This exam is a closed book, closed notes. Calculators and molecular model sets are allowed. **Time limit: 120 minutes**

Question I (10 points): ________________
Question II (24 points): ________________
Question III (20 points): ________________
Question IV (20 points): ________________
Question V (26 points): ________________

Total (out of 100) : _____________________
Question I. Multiple Choice (10 pts)

1. Which structure is NOT an intermediate in the following reaction?

\[
\begin{align*}
\text{Catalytic } H^+ & \quad \text{CH}_3\text{CH}_2\text{OH} \\
\text{OCH}_2\text{CH}_3 & \quad \text{OCH}_2\text{CH}_3
\end{align*}
\]

\[
\begin{align*}
(a) & \quad \begin{array}{c}
\text{H} \\
\text{O} \\
\text{H}
\end{array} \\
(b) & \quad \begin{array}{c}
\text{O} \\
\text{H} \\
\text{H}
\end{array} \\
(c) & \quad \begin{array}{c}
\text{OH} \\
\text{H} \\
\text{H}
\end{array} \\
(d) & \quad \begin{array}{c}
\text{OH}_2 \\
\end{array}
\end{align*}
\]

2. Which of the following is the least reactive toward Friedel-Crafts conditions?

\[
\begin{align*}
(a) & \quad \begin{array}{c}
\text{CH}_3
\end{array} \\
(b) & \quad \begin{array}{c}
\text{Cl}
\end{array} \\
(c) & \quad \begin{array}{c}
\text{OCH}_3
\end{array} \\
(d) & \quad \begin{array}{c}
\text{NO}_2
\end{array}
\end{align*}
\]

3. Which is the more basic N atom? Explain briefly.

\[
\begin{align*}
\begin{array}{c}
\text{H} \\
\text{N}
\end{array} & \quad \begin{array}{c}
\text{H} \\
\text{N}
\end{array}
\end{align*}
\]

(a) Nitrogen atom 1 is more basic because its conjugate acid maintains aromaticity.
(b) Nitrogen atom 1 is more basic because its lone pair is delocalized.
(c) Nitrogen atom 2 is more basic because its lone pair is delocalized.
(d) Nitrogen atom 2 is more basic because the N-H proton is weakly acidic.

4. For a reaction that generates both kinetic and thermodynamic products, which of the following is associated with the thermodynamic product?

(a) It is formed faster.
(b) It is the more stable product.
(c) It involves the lower energy transition state.
(d) It is favored with cold reaction conditions.

5. Which of the following is NOT associated with the Diels-Alder reaction?

(a) ring formation
(b) s-cis diene conformation
(c) carbocation intermediate
(d) [4+2] cycloaddition
6. Which set of starting materials could be used to prepare the following compound in one step?

![Chemical structure]

(a) \(\text{MeO} + \text{RCO}_2\text{H}\)
(b) \(\text{MeO} + \text{CHO} + \text{MeO}\)
(c) \(\text{MeO} + \text{CHO} + \text{MeO}\)
(d) \(\text{MeO} + \text{CHO} + \text{MeO}\)

7. Identify the hydrolysis products expected when the following compound is treated with \(\text{H}_3\text{O}^+\).

![Chemical structure]

(a) \(\text{HO} - \text{C} - \text{OH}\) + \(\text{HO} - \text{OH}\)  
(b) \(\text{HO} - \text{C} - \text{OH}\) + \(\text{OH}\)
(c) \(\text{HO} - \text{C} - \text{OH}\) + \(\text{OH}\)
(d) \(\text{HO} - \text{C} - \text{OH}\) + \(\text{OH}\)

8. Which of the following is least likely to undergo an \(\text{S}_\text{N}1\) reaction with \(\text{EtOH}\)?

(a) \(\text{PhBr}\)  
(b) \(\text{C_{6}H_{5}Br}\)  
(c) \(\text{CH}_2\text{=CHBr}\)  
(d) \(\text{C}_{6}\text{H}_{4}\text{Br}\)

9. Which of the following does NOT represent a likely intermediate in the mechanism of the given reaction?

![Chemical structure]

(a) \(\text{MeO} + \text{Ph}\)  
(b) \(\text{C} + \text{MeO}\)  
(c) \(\text{MeO} + \text{Ph}\)  
(d) \(\text{MeO} + \text{Ph}\)
10. Why is the following compound NOT aromatic?

![Chemical structure]

(a) An electron-count of 10 does not follow Hückel's rule.
(b) It does not have contiguous p orbitals.
(c) An aromatic compound cannot be larger than an 8-membered ring.
(d) The ring cannot achieve a planar conformation.

**Question II. (24 pts)**

A) **Provide a systematic (IUPAC) name** for each of the following structures or **draw the structure** for each compound below: (5 pts)

<table>
<thead>
<tr>
<th>Propanedial</th>
<th>2-bromo-5-nitrobenzaldehyde</th>
<th>(S)-3-Phenylbutanal</th>
</tr>
</thead>
</table>

![Chemical structures]

B) Identify each of the following as aromatic, nonaromatic, or antiaromatic. (5 pts)

![Chemical structures]

C) Explain the vast difference in pKa values for the following two apparently similar compounds. (3 pts)

(a) ![Chemical structure] pKa = 16  
(b) ![Chemical structure] pKa = 36
D) Determine which compound is expected to exhibit a larger dipole moment and explain your choice. (3 pts)

![Dienophiles](image)

E) Rank the following compounds in order of increasing reactivity toward electrophilic aromatic substitution. (3 pts)

(a) ![Compounds](image) (b) ![Compounds](image) (c) ![Compounds](image) (d) ![Compounds](image) (f) ![Compounds](image)

F) Rank the following dienophile in terms of reactivity in a Diels-Alder reaction. (2 pts)

(a) ![Dienophile](image) (b) ![Dienophile](image) (c) ![Dienophile](image)

G) The following reaction start with a chiral compound but end with an optically inactive product. Please explain why the chiral center was racemized. (3 pts)

![Reaction](image)

Question III. Reactions (20 pts)
Please provide major product or the starting materials for the following reactions, making sure to consider the regio- and stereo-chemical outcome

![Reactions](image)
Heat

1) NBS (1 eq.), heat
2) t-BuOK

\[ \text{Heat} \]

1) AlCl\(_3\), CH\(_3\)Cl
2) KMnO\(_4\), H\(_2\)O, heat
3) H\(_3\)O\(^+\)

\[ \text{Heat} \]

Heat

\[ \text{Heat} \]

\[ \text{Heat} \]

Heat

Heat
Question IV. Mechanism (20 pts)
Please provide the product(s) and detailed electron-pushing mechanism of the following reaction.
Question V. Synthesis and NMR Problems (26 pts)

A) Please propose an efficient synthesis for each of the following transformations. (Please draw the intermediate structures together with the correct conditions for every step to earn full credits. 21 pts total)

\[
\begin{align*}
\text{O} & \quad \text{Br} \\
\text{CBr}_3
\end{align*}
\]

\[
\begin{align*}
\text{O} & \quad \text{NO}_2 \\
\text{Cl}
\end{align*}
\]
B) Deduce the structure of a compound with the molecular weight m/z = 96. $^1$H NMR and $^{13}$C NMR shown below. (5 pts)

The end!