1. Provide detailed mechanisms for the following transformations:

   a. (10 pts)

   \[
   \begin{align*}
   &\text{R} = \text{N}_2^+ + \text{R} \quad \text{KBr} \quad \text{R} = \text{Br} \\
   &\text{R} = \text{O} \quad \text{Br}^- \quad \text{R} = \text{CO} \quad \text{H}^+ \\
   &\text{R} = \text{Br} \quad \text{R} = \text{O} \quad \text{Br}^-
   \end{align*}
   \]

   b. (10 pts)

   \[
   \begin{align*}
   &\text{R} = \text{O} \quad \text{N}_3 \quad \text{R} = \text{MeOH} \quad \text{R} = \text{NCO} \\
   &\text{R} = \text{NCO} \quad \text{MeOH} \quad \text{R} = \text{NCO} \quad \text{H}^+
   \end{align*}
   \]
2. Predict the major product of the following reactions:

a. (10 pts)

\[
\text{CH}_2\text{OC(O)CH_2-OCH_3} \xrightarrow{1. \text{NaOMe, MeOH}} \xrightarrow{2. \text{H}_3\text{O}^+} \text{CON}_2\text{H} \text{OC(O)CH}_2\text{OCH}_3
\]

b. (5 pts)

\[
\text{N}_2\text{HCH}_2\text{O} \xrightarrow{\text{H}^+, \text{NaBH}_3\text{CN}} \text{N}_2\text{HCH}_2\text{NCH}_2\text{CH}_3
\]

c. (5 pts)

\[
\text{N}_2\text{HCH}_2\text{O} \xrightarrow{\text{HCN}} \text{N}_2\text{HCH}_2\text{CHNCH}_2\text{CH}_3
\]
3. a. (10 pts) Shown below is a section of a peptide chain. Draw a second peptide chain underneath it such that you form an antiparallel β-sheet. Be sure to indicate the hydrogen bonds.

b. (10 pts) The imidazole of histidine is often used by proteins as a base at the active site.

Although imidazole is a reasonably competent base ($pK_a$ of protonated imidazole = 7), proteins often use a "trick" to increase its basicity. Show with structures how the basicity of imidazole may be increased. You may use any other reasonable chemical entity likely to be found in a protein that you desire.

*The protein can employ a base to deprotonate the imidazole during the reaction. In this way, the electron density of the imidazole is increased and it is thus a stronger base. Another way to look at this is that in the first reaction above we have created a positive charge on the imidazole. By using the other base, we avoid the creation of this charge.*
4. a. (10 pts) Provide a classification (e.g. D-ketotriose) and a Fischer projection for the following carbohydrate:

\[ \text{Fischer Projection} \]

\[ \text{D-Aldopentose} \]

Classification

b. (10 pts) Provide a mechanism for the following transformation:
b. (10 pts) Because most β-ketoacids readily decarboxylate, your lab partner is planning to attempt the following decarboxylation:

Even though your lab partner routinely steals your food, you decide to explain why you believe this reaction might not work based on a careful mechanistic analysis:

This enol cannot form, it’s a bridgehead double bond!