1. FUNdamentals

(a) (10 points) Use curved arrow notation and draw two resonance structures for the radical below.

*move the radical*  — half credit for not moving radical

(b) (15 points) Classify each carbocation as 1°, 2°, or 3° and whether it is alkyl, allylic, or benzylic. Circle the classifications below each example.

(c) (20 points) The arrow story – indicate the bond(s) broken and/or formed according to arrows (i) through (iv) in the mechanism below. Then draw the products.

(i) \( \text{O-H formed} \)
(ii) \( \text{O-H broken} \)
(iii) \( \text{C=O broken} \)
(iv) \( \text{C-H formed} \)

(d) (5 points) Add arrows to explain the transformation below.
2. Acids & Basics

(a) (10 points) The following compounds are arranged from most (left) to least (right) acidic. Fill in the pKa values of each in the boxes provided.

<table>
<thead>
<tr>
<th>Compound</th>
<th>pKa</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>1</td>
</tr>
<tr>
<td>H3O+</td>
<td>0</td>
</tr>
<tr>
<td>O</td>
<td>5</td>
</tr>
<tr>
<td>NH4+</td>
<td>10</td>
</tr>
<tr>
<td>H2O</td>
<td>19</td>
</tr>
<tr>
<td>NH3</td>
<td>35</td>
</tr>
<tr>
<td>CH4</td>
<td>50</td>
</tr>
</tbody>
</table>

(b) (10 points) Rank the following sets of acids from **most acidic** (1) to **least acidic** (5), where #3 is provided. Put your answers in the box below each compound.

(c) (15 points) Draw the **products** of the following acid-base reaction.

(d) (15 points) Indicate (**circle**) whether the arene substituent is an **activator** or **deactivator** and whether it is an **ortho / para** or **meta** director in electrophilic aromatic substitution. Draw one resonance structure and explain your choices.
3. (50 points) **What’s in the Box?!** – Fill in the missing reactants, reagents, and products.

(a) 

\[
\begin{align*}
\text{HCOCH}_3OCH_3 & \xrightarrow{1. \text{NaBH}_4} \xrightarrow{2. \text{H}_3\text{O}^+} \\
\text{HOCH}_2CO \text{OCH}_3
\end{align*}
\]

(b) 

\[
\begin{align*}
\text{HOCH}_3OCH_3 & \xrightarrow{1. \text{NaBH}_4} \xrightarrow{2. \text{H}_3\text{O}^+} \\
\text{HOCH}_2CO \text{OCH}_3
\end{align*}
\]

(c) 

\[
\begin{align*}
\text{HOCH}_3OCH_3 & \xrightarrow{1. \text{NaBH}_4} \xrightarrow{2. \text{H}_3\text{O}^+} \\
\text{HOCH}_2CO \text{OCH}_3
\end{align*}
\]

(d) 

\[
\begin{align*}
\text{HOCH}_3OCH_3 & \xrightarrow{1. \text{NaBH}_4} \xrightarrow{2. \text{H}_3\text{O}^+} \\
\text{HOCH}_2CO \text{OCH}_3
\end{align*}
\]

(e) 

\[
\begin{align*}
\text{HOCH}_3OCH_3 & \xrightarrow{1. \text{NaBH}_4} \xrightarrow{2. \text{H}_3\text{O}^+} \\
\text{HOCH}_2CO \text{OCH}_3
\end{align*}
\]

(f) 

\[
\begin{align*}
\text{HOCH}_3OCH_3 & \xrightarrow{1. \text{NaBH}_4} \xrightarrow{2. \text{H}_3\text{O}^+} \\
\text{HOCH}_2CO \text{OCH}_3
\end{align*}
\]
4. (50 points) Reaction Puzzles

Puzzle 1 – Fill in all missing reagents and products in the boxes.

1. CH₃MgBr
2. H₃O⁺

Puzzle 2 – Fill in all missing reagents and products in the boxes.

5 pts/box

any strong base
5. (50 points) **Mechanisms**

Draw the arrow-pushing mechanisms for both reactions. Be sure to clearly indicate all charged atoms and intermediates after each step (each mechanism involves at least two intermediates).
6. (50 points) Multi-Step Synthesis – Choose any two

Carry out two synthesis problems below using the starting material provided and any other reagents or sources of carbon needed. **Show the product after each reaction.** No mechanisms. Partial credit is given where possible so if you’re stuck, take a deep breath then work backwards and/or forwards.

(a)

(b)

(c)