I. (15 points) Using the pKa information given on page 12, match the following isoelectric point (pI) values (3.08, 6.00, and 10.76) to their corresponding amino acids by writing the correct isoelectric point value in the box beside each amino acid.

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>pI Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arg</td>
<td>10.76</td>
</tr>
<tr>
<td>Glu</td>
<td>3.08</td>
</tr>
<tr>
<td>Val</td>
<td>6.00</td>
</tr>
</tbody>
</table>

II. (18 points) Draw the full structure (including stereochemistry) for the tripeptide Cys-Pro-Arg (all L amino acids) in the predominant form it would exist at its isoelectric point. Use the Fischer projections.

Structure at the isoelectric point:

The predominant form of this tripeptide at pH 1 has a net charge of: (circle one)

\[ +2 \quad +1 \quad 0 \quad -1 \quad -2 \]

The predominant form of this tripeptide at pH 11 has a net charge of: (circle one)

\[ +2 \quad +1 \quad 0 \quad -1 \quad -2 \]

III. (20 points) Draw in the boxes below the full structures (including stereochemistry) of the products from each of the following reactions.

1. \[
\begin{align*}
\text{H}_3\text{N} &\quad \text{N} \quad \text{H}_3\text{N} \\
\text{H}_2\text{N} &\quad \text{N} \quad \text{H}_2\text{N} \\
\text{H} &\quad \text{N} \quad \text{H} \\
\end{align*}
\]

\begin{align*}
1. \text{O}_2\text{N} &\quad \text{N} \quad \text{O}_2\text{N} \\
\text{N}(\text{CH}_2\text{CH}_3)_3 &\quad \text{N}(\text{CH}_2\text{CH}_3)_3 \\
\text{H}_2\text{O} &\quad \text{H}_2\text{O} \\
\end{align*}

\[ \text{O}_2\text{N} \quad \text{N} \quad \text{O}_2\text{N} \]

\[ \text{H}_3\text{N} \quad \text{H}_3\text{N} \]

\[ \text{C}_1\text{H}_3\text{O}_2 \]

\[ \text{H}_2\text{N} \quad \text{H}_2\text{N} \]

\[ \text{C}_1\text{H}_10 \]

\[ \text{CO}_2 \]

Charge: \(-1\) or \(-2\)

Wrong stereochemistry: \(-2\)

Nitro-containing product

HCl salt

Same as above
IV. (20 points) Consider the esterification reaction (A to B) shown below.

\[
\begin{align*}
\text{PhCOOH} & \quad \text{HCl} \quad \text{HOCH(CH}_3)_2 \quad \text{PhCOOCH(CH}_3)_2 \quad \text{H}_2\text{O} \\
\text{A} & \quad & & & \text{B}
\end{align*}
\]

(1) (16 points) Which of the following would result in an increase in the amount of ester B formed?

<table>
<thead>
<tr>
<th>If the following is done:</th>
<th>Yield of B would increase (circle one)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess HOCH(CH_3)_2 is added.</td>
<td>Yes □ No □</td>
</tr>
<tr>
<td>NaOCH(CH_3)_2 is used in place of HOCH(CH_3)_2</td>
<td>Yes □ No □</td>
</tr>
<tr>
<td>HOCH(CH_3)_2 is removed during the reaction</td>
<td>Yes □ No □</td>
</tr>
<tr>
<td>Dilute aqueous HCl is used instead of concentrated HCl</td>
<td>Yes □ No □</td>
</tr>
</tbody>
</table>

(2) If isotopically labeled H-^{18}OCH(CH_3)_2 is used, the ^{18}O label would end up in:

![Diagram](image)

V. (32 points) Treatment of L-phenylalanine with excess methanol in the presence of 1.5 mol equiv of gaseous HCl at room temperature produces the HCl salt of L-phenylalanine methyl ester in 95% yield. Provide in the box below a step-by-step mechanism, using the curved arrow convention, for the formation of this methyl ester HCl salt from L-phenylalanine. You may use H-B and B' as a general acid and its conjugate base, respectively.

