1. a. (8 pts.) For each of the molecules drawn below circle the nucleophilic atom.
   b. (8 pts.) For each pair of molecules drawn below determine which molecule or atom would be the better nucleophile under the stated conditions.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>i.</td>
<td>ii.</td>
</tr>
<tr>
<td>[Chemical structure]</td>
<td>[Chemical structure]</td>
</tr>
<tr>
<td>Circle the nucleophilic atom.</td>
<td>Circle the nucleophilic atom.</td>
</tr>
<tr>
<td>dissolved in</td>
<td>dissolved in</td>
</tr>
<tr>
<td>[Chemical structure]</td>
<td>[Chemical structure]</td>
</tr>
</tbody>
</table>

2. (6 pts. ea.) Predict the outcome of the following nucleophilic substitution reactions if the reaction occurs via the indicated mechanism. Remember to indicate the stereochemistry of the product using wedged (\(\searrow\)) and dashed (\(\cdots\)) bonds where appropriate.

   a. \(\text{S}_2\) + NaSCH\(_2\)CH\(_3\) → [Chemical structure]
   b. \(\text{S}_1\) + HOCH\(_2\)CH\(_3\) → [Chemical structure]

3. (10 pts) Draw a mechanism that explains the outcome of the following substitution reaction. Please remember to include electron movement arrows.

\[
\text{[Chemical structure]} + \text{HBr} \rightarrow \text{[Chemical structure]} + \text{HBr}
\]
4. (3 pts. ea.) Determine whether the following reactants are likely to react via an S\textsubscript{N}1 or an S\textsubscript{N}2 mechanism.

a. \[
\text{CH}_3\text{OH} \quad \text{Cl}
\]

b. \[
\text{NaOCH}_3 \quad \text{Br}
\]

c. \[
\text{NaSCH}_3 \quad \text{I}
\]

d. \[
\text{HOH} \quad \text{Cl}
\]

5. (3 pts. ea.) Predict the organic products for the following elimination reactions. Draw all likely structural and stereochemical isomers that are produced by the reactions.

a. \[
\text{E}_1 \quad \text{HO} \quad \text{H}_2\text{PO}_4 \quad \text{H}_2\text{SO}_4 \quad \Delta
\]

b. \[
\text{E}_2 \quad \text{Br} \quad \text{NaOCH}_2\text{CH}_3 \quad \text{HOCH}_2\text{CH}_3
\]

c. \[
\text{E}_2 \quad \text{Br} \quad \text{NaOCH}_2\text{CH}_3 \quad \text{HOCH}_2\text{CH}_3
\]

d. \[
\text{E}_1 \quad \text{Br} \quad \text{HOCH}_2\text{CH}_3 \quad \Delta
\]
6. (4 pts. ea.) For the following elimination reactions, predict the possible products and indicate which are the major products.

a. $$\text{E2} \quad \text{NaOCH}_2\text{CH}_3 \quad \text{HOCH}_2\text{CH}_3$$

b. $$\text{E1} \quad \text{H}_3\text{PO}_4 \quad \text{H}_2\text{SO}_4 \quad \Delta$$

7. (10 pts.) In the following E1 reaction, even though the two products have the same degree of substitution, the major product is one on the left. Explain why this is the expected outcome for this E1 reaction (remember a criss-cross double bond just means all stereoisomers are present).

8. (10 pts.) Below, a transition state for an E2 reaction is drawn. What do the dotted lines mean; respond for each dotted line. Remember to describe what is happening to the bonds.

\[
\begin{align*}
\text{Br} & \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{C} & \quad \text{C} \quad \text{H} \quad \text{H} \\
\text{C} & \quad \text{H} \quad \text{H} \quad \text{O} \\
\end{align*}
\]