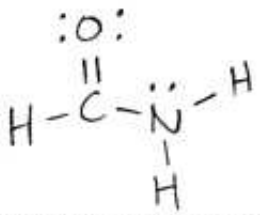
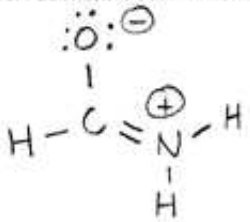
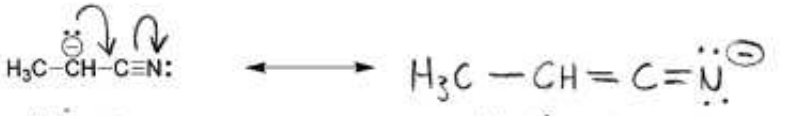
1a. Draw the best Lewis structure (the major resonance contributor) for formamide, $HCONH_2$. The carbon is the central atom, and is bonded to an H, to O, and to N. (6 pts)



1b. The C-N bond in formamide (the structure you just drew) has been shown to have a length that is somewhere between the length of a typical C-N single bond and a typical C-N double bond. Draw another resonance structure (this one is a minor contributor) to propose an explanation for this observation. (6 pts)



1c. Starting from the resonance contributor shown, draw one additional resonance structure using curved arrow formalism to show how the structure is obtained from the original structure, and label each of the structures as a "major" or "minor" contributor. (6 pts)



2a. Each of the following statements concerns the molecular orbital diagram for H_2. Circle "T" if the statement is true or "F" if the statement is false. (8 pts)

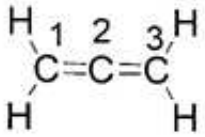
T **(F)** There is a node in the bonding orbital.

(T) **F** The anti-bonding orbital is the LUMO.

(T) **F** The σ* ("sigma star") molecular orbital is an out-of-phase combination of two hydrogen 1s orbitals.

T **(F)** There are four molecular orbitals in H_2.

2b. Consider the molecule *allene*, shown here. The numbers refer to the carbon atoms.



Complete the following statements by filling in the blanks with the appropriate orbital labels. Possible choices are: s sp^2 sp^3 p σ σ* π π* (6 pts)

The sigma bond between C-1 and C-2 is formed by the overlap of:

a/an sp^2 orbital on C-1 and a/an sp orbital on C-2.

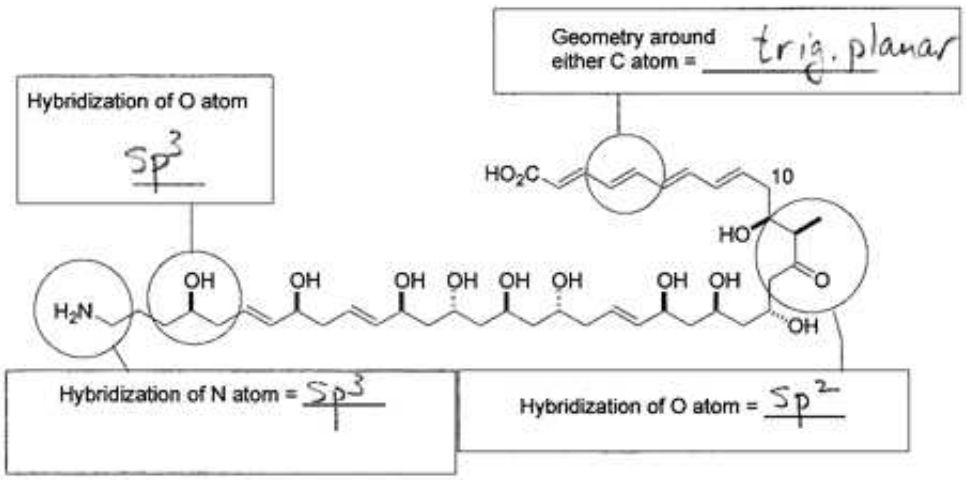
The sigma bond between C-3 and either of the hydrogens is formed by the overlap of:

a/an sp^2 orbital on C-3 and a/an s orbital on hydrogen.

