1. Consider the following solvents. For each, draw the structure and circle the appropriate solvent classification.

a) isopropanol

Structure:

Classification: (Circle one answer)
- polar, protic
- polar, aprotic
- nonpolar, aprotic

b) DMF

Structure:

Classification: (Circle one answer)
- polar, protic
- polar, aprotic
- nonpolar, aprotic

c) HMPA

Structure:

Classification: (Circle one answer)
- polar, protic
- polar, aprotic
- nonpolar, aprotic

d) Acetone

Structure:

Classification: (Circle one answer)
- polar, protic
- polar, aprotic
- nonpolar, aprotic

e) THF

Structure:

Classification: (Circle one answer)
- polar, protic
- polar, aprotic
- nonpolar, aprotic

f) water

Structure:

Classification: (Circle one answer)
- polar, protic
- polar, aprotic
- nonpolar, aprotic
2. For each compound shown below indicate whether the compound is nucleophilic or electrophilic at the marked atom (*).

a) 
\[
\begin{array}{c}
\text{O} \\
\text{electrophilic}
\end{array}
\]

b) 
\[
\begin{array}{c}
\text{N} \\
nucleophilic
\end{array}
\]

c) 
\[
\begin{array}{c}
\text{Ts} \\
electrophilic
\end{array}
\]

d) 
\[
\begin{array}{c}
\text{H}_2\text{O} \\
nucleophilic
\end{array}
\]

e) 
\[
\begin{array}{c}
\text{Me} \\
electrophilic
\end{array}
\]

3. Consider the following elimination reactions. For each:

a) draw the major product

b) determine if the elimination proceeds by E2 or E1 (circle your answer)

\[
\begin{array}{c}
\text{Br} \\
\text{NaOEt, EtOH}
\end{array}
\]

\[
\begin{array}{c}
\text{E1 or E2}
\end{array}
\]

\[
\begin{array}{c}
\text{Me} \\
\text{MeOH, heat}
\end{array}
\]

\[
\begin{array}{c}
\text{E1 or E2}
\end{array}
\]

\[
\begin{array}{c}
\text{OH} \\
\text{cat. H}_2\text{SO}_4, \text{benzene, heat}
\end{array}
\]

\[
\begin{array}{c}
\text{E1 or E2}
\end{array}
\]

\[
\begin{array}{c}
\text{Br} \\
t-\text{BuO}^- \cdot \text{K}^+, t-\text{BuOH}
\end{array}
\]

\[
\begin{array}{c}
\text{E1 or E2}
\end{array}
\]
4. Consider the following substitution reactions. For each:
   a) draw the major product(s) that arise from substitution
   b) determine if the given substitution takes place by SN2 or SN1 (circle your answer)

   ![Reaction 1](image1)
   ![Reaction 2](image2)
   ![Reaction 3](image3)
   ![Reaction 4](image4)

5. a) Which of the following two substrates would likely undergo faster E2 elimination (circle your answer)?

   ![Substrate A](image5)
   ![Substrate B](image6)

   b) Provide an explanation for your answer that includes 3-dimensional drawings.

   ![Explanation](image7)
6. Rank the following in order of nucleophilicity (1 being most nucleophilic, 4 being the least nucleophilic).

<table>
<thead>
<tr>
<th></th>
<th>CH₃MgBr</th>
<th>EtOH</th>
<th>EtO⁻</th>
<th>t-BuOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

7. Based on your knowledge of pKa values, rank the following in order of leaving group ability (1 being the best leaving group, 4 being the worst leaving group).

<table>
<thead>
<tr>
<th></th>
<th>Br⁻</th>
<th>TsO⁻</th>
<th>−CN</th>
<th>−CH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

8. Draw a reaction coordinate diagram for the following reaction. Be sure to label starting material(s), transition state(s), product(s), activation energy(ies), and intermediate(s) (if applicable).

```
substrate + nucleophile → transition state → product + LG
```

(Generic SN₂ reaction coordinate diagram)
9. Provide reaction conditions for the following transformation (place your answers above and below the reaction arrows).

\[
\begin{align*}
\text{O} & \xrightarrow{\text{NaBH}_4, \text{EtOH}} \text{OH} & & & \xrightarrow{1. \text{TsCl, pyr}} \text{Br} \\
& & & & \xrightarrow{2. \text{NaBr, DMF}} \\
\end{align*}
\]

10. Provide a synthetic scheme for the following conversion.

\[
\begin{align*}
\text{Cl} & \xrightarrow{\text{NaBr, acetone}} \text{Br} & & & \xrightarrow{\text{NaN_3, DMF}} \\
\text{Cl} & \xrightarrow{\text{NaOH, HMPA}} \text{OH} & & & \xrightarrow{\text{TsCl, pyridine}} \text{OTs} \\
\text{Br} & & & & \xrightarrow{\text{NaN_3, DMF}} \\
\end{align*}
\]

11. Amanda has performed a retrosynthetic analysis on Compound F. After performing several disconnections, she arrived at bromobenzene and acetaldehyde (shown below). Provide a forward synthesis of Compound F that relies on Amanda’s strategy.

\[
\begin{align*}
\text{F} & \xrightarrow{1. \text{Mg}} \xrightarrow{2. \text{acetaldehyde}} \text{with aqueous workup} \\
& \text{OH} + \text{H}_2\text{CMe} \\
\end{align*}
\]
12. Grace has performed a retrosynthetic analysis on Compound A. After performing several disconnections, she arrived at allyl bromide and carbon dioxide (shown below). Provide a forward synthesis of Compound A that relies on Grace’s strategy.

![Diagram of retrosynthetic analysis and forward synthesis of Compound A]

13. Draw an arrow-pushing mechanism for the following transformation.

![Diagram of arrow-pushing mechanism]
14. Draw an arrow-pushing mechanism for the following solvolysis experiment.

15. Draw an arrow-pushing mechanism for the following elimination reaction.