1. Provide names or structures for the following. 2 points each. Specify stereochemistry when appropriate!

\[
\begin{align*}
\text{Cl} & \quad \text{trans-4-methyl-1-chlorocyclohexane} \\
\text{Br} & \quad (R)-2\text{-bromobutane} \\
\end{align*}
\]

\[
\begin{align*}
\text{Cl} & \quad \text{Z-2-chloro-2-hexene} \\
\end{align*}
\]

\[
\begin{align*}
\text{Cl} & \quad \text{m-butylphenol} \\
\end{align*}
\]

2. Identify the functional groups in the following molecule. (4 points)

\[
\begin{align*}
\text{alkene} & \quad \text{ester} \\
\text{arene} & \quad \text{aromatic} \\
\end{align*}
\]
3. Predict the major products for the following reactions. Pay careful attention when orientation is a factor. Draw just one major product in each case. (3 points each)

\[
\text{OCH}_3 + \text{CN} + \text{CN} \rightarrow \text{CN} \text{CN} \quad \text{CH}_3 \text{O} \\
\text{Br}_2, \text{hv} \\
\text{Me}_2\text{S} \\
\text{NaOCH}_3 \\
\text{OsO}_4, \text{H}_2\text{O}_2 \\
\text{HBr} \\
\text{Br}_2, \text{FeBr}_3 \quad \text{Zn(Hg), HCl} \quad \text{Br}_2, \text{hv} \\
\text{H}_2\text{O}, \text{Hg(OAc)}_2 \quad \text{NaBH}_4
\]
4. Classify the pairs of molecules as totally different, identical, structural isomers, diastereomers, or enantiomers. (2 points each)

![Structural images](image1)

**enantiomers**

**structural isomers**

identical

5. Classify each chiral carbon as R or S. (2 points each)

![Chiral carbon images](image2)

6. Classify the hybridization and bond angles (109, 120, or 180) at the labelled atoms. (5 points)

![Bond angles and hybridization](image3)

<table>
<thead>
<tr>
<th>Atom</th>
<th>Hybridization</th>
<th>Bond Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>sp²</td>
<td>120</td>
</tr>
<tr>
<td>C-2</td>
<td>sp³</td>
<td>109</td>
</tr>
<tr>
<td>C-3</td>
<td>sp²</td>
<td>120</td>
</tr>
<tr>
<td>O-4</td>
<td>sp³</td>
<td>109</td>
</tr>
</tbody>
</table>
7. Draw the mechanisms for the following reactions. For any radical reactions, draw propagation steps only. 5 points each.

\[ \text{OCH}_3 \text{Cl} \rightarrow \text{AlCl}_3 \rightarrow \text{OCH}_3 \]

\[ \text{Cl} \rightarrow \text{Cl} \rightarrow \text{AlCl}_3 \rightarrow \text{Cl} \]

\[ \text{PhH} \rightarrow \text{Cl} \rightarrow \text{H} \]

\[ \text{Br}_2, \text{hv} \rightarrow \text{PhH} \rightarrow \text{Br} \rightarrow \text{Br} \]

\[ + \text{H-Br} \]

\[ \text{Br}_2, \text{H}_2\text{O} \rightarrow \text{Br} \rightarrow \text{OH} \]

\[ -\text{H}^+ \]

\[ \text{Br}_2 \rightarrow \text{Br} \rightarrow \text{Br} \]

\[ + \text{Br}_2 \]

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

\[ + \text{Br}_2 \]

\[ 4 \]
8. Draw the products of the following multi-step sequences. (4 points each)

- **Ph**
  - 1. NaOH
  - 2. HBr, peroxides
  - 3. NaOMe

- **CH₃**
  - 1. SO₃, H₂SO₄
  - 2. 2-bromopropane, AlCl₃
  - 3. H₂O, H⁺

- **OH**
  - 1. H₂SO₄
  - 2. HBr, Peroxides
  - 3. NEt₃

9. Draw as many structural isomers as you can for C₆H₁₄. Circle any that are chiral. (Note: be careful! You will lose points for any repeats!) (6 points)

- C₆H₁₄
  - EU = 0 no rings or alkenes
  - 6
  - 4
  - 5

None are chiral
10. Rank the Following, from most to least. 2 points each.

a. Reactivity toward $S_N2$

\[
\begin{align*}
\text{I} & > \text{Br} > \text{Cl} \\
\text{E} & > 2^\circ
\end{align*}
\]

b. Stability

\[
\begin{align*}
\text{1} & \text{ allylic} > \text{isolated} \\
\text{2} & 3^\circ > 2^\circ > 1^\circ
\end{align*}
\]

c. Stability

\[
\begin{align*}
\text{1} & \text{ Equatorial preferred} \\
\text{2} & \text{If forces to be axial, worse for big group than for smaller group}
\end{align*}
\]

d. Acidity

\[
\begin{align*}
\text{1} & \text{ Anion stability} \\
\text{2} & \text{HCl by memory is strong} \\
\text{3} & \text{Electronegativity factor} \\
\text{4} & \text{Resonance factor}
\end{align*}
\]

e. Stability

\[
\begin{align*}
\text{1} & \text{ staggered vs eclipsed} \\
\text{2} & \text{Anti} > \text{gauche} \\
\text{3} & \text{Eclipsed} > \text{total eclipsed}
\end{align*}
\]

f. Reactivity toward $H_2SO_4$ catalyzed dehydration

Cation stability is key

\[
\begin{align*}
\text{1} & \\
\text{2} & \\
\text{3} &
\end{align*}
\]

g. Boiling Point

\[
\begin{align*}
\text{1} & \text{ Hydrogen bonding} \\
\text{2} & \text{Molecular weight factor}
\end{align*}
\]
11. Provide reagents for the following transformations. You may use anything you like. Each can be done within \( \leq 3 \) steps. (4 points each)

\[
\begin{align*}
1. \text{NBS + peroxides or } & \text{Br}_2, \text{ hv} \\
2. & \text{E} \\
\end{align*}
\]

12. Provide the appropriate reactant for the following transformation. (3 points)
13. Suggest a structure for X, given the following info: (5 points)

- Formula: $C_8H_{12}$
- It reacts with excess H$_2$/Pt to produce $C_8H_{16}$
- When it reacts with O$_3$/Me$_2$S, one of the products is CH$_3$=O.

14. Which of the following are aromatic

15. Draw the products and mechanism for the following reaction:

16. Rank the following:

- Diene-wise: 3
- Dienophile-wise: 1
- Nuc: $\text{Br} > \text{Cl}$