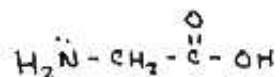


Question 1 (18 points)

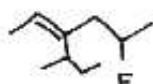
Name Key

Draw stable structures that match each of the following descriptions:

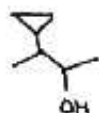
- a. (4 pts) Any structure which has *both* a primary amine and a carboxylic acid.



- b. (4 pts) 3-secbutyl-5-fluoro-2-hexene

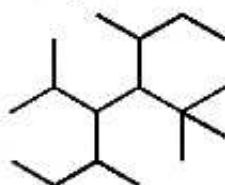


- c. (4 pts) 3-cyclopropyl-2-butanol



Give the correct IUPAC name for the following molecule. You may use common names for any substituents.

- d. (4 pts)



4-*t*-butyl-5-isopropyl-3,6-dimethyloctane

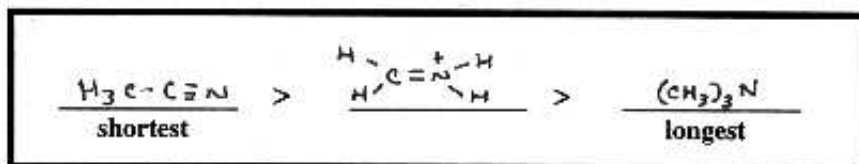
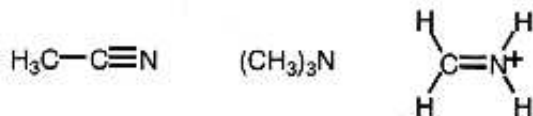
- e. (2 pts) How many primary and tertiary carbons are in the molecule shown in part d?

Number of primary carbons 9 Number of tertiary carbons 5

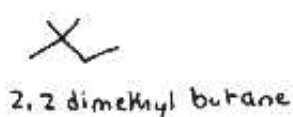
Question 2 (17 points)

Name key

- a. (3 pts) Rank the following molecules in order of increasing C-N bond length.



- b. (3 pts) Which molecule, 2,2-dimethylbutane or hexane, has the higher boiling point?

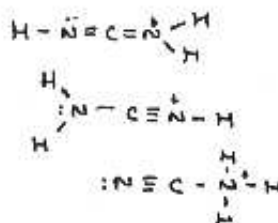
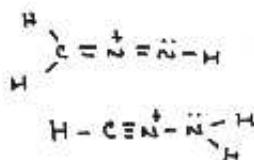
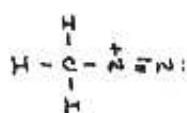


- c. (3 pts) What type of molecular interaction explains your answer to part b? Use as few words as possible.

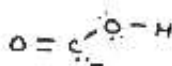
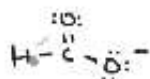
Van der Waals forces - induced dipole - induced dipole

Draw stable Lewis structures for the following molecules. Include all lone pairs and formal charges, if necessary. Note: the atoms may not be bonded in the order listed.

- d. (4 pts) CH_3N_2^+



- e. (4 pts) CO_2H^-



Question 3 (22 points)

Name Key

Answer each of the following by circling T if the statement is TRUE or F if it is FALSE. (2 pts each)

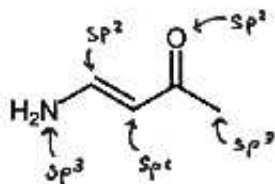
- a. CH_2Cl_2 has a molecular dipole moment. T F
- b. Cyclopropane is free of strain. T F
- c. Alkane **A**, has a lower heat of combustion than alkane **B**; therefore alkane **A** is less stable than alkane **B**. T F
- d. Compounds with smaller pK_a 's are weak acids. T F
- e. Ammonia, NH_3 , is both a Brønsted-Lowry base and Brønsted-Lowry acid. T F

- f. (6 pts) A carbon-oxygen double bond is shorter than a carbon-oxygen single bond, yet all the C-O bonds in the carbonate ion (CO_3^{2-}) have been experimentally determined to be of equal length. Explain this observation, using mostly drawings and as few words as possible.



