1. a. Place the following nucleophiles in order of strength (1 = strongest; 3 = weakest).

\[
\begin{align*}
\text{OH} & \quad \text{O} & \quad \text{O} & \quad \text{ONa} & \quad \text{OH} & \quad \text{NHNa} \\
\text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.}
\end{align*}
\]

b. Place the following in order of leaving group ability (1 = best; 7 = worst).

\[
\begin{align*}
\text{O} & \quad \text{CH}_3 & \quad \text{Br} & \quad \text{CO}_2 & \quad \text{H} & \quad \text{H}_2O & \quad \text{O} \\
\text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.}
\end{align*}
\]

c. Rank these molecules as strong (more effective) or weak (less effective) nucleophiles.

\[
\begin{align*}
\text{O} & \quad \text{CH}_3 & \quad \text{Br} & \quad \text{CO}_2 & \quad \text{CH}_3OH & \quad \text{H}_2O & \quad \text{O} \\
\text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.}
\end{align*}
\]

d. Rank the following in order of increasing reaction via a $S_N1$ mechanism (1 = fastest; 5 = slowest). If a species does not undergo $S_N1$ reactivity, then mark the box with an X. What would be your expected order if you were discussing $S_N2$ reactivity?

\[
\begin{align*}
\text{Cl} & \quad \text{Cl} & \quad \text{Cl} & \quad \text{Cl} & \quad \text{Cl} \\
\text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.} & \quad \text{ii.}
\end{align*}
\]

2. Each carbocation below is capable of rearranging, through either a hydride or methyl shift, to a more stable carbocation. Limiting yourself to a single 1,2-shift, determine the structure for the more stable rearranged carbocation. Be able to explain clearly why the new carbocation would be of higher stability than what is given AND how to use arrows to demonstrate this shift.

\[
\begin{align*}
\text{a.} & \quad \text{b.} & \quad \text{c.} & \quad \text{d.} & \quad \text{e.}
\end{align*}
\]

3. Identify each of the following solvents as either polar protic, polar aprotic or non-polar aprotic. Why is non-polar protic solvent not an option?

\[
\begin{align*}
\text{DMSO} & \quad \text{DMF} & \quad \text{toluene} & \quad \text{acetic acid} & \quad \text{ammonia} \\
\text{acetone} & \quad \text{diethyl ether} & \quad \text{hexane} & \quad \text{benzene} & \quad \text{methanol}
\end{align*}
\]
4. Contrast the mechanisms for the following reactions, providing correct stereochemical product(s) as necessary.

\[
\begin{align*}
&\text{Br} \quad \text{CH}_3\text{OH} \\
&\text{Br} \quad \text{NaOCH}_3
\end{align*}
\]

5. For the following reaction, indicate which reaction mechanism (i.e. write \textbf{SN1} and/or \textbf{SN2} in the blank below) the following observations would support. Start by writing the rate law for an SN1 and an SN2 reaction, and draw products for the reaction if the reaction proceeds via SN1 or SN2.

\[
\begin{align*}
\text{SN2 rate law and product} & \quad \text{SN1 rate law and product} \\
\text{NaSH} & \quad \text{Br} \quad \text{NaSH} \\
\end{align*}
\]

A. the reaction rate increased when the [Nucleophile] was increased
B. the reaction rate increased when the [RX] was increased
C. the reaction rate increases in the presence of an aprotic solvent
D. the reaction rate increases in the presence of a polar protic solvent
E. the reaction showed a rearranged product
F. the reaction involved a carbocation intermediate
G. the products showed inversion of configuration

6. Consider the following methyl ester cleavage reaction:

\[
\begin{align*}
&\text{O} \quad \text{LiF} \\
&\text{O} \quad \text{DMF}
\end{align*}
\]

a. Identify the reactant, reagent, solvent and the product.
b. Identify the electrophile, the nucleophile and the leaving group.
c. Based on the following evidence, determine the mechanism for the reaction.
   o the reaction occurs much faster in DMF than in ethanol
   o the corresponding t-butyl ester reacts approximately 1000 times more slowly than the methyl ester
d. Based on your proposed mechanism for this reaction, draw the mechanism.
e. What other kinds of experimental evidence could one gather to support your proposed mechanism?
7. **Substitution Reactions.** Predict the **SUBSTITUTION** mechanism for the following reactions and draw the appropriate product(s). Indicate clearly the correct stereochemistry in your product(s).

![Reaction 1](image1.png)

**Mechanism?**

![Reaction 2](image2.png)

**Mechanism?**

![Reaction 3](image3.png)

**Mechanism?**

![Reaction 4](image4.png)

**Mechanism?**

![Reaction 5](image5.png)

**Mechanism?**
8. Determine the anticipated mechanisms for the reactions below. Using correct mechanistic arrows, provide the step-by-step mechanism that shows how the following substitution reactions proceed. You do not need to show stereochemistry while providing the mechanism, but provide correct stereochemistry in the final product(s).

**Chemical Reaction 1:**

\[
\text{Cl} \quad \xrightarrow{\text{CH}_3\text{NH}_2} \quad \text{Product}
\]

**Chemical Reaction 2:**

\[
\text{HO} \quad \text{Br} \quad \xrightarrow{\text{NaH}} \quad \text{Product}
\]