![Mechanism Diagram](image)

Str of intermediates: 3 pts each
Mechanistic steps: 2 pts each
VI. (18 points) A levulinyl group [CH$_3$C(=O)CH$_2$CH$_2$C(=O)-] is an extremely versatile hydroxyl-protecting group. A team of scientists at The Scripps Research Institute in La Jolla, CA, reported in 2003 that the levulinate group (indicated by a rectangular box) in differentially protected disaccharide C can be deprotected selectively to provide alcohol D in quantitative yield [Proc. Natl. Acad. Sci., USA 2003, 100, 797].

![Chemical structures of C and D]

(1) The methods used to achieve this selective deprotection take advantage of the difference in electrophilicity between aldehyde/ketone and ester carbonyl groups. Among these methods known, the use of NaBH$_4$ is most convenient. In the reaction shown below, the levulinate ester of cyclohexanol, E, is treated with NaBH$_4$ to afford cyclohexanol (F). The by-product (G) from this reaction has the molecular formula of C$_5$H$_8$O$_2$. Provide in the box below the structure of this compound.

![Chemical structures of E, F, and G]

(2) When a levulinate such as E is treated with hydrazine (NH$_2$-NH$_2$) in acetic acid, the levulinate-protected alcohol undergoes facile deprotection (see below). Draw in the box provided the structure of the by-product H. It might be easier if you solve # (3) before this question.

![Chemical structures of E, F, and G]

(3) The reaction of levulinate E with hydrazine first produces its hydrazone derivative, which further undergoes an intramolecular reaction to produce H. Draw in the box below the structure of this hydrazone derivative of E.

![Chemical structures of E, F, and G]
VII. (22 points) Provide in the box below a step-by-step mechanism for the following reaction using the curved arrow convention. Use B- and B-H for the base and the conjugate acid, respectively. Make sure to show the mechanism for the catalytic cycle, i.e., regeneration of B- [or $\text{OC}$(CH$_3$)$_3$]. You do not need to rationalize the stereochemistry of the new chiral centers created [Tetrahedron Lett. 2007, 48, 4683].

VIII. (22 points) Provide in the box below a step-by-step mechanism for the following acid-catalyzed reaction using the curved arrow convention. Use H-B and B- for the acid and the conjugate base, respectively.
IX. (39 points) Complete the following transformations as indicated by the data provided. Clearly indicate the stereochemistry where applicable.

1. 

\[
\text{Which amino acid is this? Use its 3-letter abbreviation as your answer.}
\]

\[\text{Ser} \]

2. 

\[\text{H}_2 \text{Pd/C} \]

with added DCC

3. 

\[\text{HBr/H}_2\text{CC(\text{=O})OH or HBr/F}_3\text{CC(\text{=O})OH} \]

4. 

\[\text{C}_{14} \text{H}_{18} \text{O}_3 \text{ (Z-isomer)} \]

5. 

\[\text{Wrong stereo:} \]

\[\text{C}_{20} \text{H}_{22} \text{O}_{11} + \text{CsBr} \]


X. (34 points) Complete the following transformations as indicated by the data provided. Clearly indicate the stereochemistry where applicable. Sequential experimental steps must be numbered.

1. 
   \[
   \text{H} + \text{S} \quad \text{THF (solvent)} \quad \rightarrow \quad \text{HO} \quad \text{S} \quad \text{Li} \quad \text{O} \quad \text{H}
   \]
   2. \( \text{aq NH}_4\text{Cl} \)

2. \([\text{Tetrahedron 2007, 63, 5855}]\)

3. \([\text{J. Org. Chem. 2007, 72, 5943}]\)

4. \([\text{Tetrahedron Lett. 2007, 48, 5623}]\)

Diastereomers

\[
\begin{align*}
\text{2 HOCH}_3 + & \text{ diastereomers} \\
& \text{dianion} \\
& \text{diastereomeric mixture at a new chiral center (show that stereochemistry with \(\text{mm}\))}
\end{align*}
\]