CO_3^{2-} has 3 equivalent resonance structures, so the C-O bonds in CO_3^{2-} are equivalent. Note the C-O bonds are in between a single bond and a double bond.

- g. (6 pts) Indicate the hybridization of each carbon, oxygen, and nitrogen in the following molecule.

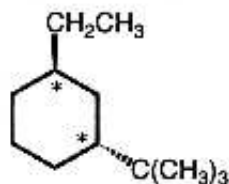


Question 4 (14 points)

Name key

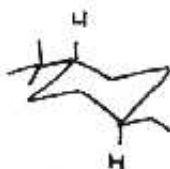
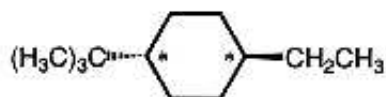
Draw a three dimensional representation in the **lowest energy** conformation of the following molecules. Also, show the hydrogens on the starred carbons.

a. (5 pts)



Cyclohexane A

b. (5 pts)



Cyclohexane B

c. (2 pts) Are substituents in cyclohexanes A and B *cis* or *trans* to each other?

Both A + B have trans substituents

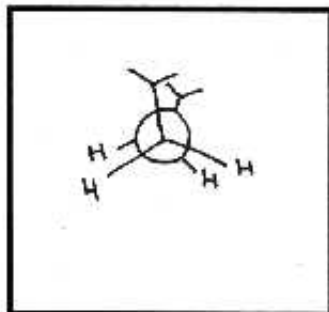
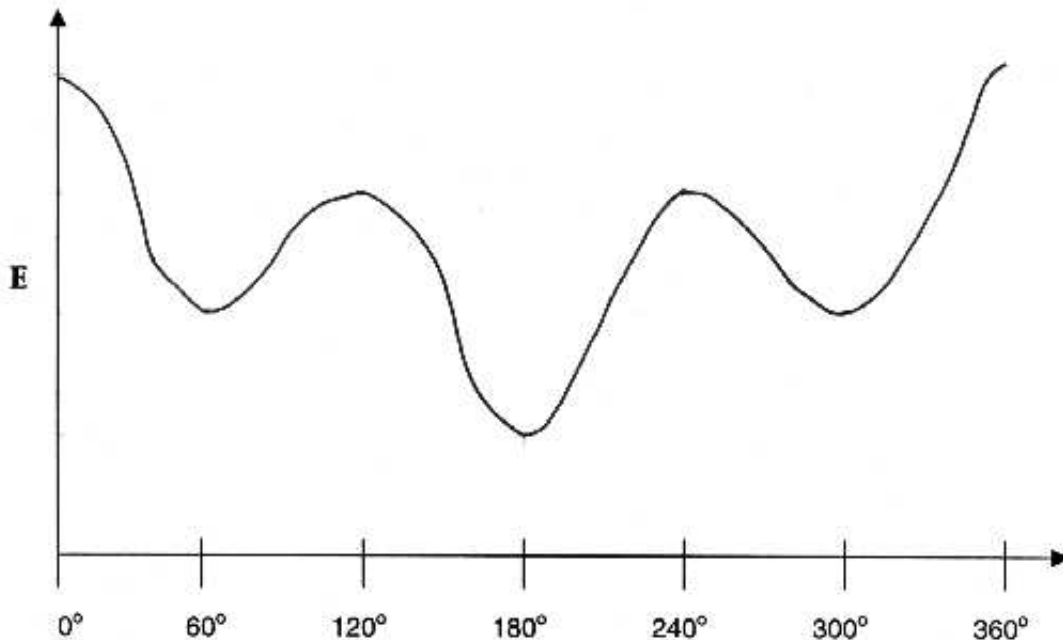
d. (2 pts) Which cyclohexane, A or B, is more stable?