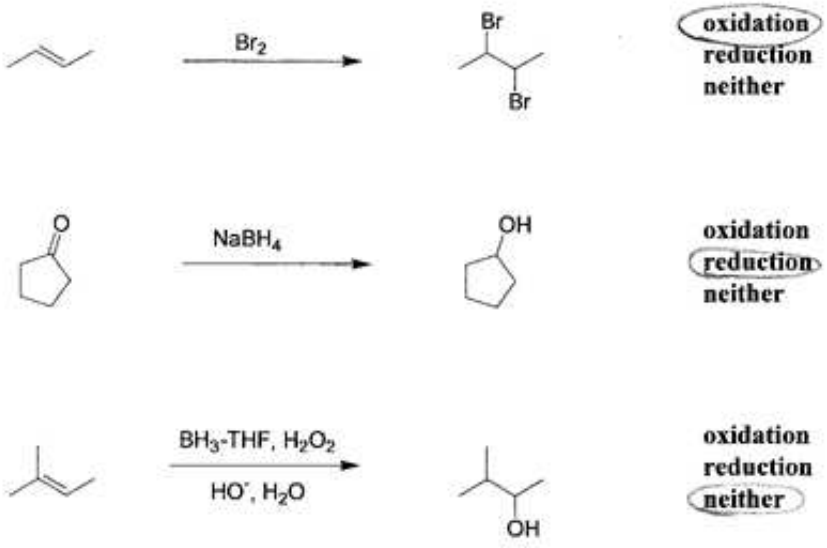
The pi bond between C-1 and C-2 is formed by the overlap of:

a/an p orbital on C-1 and a/an p orbital on C-2.

3a. Several functional groups are circled in the molecule shown below. For each, write the hybridization or geometry of the indicated atoms. Notice that lone pairs have not been drawn in. All atoms are neutral. (8 pts)



3b. For each of the following reactions, circle the correct word to indicate whether the process is a reduction, an oxidation, or neither. (6 pts)



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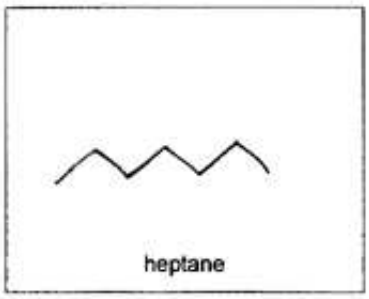
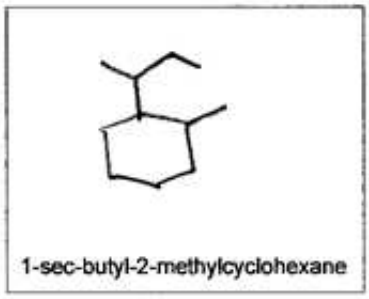
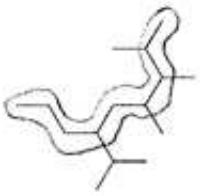
4. Provide either an acceptable IUPAC name or a correct structure for each of the following. You may use either common names or IUPAC names for the substituents. (12 pts)



heptane



1-sec-butyl-2-methylcyclohexane



6-Isopropyl-2,3,4-trimethylnonane

or

6-(1-methylethyl)-2,3,4-trimethylnonane

5-isobutyl-3,6-dimethylnonane

or

3,6-dimethyl-5-(2-methylpropyl)nonane

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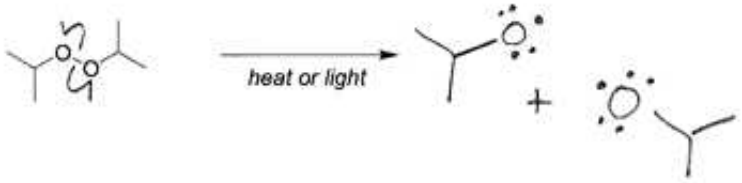
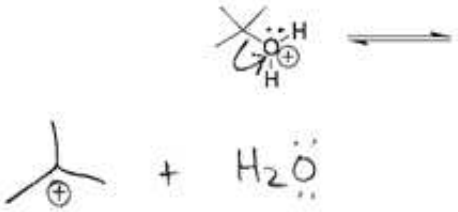
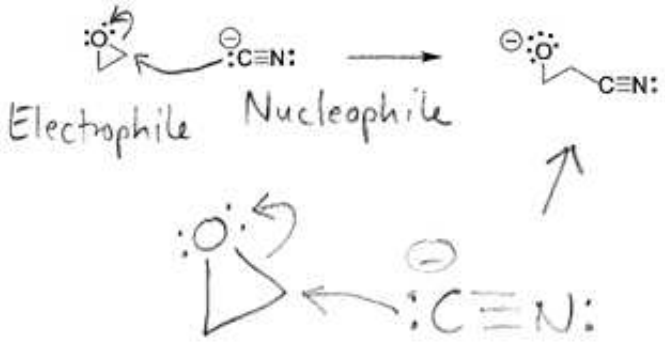
5a. Draw an arrow-pushing mechanism to show the homolytic bond cleavage of the O-O bond in the molecule shown. Draw all products, and include all lone pairs and unpaired electrons and any non-zero formal charges. Note that not all lone pairs are shown in the drawing below. (5 pts)



