1. Rank the following compounds in the trend requested. (15 points each)
   a. Rank by acidity. The most acidic compound is 1, while the least acidic compound is 5.
      \[
      \begin{array}{cccc}
      \text{OH} & \equiv & \text{SH} & \text{O}_2\text{C} \\
      2 & 3 & 1 & 5 \\
      \text{NH}_2 & \\
      4
      \end{array}
      \]
   b. Rank by reactivity with HBr. The compound that reacts the fastest with HBr is 1, while the compound that reacts the slowest with HBr is 5.
      \[
      \begin{array}{cccccccc}
      \text{phenyl} & \text{cyclohexyl} & \text{benzyl} & \text{ethyl} & \text{tert-butyl} \\
      3 & 5 & 2 & 4 & 1 \\
      \end{array}
      \]
   c. Rank by boiling point. The compound with the highest boiling point is 1, while the compound with the lowest boiling point is 5.
      \[
      \begin{array}{cccc}
      \text{O} & \text{HO} & \equiv & \text{HO} \\
      4 & 1 & 5 & 2 \\
      \text{OH} & \equiv & \\
      3
      \end{array}
      \]
2. Fill in the missing products for the following reactions. Assume proper work-up for each step. Write structure in the boxes provided. (5 points each)
   a.

   \[
   \text{OsO}_4, \text{H}_2\text{O}_2 \quad \rightarrow \quad \text{structure}
   \]

   b.

   \[
   \text{Br} \quad \rightarrow \quad \text{structure}
   \]

   \[
   \text{structure} \quad \rightarrow \quad \text{Cl-structure}
   \]

   \[
   \text{structure} \quad \rightarrow \quad \text{MgBr}
   \]

   \[
   \text{structure} \quad \rightarrow \quad \text{OH}
   \]

   c.

   \[
   \text{H}_3\text{CO}-\text{H} \quad \rightarrow \quad \text{H}_3\text{CO-structure}
   \]

   \[
   \text{structure} \quad \rightarrow \quad \text{CH}_3\text{MgBr (excess)} \quad \rightarrow \quad \text{OH}
   \]
3. Consider the following hydrocarbons.

a. (10) The final steps of the synthesis of trimethylphenalene are shown below. Fill in the empty boxes below.

b. (6) How many degrees of unsaturation are in trimethylphenalene?

9 – one for each π bond and one for each ring

c. (15) For each pair of alkenes shown below, circle the compound that will be the most exothermic when reacted with hydrogen gas and a catalyst. The fully hydrogenated alkane is lower in energy than the alkenes shown. In each pair, therefore, which alkene will generate more heat upon hydrogenation?

In all cases, the less stable alkene will be more exothermic hydrogenation.
4. Draw the preferred product obtained for the following reactions. Assume proper work-up for each step. (7 points each)

a. 
\[
\text{Br}_2, \text{H}_2\text{O}
\]

b. 
\[
\text{KMnO}_4, \text{H}^+, \Delta
\]

c. 
\[
\text{NaBH}_4
\]

d. 
\[
\text{LiAlH}_4
\]

e. 
\[
\text{CH}_3\text{CH}_2\text{MgBr}
\]

f. 
\[
1) \text{NaNH}_2
2) \text{O}
\]
g.  
\[ \text{1) NaNH}_2 \]  \[ \text{2) CH}_3\text{Br} \]  \[ \text{3) Na, NH}_3(\text{l}) \] 

h.  
\[ \text{HBr (excess)} \] 

i.  
\[ \text{1) (Si)}_2\text{BH} \]  \[ \text{2) H}_2\text{O}_2, \text{NaOH} \] 

j.  
\[ \text{1) PhCO}_3\text{H} \]  \[ \text{2) H}^+, \text{CH}_3\text{OH} \] 

k.  
\[ \text{1) H}_2\text{SO}_4 \]  \[ \text{2) BH}_3\text{•THF} \]  \[ \text{3) H}_2\text{O}_2, \text{NaOH} \] 

l.  
\[ \text{HBr} \]
5. Indicate a route to synthesize the following compounds using the starting materials shown. You may use any other inorganic or organic reagents you desire, but you must use the starting material shown to synthesize the product. More than one step may be required. Must indicate what reagents are being used, and the proper sequence of steps required. (15 points each)

a. 

\[ \begin{align*}
\text{CH}_2=\text{CH}_2 & \quad \xrightarrow{?} \quad \text{CH}_3\text{CO}_2\text{H} \\
\text{CH}_2=\text{CH}_2 & \quad \xrightarrow{\text{H}^+, \text{H}_2\text{O}} \quad \text{CH}_2\text{OH} & \quad \xrightarrow{\text{H}_2\text{SO}_4} \quad \text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 & \quad \xrightarrow{1) \text{O}_3} \quad \text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \\
\text{CH}_2=\text{CH}_2 & \quad \xrightarrow{2) \text{CH}_3\text{SCH}_3} \quad \text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 & \quad \xrightarrow{\text{O}} \quad \text{CO}_2\text{H}
\end{align*} \]

b. 

\[ \begin{align*}
\text{C}_6\text{H}_5\text{CH}_3 & \quad \xrightarrow{?} \quad \text{C}_6\text{H}_5\text{C}_2\text{H}_5\text{OH} \\
\text{C}_6\text{H}_5\text{CH}_3 & \quad \xrightarrow{\text{HgSO}_4, \text{H}_2\text{SO}_4} \quad \text{C}_6\text{H}_5\text{C}_2\text{H}_5\text{CHO} & \quad \xrightarrow{\text{CH}_3\text{MgBr}} \quad \text{C}_6\text{H}_5\text{C}_2\text{H}_5\text{OH}
\end{align*} \]
6. When compound A (molecular formula C₆H₈) was partially hydrogenated with hydrogen gas and palladium catalyst, four products were isolated (compounds B-E). Partial hydrogenation means that not enough hydrogen was used to hydrogenate every π bond to completion. (When the reaction was performed with excess hydrogen gas, only compound B was obtained.) When the products were separated, they were reacted with ozone followed by dimethylsulfide. Compound B did not react under these conditions. Compound C yielded acetic acid and butanoic acid. Compound D yielded acetaldehyde and glyoxal (CHOCHO as shown below). Compound E yielded acetaldehyde and butanal. Draw the structures for compounds A-E in the space provided. (20 points)

b. (5) Which compound (B-E) would react the fastest with HBr? (circle the correct answer)

B C D E

c. (5) Which compound (B-E) would react the slowest with HBr?

B C D E