Question 5 (10 points)

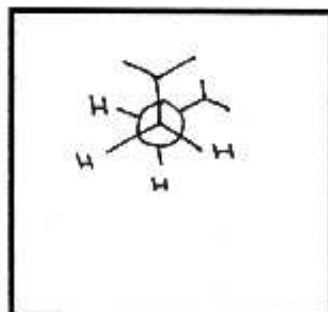
Name key

Consider 2,5-dimethylhexane and sight down the C3-C4 bond from C3 to C4. Sketch an approximate potential energy diagram for each 60° rotation about the C3-C4 bond from 0° to 360° starting with the highest energy conformation at 0°. Also, draw the Newman projections for the conformations at 0°, 60°, and 180° in the boxes below.

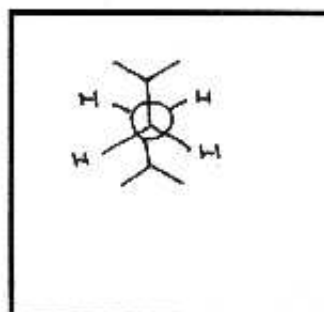
If you draw a structure for 2,5-dimethylhexane on this page, make sure that it is complete and correct.



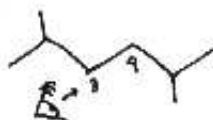
0°



60°



180°



Question 6 (11 points)

Name key

Determine a molecular orbital picture for $\text{H}_2\text{C}=\text{C}=\text{C}=\text{CH}_2$, 1,2,3-butatriene, as follows:

a. (4 pts) Sketch all the σ bonds.



b. (5 pts) Sketch the π bonds. Indicate the relative orientation of the π bonds.



The π bond between $\text{C}_1 + \text{C}_2$ is perpendicular to the π bond between $\text{C}_2 + \text{C}_3$. The π bond between $\text{C}_2 + \text{C}_3$ is perpendicular to the π bond between $\text{C}_3 + \text{C}_4$.

c. (2 pts) Are all four hydrogens in 1,2,3-butatriene in the same plane?

yes

Question 7 (8 points)

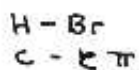
Name key

Using bond dissociation energies, calculate the $\Delta H^\circ_{\text{rxn}}$ for the reaction shown below. Some useful BDE's are listed below.

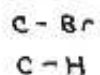


Bond	Energy (KJ/mol)
C=C	611
C-C π	234
C-C σ	377
C-C	377
C-H	410
C-Br	284
H-Br	366

Bonds Broken



Bonds made



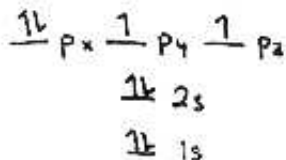
$$\begin{aligned} \Delta H^\circ_{\text{rxn}} &= \sum \text{BDE's for bonds broken} - \sum \text{BDE's for bonds made} \\ &= \text{BDE}(\text{H-Br}) + \text{BDE}(\text{C-C}\pi) - \text{BDE}(\text{C-Br}) - \text{BDE}(\text{C-H}) \\ &= 366 + 234 - 284 - 410 \\ &= -94 \text{ kJ/mol} \end{aligned}$$

Extra Credit (10 points)

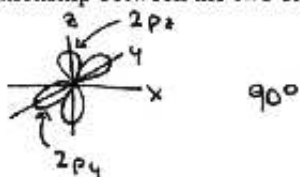
Name Key

In this problem you will use both atomic orbitals and hybrid orbitals to propose bonding models for the water molecule.

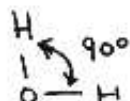
- a. Write the ground state electron configuration of oxygen. Which orbitals contain the unpaired electrons for oxygen?



- b. What is the geometrical relationship between the two orbitals containing the unpaired electrons?



- c. If the unpaired electrons in oxygen pair up with two hydrogen atoms, what shape is the water molecule? What is the H-O-H bond angle in this water molecule (ignore VSEPR theory for the moment)?



- d. The actual bond angle is 105° (closer to the bond angle of a tetrahedral atom). If your answer in part c is 109.5° , then you do not need to consider hybridization. If your answer is significantly different, then hybridize the appropriate atomic orbitals of oxygen to generate the correct bond angles in water.



- e. Why does hybridization give the correct bond angles around the oxygen atom?

Two of the hybrid orbitals would be used for bonding and all four of them would be directed as far apart from each other as possible. The angles would be close to 109° .