	AO	MO
p	sigma: hybrid + s	sigma: s + s	hybrid	pi: p + p

6.2 a) The total number of sigma bonds in the compound is 14.
b) The total number of pi bonds is 3.
c) The total number of electrons in the pi orbitals is 6.
d) The total number of bonds formed by the overlap of two sp^3 orbitals is 2.
e) Bond 1 is formed from the overlap of a(an) sp^2 orbital with a(an) sp orbital.
f) Bond 2 is formed from the overlap of a(an) sp orbital with a(an) sp^3 orbital.
g) Bond 3 is formed from the overlap of a(an) sp^3 orbital with a(an) s orbital.

7.1 B is highest BP; A is lowest.

7.2 B is most soluble in water. D is most soluble in hexanes.

Name _____ First Drill Test (Sample A)
Organic Chemistry 2210 DR Answer All Questions

1. Draw two isomers having the molecular formula C_2H_6O

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

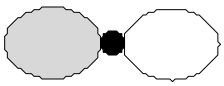
3. What is the formal charge on the indicated atoms?

```
   H
    \
   :C-N≡N:
    /
   H
```

a) the C
b) the center N
c) the N on the right

d) What is the total charge on the species?

4. What is the orbital shown?



☐ σ ☐ s ☐ p ☐ sp^2

5. Arrange these compounds based on boiling point. 1 = highest boiling

$CH_3CH_2CH_2Br$	CH_3CH_2OH	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH{=}O$
_____	_____	_____	_____

6. Consider the molecule on the left. Give:

```
          O  Cl
          ‖  |
CH3-CH2-C—CH-C≡N:
5   4    3  2  1
```

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).

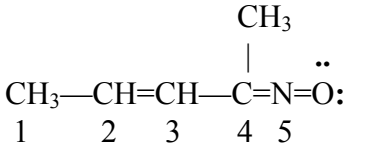
7. Draw $CH_2{=}CF_2$ in its approximate shape. Draw all bond dipoles and draw the overall molecular dipole moment.

Name _____ First Drill Test (Sample B)
Organic Chemistry 2210 DR Answer All Questions

1. Draw the Lewis structure of a molecule having the formula C_3H_4O

2. Identify this orbital.

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 $CH_3—CH=CH_2$.
1 2

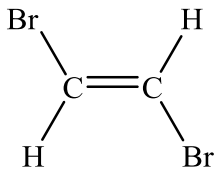
a) Which carbon-carbon bond is the longest? _____

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

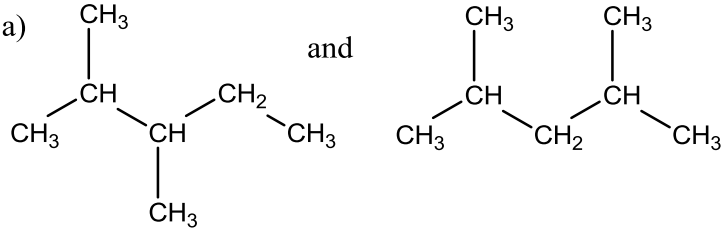
c) Bond 2 is composed of a _____ bond made from head-to-head overlap of _____ orbitals

and a _____ bond made from side-to-side overlap of _____orbitals.

5. Draw the bond dipoles and overall molecular dipole moment for:



6. What is the relationship between the structures shown below? (Possible answers: same compound, constitutional isomers, unrelated molecules)

a)  and

b) CH_2Br-CHBr-CH_3

and

CH_3-CHBr-CH_2Br

Multiple Choice:

7. Which of these molecules is most soluble in water?

A. CH_3OH B. CH_3CH_2OH C. CH_3CH_2Br D. CH_3CH_3

8. Which of these molecules has the lowest boiling point?

A. CH_3Li B. CH_3CH_3 C. CH_3NH_2 D. CH_3CHBr_2

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

A. SO_2 B. SCO C. H_2O_2 D. H_2S E. OF_2

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? (Hint: What is the hybridization of B?)

A. 1 B. 2 C. 3 D. 4 E. 5