In each of the following problems, use your knowledge of organic chemistry conventions to answer the questions in the proper manner. **Be sure to read each question carefully.** You have most of the class period to complete this exam (2 hrs), but hopefully you won't need it! **Pay attention to provided point values and instructions to skip problems on pages 1, 3, 5, and 6 to use your time wisely.** You are welcome to use pre-built models.

Keep your eyes on your own paper. Electronic devices of any kind are not allowed, including cell phones and calculators. Any student found using any of said devices, or found examining another student’s exam or ‘cheat sheet’, will be promptly removed from the exam room and will receive a zero on this exam. Such an incident will be reported to the UCSC Judiciary Affairs Committee, which determines the consequences (it’s not worth it).

*Breathe, do your best, and take it one problem at a time!*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(40)</td>
</tr>
<tr>
<td>2</td>
<td>(40)</td>
</tr>
<tr>
<td>3</td>
<td>(50)</td>
</tr>
<tr>
<td>4</td>
<td>(70)</td>
</tr>
<tr>
<td>5</td>
<td>(50)</td>
</tr>
<tr>
<td>6</td>
<td>(50)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>/ 300</td>
</tr>
<tr>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>
1. Nomenclature

(a) (15 points) Rates and substitution patterns in **electrophilic aromatic substitution (EArS) reactions** change depending on the groups attached to the ring. In the box below each benzene derivative, indicate whether the next EArS reaction would be directed to the *ortho & para (o/p)* positions or *meta (m)* position.

Also **circle** whether the next EArS reaction would occur faster or slower than benzene.

(b) (25 points) **Draw structures** corresponding to any five of the following names **(skip one, by drawing a large X over the name)**.

- 2,4-hexanediol
- (E)-2-ethyl-2-buten-1-ol
- *para*-hydroxyacetophenone
- (5S)-5-hydroxy-3-oxohexanal
- Isopropyl methyl ether
- 3-methoxypentane
2. Acid-Base Chemistry

(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.

(b) (10 points) Rank the following sets of compounds in terms of acidity where 1 is the most acidic and 4 is the least acidic.

Set 1

<table>
<thead>
<tr>
<th>HO-</th>
<th>HO-</th>
<th>O-</th>
<th>O-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Br</td>
<td>N</td>
<td>Cl</td>
<td>H</td>
</tr>
<tr>
<td>OH</td>
<td>OH</td>
<td>OH</td>
<td>OH</td>
</tr>
<tr>
<td>Cl</td>
<td>Cl</td>
<td>Cl</td>
<td>Cl</td>
</tr>
<tr>
<td>OH</td>
<td>OH</td>
<td>OH</td>
<td>OH</td>
</tr>
<tr>
<td>OH</td>
<td>OH</td>
<td>OH</td>
<td>OH</td>
</tr>
<tr>
<td>OH</td>
<td>OH</td>
<td>OH</td>
<td>OH</td>
</tr>
</tbody>
</table>

Set 2

(c) (20 points) Draw two non-equivalent resonance structures of aniline that explain why it directs the next EArS substituent to the ortho and para positions. Use curved arrow notation to tell the story of this electron dance. No verbal explanation necessary.
3. (50 points) **Single Step Reactions** – Choose five, skip one reaction (“X” it out, otherwise a-e are graded). Fill in the **missing product, reagent, and reactants** in the reactions below.

(a)

\[
\begin{align*}
\text{H}_3\text{C}-\text{CO}-\text{CO}-\text{CH}_3 & \quad 1. \text{LiAlH}_4 \\
& \quad 2. \text{H}_3\text{O}^+ \quad \square
\end{align*}
\]

(b)

\[
\begin{align*}
\text{Cyclohexanol} & \quad \text{CrO}_3 \\
& \quad \text{H}_2\text{SO}_4 \quad \square
\end{align*}
\]

(c)

\[
\begin{align*}
\text{H}_3\text{C}-\text{CO}-\text{CH}_2-\text{CO} & \quad 1. \quad \square \\
& \quad 2. \quad \text{H}_3\text{C}-\text{CO}-\text{CH}_2-\text{COH} \quad \text{H}_3\text{C}-\text{CO}-\text{CH}_2-\text{COH}
\end{align*}
\]

(d)

\[
\begin{align*}
\text{HO-CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{OH} & \quad 1. \text{Excess CH}_3\text{MgBr} \\
& \quad 2. \text{H}_3\text{O}^+ \quad \square
\end{align*}
\]

(e)

\[
\begin{align*}
\text{PhOH} & \quad \square \\
& \quad \text{PhCHO}
\end{align*}
\]

(f)

\[
\begin{align*}
\text{PhNH}_2 & \quad \text{Cl}_2 \\
& \quad \text{FeCl}_3 \quad \text{PhNO}_2
\end{align*}
\]

3____
4. (70 points) Reaction Puzzle — Fill in the missing reagents and products.
5. Mechanisms – complete any two mechanisms. Skip one by placing a large X over the entire reaction, otherwise the first two will be graded.

(50 points) Show the product and full arrow-pushing mechanisms for any two reactions (including all acid-base steps). Be sure to clearly indicate all charged atoms and intermediates after each step. Redraw given structures to clearly indicate bonds broken if necessary.

\[
\text{ClOH} \quad \text{NaH} \quad \text{ClO}\]

\[
\text{OH} \quad \text{H}_2\text{SO}_4 \quad \text{H}_2\text{O}, \Delta \quad \text{+ H}_2\text{O}
\]

\[
\text{Cl} \quad \text{AlCl}_3 \quad \text{Ph}
\]

Draw a large X over the problem to skip – we will not choose the best one for you!
6. (50 points) Multi-Step Synthesis – Choose any two

Carry out the synthesis of the indicated target molecules 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 your way backwards and/or forwards. Don’t forget to count your carbons!

**CHOOSE ANY TWO, SKIP TWO, LARGE X OVER PROBLEMS TO SKIP**

(a)  
\[ \text{starting material} \rightarrow \text{product} \]

(b)  
\[ \text{starting material} \rightarrow \text{product} \]

(c)  
\[ \text{starting material} \rightarrow \text{product} \]

(d)  
\[ \text{starting material} \rightarrow \text{product} \]

Draw a large X over the problem to skip – we will not choose the best one for you!