Before you begin this exam: First: You are allowed to have a simple model set at your seat. Please put away all other materials. Second: Place your student identification on your desk. A proctor will come around to check everyone’s ID. Third: Read through the entire exam. Your goal, as always, is to score as many points as possible. Do not waste time on problems that you can’t do if there are others that look easy. Fourth: It is critically important that your answers be written in a clear, unambiguous manner. Answers in which your intentions are unclear will not receive credit. Fifth: READ THE INSTRUCTIONS FOR EACH PROBLEM. You have until 11:30 to complete this exam. There will be no extensions, so budget your time carefully.

If you wish to have your exam score posted beside your student ID number in the glass case (1st floor, CP Building, behind CP-139) with the exam key, place an ‘X’ in this space. If you do not mark this space, your exam score will not be posted.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Points</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
1. (12 points) For each of the following compounds or ions, determine if each of they are aromatic, antiaromatic, or if they are simply "normal" alkenes (neither aromatic nor antiaromatic).

![Chemical structures](image)

2. (25 points) Provide the expected organic product of the following reactions. If the reaction stereospecific, show the stereochemistry in the product. If you believe that no reaction will occur, write "no reaction." Do any 5 of a) - g). If you answer more than 5, we will grade the first 5.

a)

![Chemical reaction](image)

b)

![Chemical reaction](image)

c)

![Chemical reaction](image)

d)

![Chemical reaction](image)
3. (10 points) Draw a viable mechanism for the transformation below. Be very careful with your use of mechanism arrows.

\[
\begin{align*}
\text{Ph} & \quad \text{OTs} \quad \text{NaOH} \\
\text{Ph} & \quad \text{OH} \quad \rightarrow \\
\end{align*}
\]
4. (6 points) ortho-Xylylene (below) is an *extraordinarily* reactive Diels-Alder diene, much more reactive than other dienes that are also locked in the s-cis conformation. Explain why o-xylylene is so reactive. **Do not exceed the space provided.**

![Diels-Alder reaction](image)

5. (10 points) Propose a viable synthesis of the compound below, starting from any compounds containing *four carbons or less.*

![Proposed synthesis](image)
6. (12 points) Provide the reagents needed for any 3 of the transformations shown below. Please provide specific reagents (i.e. "HCl" rather than "acid" or "H+”). If more than one step is needed, show the reagents needed for each step. If you provide more than 3, we will only grade the first 3 we see.

7. (5 points) Free-radical, photochemical halogenation of the optically pure compound below results in formation of the benzylic chloride shown. Based on your knowledge of the mechanism of such reactions, predict whether the product will be formed as the R enantiomer, the S enantiomer, or as a mixture of the two. (just state R, S, or mixture)
8. (10 points) Show the products of the following Diels-Alder reactions, clearly indicating the stereochemistry.

a)

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

\[
\text{H} + \text{CH} \quad \text{H} \quad \text{CH} \quad \text{OH} 
\]

b)

\[
\text{OCH}_3 \quad \text{CO}_2\text{Et} 
\]

\[
\text{CO}_2\text{Et} 
\]

9. (10 points) The heteroaromatic compound *imidazole* is a very common organic base, and forms the sidechain of the amino acid *histidine*. Interestingly, only one of the nitrogens is basic. This means that the lone pair on one of the nitrogens can be easily protonated, but the lone pair on the other cannot.

Show which lone pair is **NOT** easily protonated, and explain it is so much less reactive than the other lone pair. Do not exceed the space provided.