1. Give the products which would be formed when acetyl chloride reacts with the following reagents.

a) \( \text{Li excess} \) \( \rightarrow \text{H}_3\text{O}^+ \)

b) \( \text{excess} \)

c) \( \text{AlCl}_3 \) \( \rightarrow \)

d) \( \text{LiAlH}(t-\text{BuO})_3 \) \( \rightarrow \text{H}_3\text{O}^+ \)

e) \( \text{pyridine} \)

f) \( \text{Li} \)

\( \rightarrow \text{H}_2\text{O} \)

g) \( \text{H}_2/\text{Pd}, \text{sulfur, quinoline} \)

2. Draw the product(s) and mechanism.

a) \( \text{1. NH}_3, \text{xs} \)
\( \rightarrow \text{2. H}_3\text{O}^+ \)

b) \( \text{CH}_3\text{CH}_2\text{OH, xs} \)
\( \rightarrow \text{HCl} \)
3. Show how you would accomplish the following transformation. Show the intermediate isolable products. More than one step is required.

a) \[ \text{pentane-2-one} \xrightarrow{\text{H}_{2} \text{O}^+} \text{pentane-2-carboxylic acid} \xrightarrow{\text{SOCl}_2} \text{pentane-2-sulfonyl chloride} \xrightarrow{1. \text{LiCH}_2-\text{CH}_3, 2. \text{H}_3\text{O}^+} \text{pentane-2-carboxylic acid methyl ester} \]

b) \[ \text{phenol} \xrightarrow{\text{HBr}, \Delta} \text{phenylmethanol} \xrightarrow{1. \text{Br}_2, 2. \text{H}_3\text{O}^+} \text{phenylmethanol bromide} \xrightarrow{\text{Et}_3\text{O}} \text{phenylmethanol ether} \]

4. Give the product(s) of the following reactions showing stereochemistry in 3-D and all stereoisomers that are formed.

a) \[ \text{3-methylpentane-2-carboxylate} \xrightarrow{1. \text{CH}_3\text{CH}_2\text{MgBr}, \text{xs}, 2. \text{H}_2\text{SO}_4, \text{heat}} \]

b) \[ \text{cyclohexane-2-carbonitrile} \xrightarrow{1. \text{KCN}} \xrightarrow{2. \text{H}_3\text{O}^+, \text{H}_2\text{O}} \]
5. $^{18}\text{O}$ is an isotope of oxygen that can be used as a label to elucidate a reaction mechanism. In a) there is the normal basic ester hydrolysis shown which confirms the mechanism you have learned. The oxygens with an asterisk are labeled with $^{18}\text{O}$. In b) and c) the mechanism takes a different course. Explain why and write the mechanism for each b) and c).

\[
\begin{align*}
\text{a)} & \quad \text{\begin{tikzpicture}
    \node (A) at (0,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (B) at (0.5,0) {$\text{NaOH}$};
    \node (C) at (0.5,-0.5) {$\text{H}_2\text{O}$};
    \draw (A) -- (B); \draw (B) -- (C);
\end{tikzpicture}} & \xrightarrow{\text{NaOH} \quad \text{H}_2\text{O}} & \text{\begin{tikzpicture}
    \node (A) at (0,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (B) at (0.5,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (C) at (0.5,-0.5) {$\text{H}_2\text{O}$};
    \draw (A) -- (B); \draw (B) -- (C);
\end{tikzpicture}}
\end{align*}
\]

\[
\text{b)} & \quad \text{\begin{tikzpicture}
    \node (A) at (0,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (B) at (0.5,0) {$\text{H}_3\text{O}^+$};
    \node (C) at (0.5,-0.5) {$\text{H}_2\text{O}$};
    \draw (A) -- (B); \draw (B) -- (C);
\end{tikzpicture}} & \xrightarrow{\text{H}_3\text{O}^+ \quad \text{H}_2\text{O}} & \text{\begin{tikzpicture}
    \node (A) at (0,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (B) at (0.5,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (C) at (0.5,-0.5) {$\text{H}_2\text{O}$};
    \draw (A) -- (B); \draw (B) -- (C);
\end{tikzpicture}}
\]

\[
\text{c)} & \quad \text{\begin{tikzpicture}
    \node (A) at (0,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (B) at (0.5,0) {$\text{NaOH}$};
    \node (C) at (0.5,-0.5) {$\text{H}_2\text{O}$};
    \draw (A) -- (B); \draw (B) -- (C);
\end{tikzpicture}} & \xrightarrow{\text{NaOH} \quad \text{H}_2\text{O}} & \text{\begin{tikzpicture}
    \node (A) at (0,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (B) at (0.5,0) {$\text{CH}_3\text{CO}_2\text{H}$};
    \node (C) at (0.5,-0.5) {$\text{H}_2\text{O}$};
    \draw (A) -- (B); \draw (B) -- (C);
\end{tikzpicture}}
\]

6. Ketene shown below is an important industrial compound. Predict the products when ketene reacts with a) ethanol, b) ethylamine and c) acetic acid. Draw electron-pushing arrows.

\[
\begin{align*}
\text{(a) on back}
\]

\[
\text{(b) on back}
\]

\[
\begin{align*}
\text{(c) on back}
\end{align*}
\]
Protonated carbonyl is a good leaving group to form the stable 3° carbocation. Labeled oxygen remains on the carbonyl acid leaving group.

C. Carbonyl is a good leaving group off of the uncharged –CH$_3$ resonance places labeled O$^{18}$ in both positions of carbonyl.

6. a. \[ \text{Nucleophilic attack onto the very electrophilic ketene results in an enolate intermediate which undergoes rapid proton transfer to yield the carbonyl-containing product.} \]