5b. Draw an arrow-pushing mechanism to show the heterolytic bond cleavage of the C-O bond in the molecule shown below. Draw all products, and include all lone pairs and unpaired electrons and any non-zero formal charges. Note that not all lone pairs are shown in the drawing below. (5 pts)



5c. Draw an arrow-pushing mechanism for the reaction shown below to show how the product forms. Label the nucleophile and the electrophile in the reaction. All lone pairs and formal charges are shown. (4 pts)



6a. Draw an arrow-pushing mechanism for the reaction of isobutyric acid ($pK_a = 4$) with methylamine. Draw the products of this reaction, showing all lone pairs and non-zero formal charges. Indicate which side of the reaction is favored at equilibrium and explain your answer IN ONE SENTENCE. The pK_a of $CH_3NH_3^+$ is 10. (8 pts)

isobutyric acid *methylamine* products

pka = 4 pka = 10

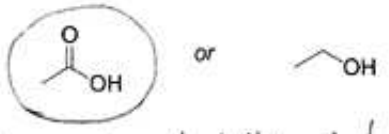
Products favored - weaker acid + base

6b. Electrons always attack empty orbitals. What is the empty orbital being attacked in the reaction you just drew in 6a (circle it from the choices shown below)? (2 pts)

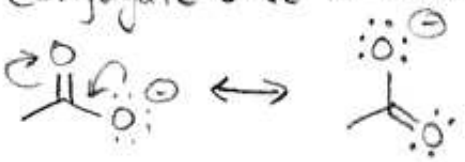
Choices are:	C-O σ	C-O σ*	N sp^2	O-H σ
	C-H σ	C-H σ*	N sp^3	(O-H σ*)
	N-H σ	N-H σ*	O sp^2	C-O π

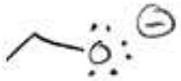
10

7a. Which of the following molecules is a stronger acid? Circle it, and *briefly* explain your answer using words and pictures. Explanation is necessary for full credit. (7 pts)



Conjugate base is stabilized by resonance

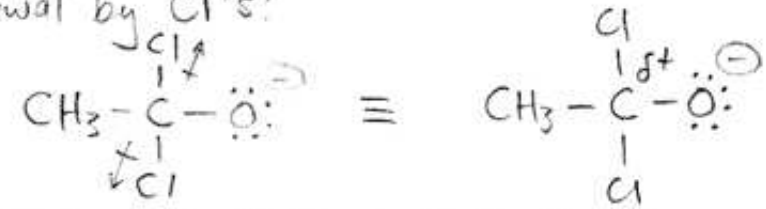


unlike in  which has no resonance stabilization

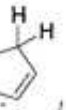
7b. Which of the following molecules has a lower pK_a? Circle it, and *briefly* explain your answer using words and pictures. Explanation is necessary for full credit. (7 pts)

CH_3CH_2OH or CH_3CCl_2OH Lower pk_a = stronger acid

Conjugate base is stabilized by inductive electron withdrawal by Cl's:



7c. Most hydrocarbons have high pK_a values; *i.e.*, 25 and above. However, cyclopentadiene, shown below, has a pK_a of 16. Use what you know about assessing acid strengths to *briefly* explain why cyclopentadiene is so acidic. The acidic hydrogens are shown. (6 pts)



Conjugate base stabilized by resonance