A note about drawing structures: you should make your drawings as clear as possible to understand - stereochemistry should be indicated unambiguously using conventional drawing techniques (e.g., bold wedges and dashes). You may use line structures, Kekulé structures, or condensed structures. If you use the latter two options, you must include the proper number of hydrogens.

If you need scrap paper or more room, use the back of the test pages.

Please read through each problem carefully. Enter your answers in the spaces provided.
1. For the following pairs of compounds, check the appropriate box which best describes their relationship. (10 points)

<table>
<thead>
<tr>
<th></th>
<th>identical</th>
<th>enantiomers</th>
<th>diastereomers</th>
<th>constitutional isomers</th>
</tr>
</thead>
<tbody>
<tr>
<td>HO-Cl</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Cl-OH</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>OH-Cl</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Cl-OH</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Br-Cl</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Cl-Br</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>HO-Cl</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Cl-OH</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

2. Indicate (by circling the structure) which of the following molecules are optically active. (8 points)

- OH-CH₃
- CH₃CH₂NCH₃
- HO-C-C=CH₃
- HO-C=C=CCH₃
- N-HCl
- CH₃
- Cl-Cl
- HO₂C-CH₃
3. Answer True or False for the following statements. (10 points)

a. (2R,3S)-2,3-dichlorobutane will rotate plane polarized light.

b. Free radical bromination is more selective for 3° positions than chlorination.

c. The carbocation intermediate formed in a $S_N 2$ reaction is lower in energy than the carbocation formed in a $S_N 1$ reaction.

d. Tertiary chlorides can be easily prepared from the corresponding alcohol with HCl.

e. A mixture of enantiomers can be readily separated based on their different boiling points.

4. For the following molecules, draw an arrow to each of the stereogenic centers and indicate their absolute configuration using R or S. (12 points)

5. For each of the following reactions, indicate whether the products will be . . . (12 points)

A - a racemic mixture of enantiomers
B - a mixture of diastereomers which are both optically active (not necessarily equal mixture)
C - a mixture of diastereomers which are both racemic (not necessarily equal mixture)
D - a meso compound

Also indicate what type of change is occurring (oxidation, reduction, no change) overall.
6. Draw the major organic product for the following reactions. Be sure to indicate any stereochemistry where necessary. (19 points)

- [Diagram of compound with structure and reactions]
  - 1) OsO₄, then NaHSO₃
  - 2) HIO₄

- [Diagram of compound with structure and reactions]
  - NBS, light

- [Diagram of compound with structure and reactions]
  - 1) Mg
  - 2) CH₃OH

- [Diagram of compound with structure and reactions]
  - H₂, Lindlar Catalyst

- [Diagram of compound with structure and reactions]
  - 1) NaNH₂
  - 2) CH₃Cl

- [Diagram of compound with structure and reactions]
  - 1) HBr (1 eq)
  - 2) Cl₂ (1 eq)
7. Provide the necessary starting compound to carry out the following transformations. (15 points)

8. An unknown hydrocarbon with a molecular formula $C_{9}H_{14}$ reacts with $H_{2}$ over Pd/C to absorb 3 equivalents of hydrogen. When first treated with Li in NH$_3$ and then hydrogenated over Pd/C, only two equivalents of hydrogen gas were absorbed. In addition, treatment with ozone afforded the three products shown below. What is the structure of the unknown molecule? (5 points)
9. How would you carry out the following transformation? More than one step may be necessary. Show all reagents and intermediate structures. (9 points)

BONUS: Give a specific example of the Finkelstein reaction showing all reactants and the solvent that is typically used. (2 points)