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. If you do not have ID, tell the proctor. 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 75 minutes to complete this exam. There will be no extensions, so budget your time carefully.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Points</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
1. (6 points) Label each of the following as either an acid, acid chloride, aldehyde, amide, anhydride, ester, or ketone. You may use labels more than once, if appropriate.

\[
\begin{array}{c}
\text{PhO-} \text{O-Ph} \\
\text{PhOH} \\
\text{PhO-CH}_3 \\
\text{PhO-N}\text{CH}_3 \\
\text{PhO-CH}_3 \\
\text{PhO}\text{Cl}
\end{array}
\]

2. (8 points) In each pair, circle the compound that you believe will be the most acidic.

\[
\begin{array}{c}
\text{PhO} \text{H} \\
\text{PhCH}_3 \\
\text{PhO-CH}_3 \\
\text{PhCH}_3 \\
\text{PhCH}_3 \\
\text{PhCH}_3
\end{array}
\]
3. (10 points) Circle the end of the equilibrium that will be favored in each of the following reactions. Assume equal concentrations of the species on the left side.

a) 
\[ \text{EtCO} + \text{H}_2\text{NCH}_3 \rightleftharpoons \text{EtCONH} + \text{HOCH}_2\text{CH}_3 \]

b) 
\[ \text{EtCO} + \text{HCl} \rightleftharpoons \text{EtCOCl} + \text{HOCH}_2\text{CH}_3 \]

c) 
\[ \text{CH}_3\text{CH}_2\text{CO} + \text{HCl} \rightleftharpoons \text{CH}_3\text{CH}_2\text{Cl} + \text{HO} \]

d) 
\[ \text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{2 eq. CO} \]

e) 
\[ \text{NH}_2\text{C} + \text{CO} \rightleftharpoons \text{CO} + \text{NH}_2\text{C} \]
4. (30 points) Provide the expected organic product from the following reactions. **DO ANY SIX OF THE SEVEN GIVEN.**

a) ![Chemical Structure]

1. LiAl₄
2. H₂O, HCl

b) ![Chemical Structure]

1. LiAlH₄
2. H₂O

c) ![Chemical Structure]

1. SOCl₂
2. CH₃CH₂OH

d) ![Chemical Structure]

![Chemical Structure]

(DCC)

e) ![Chemical Structure]

H₂O, HCl
heat

f) ![Chemical Structure]

NaOCH₃
5. (6 points) Fill the boxes below with either the appropriate reagents (be sure to indicate any multiple step reaction sequences as 1) reagent A; 2) reagent B.

\[ \text{CH}_3\text{C}_\text{H}_2\text{Br} \text{ (1) } \text{LDA; 2) PhCH}_2\text{Br} \text{ (2) CH}_3\text{OH, H}_2\text{SO}_4 \]
6. (10 points) Provide a viable mechanism for the following reaction. Pay attention to the use of mechanism arrows, and watch every proton transfer step! NOTE: DO NOT ADD ANY ADDITIONAL REAGENTS!

\[
\begin{align*}
\text{Cyclohexanone} & \quad \text{NaH} \\
\rightarrow & \\
\text{Carboxyethyl cyclohexanone}
\end{align*}
\]

7. (10 points) The direct alkylation of cyclohexanone can be done, but is plagued with several side reactions. In a sentence or two, a) state the side reactions that can occur in the alkylation of cyclohexanone, and b) state why alkylation of carboxyethyl cyclohexanone is so much cleaner.

\[
\begin{align*}
\text{Cyclohexanone} & \\
\text{Carboxyethyl cyclohexanone}
\end{align*}
\]
8. (20 points) Provide viable syntheses for the compounds below, using only benzene, inorganic reagents, triphenylphosphine, LDA, and organic reagents of 3 carbons or less, unless other reagents are mentioned. **DO ANY TWO OF THE FOUR GIVEN.**

a) Use the malonic ester route to prepare the acid shown below, starting from cyclohexyl bromide and other reagents of 3 carbons or less:

\[
\text{EtO}_2\text{C}_-\text{CO}_2\text{Et} \xrightarrow{\text{Several steps}} \text{CO}_2\text{H}
\]

b) Show how the ketone below can be made from ethyl acetoacetate, benzyl bromide, and other reagents of 3 carbons or less:

\[
\text{O} \quad \text{O} \quad \xrightarrow{\text{Several steps}} \quad \text{O}
\]
c) Show how Aklomide (a veterinary antibacterial agent) can be prepared from toluene. Show all reagents and all intermediate compounds.

\[ \text{Several steps} \]

\[ \text{CH}_3 - \text{C}_6\text{H}_4 - \text{Cl} \]

\[ \text{O} \]

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

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]

\[ \text{Z} \]

\[ \text{E} \]

\[ \text{N} \]

\[ \text{O} \]

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

\[ \text{Cl} \]

\[ \text{NO}_2 \]

\[ \text{Several steps} \]

\[ \text{EtO}_2\text{C} - \text{C}_6\text{H}_{11} - \text{CO}_2\text{Et} \]

\[ \text{OH} \]