General Instructions:
Use scratch paper at the back of the exam to work out answers. Final answers must be recorded at the proper place on the exam itself for credit.
Print your name and ID # on each page.
Please keep your paper covered and your eyes on your own work.
Academic misconduct will lead to failure in the course.

1. (30 pts.) Give the major product(s) of the following reactions. Show stereochemistry in 3-D where necessary and all stereoisomers.

(a)  
\[
\begin{align*}
\text{N} & \quad \text{CH}_3I, \text{xs} \\
& \quad \text{2. Ag}_2\text{O, H}_2\text{O}
\end{align*}
\]

(b)  
\[
\begin{align*}
\text{N} & \quad \text{CH}_2\text{CH}_3 \\
& \quad \text{Br}_2 \quad \text{FeBr}_3
\end{align*}
\]

(c)  
\[
\begin{align*}
\text{C} & \quad \text{C} \\
\text{O} & \quad \text{Et} \\
& \quad \text{1. NaOEt} \\
& \quad \text{2. CH}_2=\text{CHCN} \\
& \quad \text{3. H}_3\text{O}^+, \text{H}_2\text{O}, \text{heat}
\end{align*}
\]

(d)  
\[
\begin{align*}
\text{O} & \quad \text{H} \\
& \quad \text{NaOH, H}_2\text{O}
\end{align*}
\]

(e)  
\[
\begin{align*}
\text{O} & \quad \\
& \quad \text{1. NaSCH}_3 \\
& \quad \text{2. CH}_3\text{I}
\end{align*}
\]

(f)  
\[
\begin{align*}
\text{N} & \quad \text{O} \quad \text{OCH}_3 \\
& \quad \text{H}_3\text{O}^+ \quad \text{H}_2\text{O}
\end{align*}
\]
2. (24 pts.) Give an intermediate formed in the mechanism of the following reactions. If you write the product as well, circle the intermediate. The product is not required.

(a) \[ \text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{AlCl}_3 \]

(b) \[ \text{HNO}_2 \rightarrow \text{HCl} \]

(c) \[ \text{NaOH} \rightarrow \text{Br}_2 \]

(d) \[ \text{KOH} \rightarrow \text{heat} \]

(e) \[ \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{NaOH} \]

(f) \[ \text{HNO}_2 \rightarrow \text{HCl} \]
3. (25 pts.) Follow the directions for each question.

(a) **Circle all** the amino acids that have the S configuration.

(b) **Circle** the aldehyde which would react **most rapidly** with NaCN and put a **box** around the aldehyde which would be **slowest** to react.

(c) **Circle** the **strongest acid** and put a **box** around the **weakest acid**.

(d) **Circle** the structure which is **not** correct for glutamic acid at any pH.

(e) **Circle** the **starting material** that should be used for the reaction in the box.
4. (24 pts.) Show the reagents necessary for the following transformations. Number the steps required if the reagents cannot be mixed.

(a)  

(b)  

(c)  

(d)
5. (19 pts.) Give the mechanisms of the following transformations using electron-pushing arrows and showing **all** intermediates.

(a) ![Diagonal arrows between two molecules](image)

(b) ![Diagonal arrows between two molecules](image)
6. (30 pts.) Give a **specific** example of the following reactions. Show reactant, reagents (over the arrow) and products.

(a) Formation of a glycoside

(b) Synthesis of a tertiary alcohol

(c) Aromatic nucleophilic substitution

(d) Reaction of an epoxide with a basic reagent

(e) Nucleophilic acyl substitution

(f) Preparation of an ether

TOTAL
7. (18 pts.) The following reactions could give more than one product, but they are selective and give only **one major product**. Write the major product of each reaction.

(a)  
\[
\text{\begin{tikzpicture}
\node at (0,0) {\text{\textbf{\textit{Intramolecular}}}};
\node at (-3,0) {\text{\includegraphics[width=2cm]{reaction.png}}};
\end{tikzpicture}}
\]

(b)  
\[
\text{\begin{tikzpicture}
\node at (0,0) {\text{\textbf{\textit{Robinson}}}};
\node at (-3,0) {\text{\includegraphics[width=2cm]{reaction.png}}};
\end{tikzpicture}}
\]

8. (5 pts.) On treatment with strong base followed by protonation **A** and **B** undergo cis-trans isomerization. **C** does not. Explain briefly

\[\text{\begin{tikzpicture}
\node at (0,0) {\text{\includegraphics[width=3cm]{reaction.png}}};
\end{tikzpicture}}\]

9. (10 pts.) How many signals would be present in the $^1$H NMR spectrum of each of the following cyclopentene derivatives shown? Consider carefully the geometric environments around each hydrogen.

\[\text{\begin{tikzpicture}
\node at (0,0) {\text{\includegraphics[width=5cm]{reaction.png}}};
\end{tikzpicture}}\]
10. (15 pts.) Determine the structure of C_{11}H_{14}O_{3} from the $^1$H NMR spectrum shown. Determine the index of hydrogen deficiency. Write part structures revealed by the chemical shifts, splitting and integrals for all the multiplets. In each part structure circle the hydrogens responsible for the absorption and underline the hydrogens that give rise to the splitting. *Hint: The multiplet at $\delta$ 1.40 consists of 2 overlapping triplets.*

\[ \text{IHD} = \]

If your structure seems correct. Assign the protons in it to the various peaks in the spectrum.