1. Provide the line structures of the following compounds: (24 pts)

(a) butylisopropylether

(b) 5-methyl-1,3-cycloheptadiene

(c) E-3-chloro-3-hexene

(d) 5-hexyn-2-ol
2. Provide the [IUPAC] names for the following structures: (24 pts)

(a) ethoxy cyclohexane

(b) 4-bromo-3,5,5-trimethyl octane

(c) 3-tert-butyl-hexyne

(d) (2R,3S)-1,2,3-butanetriol

3. Provide the hybridization of the atomic orbitals for all non-hydrogen atoms. (17 pts)
4. Rank the acidities of the following molecules in terms of their pKa values (from high to low) and provide a detailed explanation for your choice based on one of the following (inductive effect, electronegativity, resonance, orbital hybridization, bond dissociation energy). Provide structures to support your rationale. (30 pts)

(a) 
\[ \text{HC=CH} \quad \text{H}_2\text{C}==\text{CH}_2 \quad \text{H}_3\text{C}===\text{CH}_3 \]

\[
\begin{align*}
\text{C} & > \quad \text{B} & > \quad \text{A} \\
\text{highest pKa} & \quad & \text{lowest pKa}
\end{align*}
\]

orbital hybridization:
- HC=CH
  - sp
  - \( s^3 \) character
  - highest acidity
- \( \text{H}_2\text{C}==\text{CH}_2 \)
  - sp\(^2\)
  - \( s^1 \) character
- \( \text{H}_3\text{C}===\text{CH}_3 \)
  - sp\(^3\)
  - \( s^0 \) character

(b) 
\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{A} & \quad \text{B} & \quad \text{C}
\end{align*}
\]

\[
\begin{align*}
\text{B} & > \quad \text{A} & > \quad \text{C} \\
\text{highest pKa} & \quad & \text{lowest pKa}
\end{align*}
\]

Resonance stability:
- \( \text{A} \)
  - negative charge stabilized over the greatest number of carbons
  - most stable conjugate base = weakest base in strongest conjugate acid
5. Circle the compound that: (10 pts)
(a) is the most soluble in water

\[ \text{Options:} \]
- \[ \text{structure 1} \]
- \[ \text{structure 2} \]
- \[ \text{structure 3} \]
- \[ \text{structure 4} \]
(b) has the highest boiling point

\[ \text{Options:} \]
- \[ \text{structure 5} \]
- \[ \text{structure 6} \]
- \[ \text{structure 7} \]
- \[ \text{structure 8} \]

6. Draw the Newman projection for the lowest energy conformation of 2-methylbutane looking down the C2-C3 bond. (15 pts)

\[ \text{Structure:} \]

7. Designate whether the following molecules are chiral or achiral: (15 pts)

- \[ \text{structure 9} \] \( \text{chiral} \)
- \[ \text{structure 10} \] \( \text{chiral} \)
- \[ \text{structure 11} \] \( \text{achiral} \)
8. Draw the lowest energy chair conformation of cis-1-tert-butyl-2-methylcyclohexane showing all axial and equatorial hydrogens. (21 pts)

9. Designate whether the following pairs of compounds are enantiomers, diastereomers or identical. (20 pts)

(a) 

(b) 

Enantiomers

Identical

(c) 

(d) 

Identical

Diastereomers
10. Draw all five of the constitutional isomers for cycloalkanes of the molecular formula C₅H₁₀. (20 pts)

11. Show the 2 different pairs of reagents that could be used to synthesize the molecule below by the Williamson Ether synthesis. Circle the pair that would be most likely to provide the desired ether product, and provide a brief rationale for your choice. (14 pts)
12. Predict the product of the following reactions. (15 pts)

a)

\[ \text{HBr} \]

b)

\[ \text{H}_2\text{O} \]

\[ \text{HgSO}_4 \]

\[ \text{H}_2\text{SO}_4 \]

c)

\[ \text{H}_2\text{CrO}_4 \]

13. Predict the starting material needed to produce the following product. (15 pts)

a)

\[ \text{peroxy-carboxylic acid} \]

b)

\[ 1. \text{BH}_3 \]

\[ 2. \text{H}_2\text{O}_2, \text{NaOH} \]
14. Predict the reagents needed to produce the following product. (15 pts)

a) 

\[
\begin{align*}
\text{O} & \quad \text{OCH}_3 \\
\text{H} & \quad \text{OCH}_3 \\
\text{H} & \quad \text{OCH}_3 \\
\text{H} & \quad \text{OCH}_3 \\
\text{H} & \quad \text{OCH}_3 \\
\end{align*}
\]

b) 

\[
\begin{align*}
\text{CH}_3 \quad \text{I} \\
\text{CH}_3 \quad \text{I} \\
\text{CH}_3 \quad \text{I} \\
\text{CH}_3 \quad \text{I} \\
\text{CH}_3 \quad \text{I} \\
\end{align*}
\]

c) 

\[
\begin{align*}
\text{NBS} & \quad \text{Br} \\
\text{Br}_2 & \quad \text{light} \\
\text{Br}_2 & \quad \text{light} \\
\text{Br}_2 & \quad \text{light} \\
\text{Br}_2 & \quad \text{light} \\
\end{align*}
\]
15. Fill in the reagents and starting materials needed for the 2 step conversion of A into B (Remember to work backwards!). (15 pts)

\[
\begin{align*}
\text{A} & \xrightarrow{\text{H}_2\text{SO}_4, \text{heat}} \text{ } & \text{ } & \text{ } \xrightarrow{\text{H}_2, \text{Pd}} \text{B} \\
\end{align*}
\]

16. Circle the correct answer: (10 pts)

(a) would the following reaction go through an E1 or E2 process:

\[
\begin{align*}
\text{Br} & \xrightarrow{\text{H}_2\text{O}} \text{ } & \text{ } & \text{E1} & \text{E2} \\
\end{align*}
\]

(b) would the following reaction go through an Sn1 or Sn2 process:

\[
\begin{align*}
\text{Br} & \xrightarrow{\text{NaI, H}_2\text{O}} \text{ } & \text{ } & \text{I} & \text{Sn1} & \text{Sn2} \\
\end{align*}
\]
17. Provide a mechanistic rationale for the formation of the following product (structures only - no words). (20 pts)

Extra Credit:
Classify the following reactions as oxidation, reduction, elimination or substitution: (20 pts)

(a)  
\[ \text{Na} \quad \text{NH}_3 \quad \text{Reduction} \]

(b)  
\[ \text{Cl} \quad \text{CH}_3\text{O}^- \quad \text{Elimination} \]