1. (36 points) Show the major product or products expected from each reaction.

(a) \[
\text{Excess } \text{H}_2 \\
\text{Pd/C}
\]

(b) \[
\text{1) } \text{Hg(OAc)}_2, \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \\
\text{2) } \text{NaBH}_4
\]

(c) \[
\text{CN} \\
\text{CN}
\]

(d) \[
\text{1) } \text{BH}_3, \text{ THF} \\
\text{2) } \text{H}_2\text{O}_2, \text{ NaOH}, \text{ H}_2\text{O}
\]

(continued on next page)
2. (12 points) Shown below is a drug called lopinavir for patients infected with HIV. **CIRCLE** all sp³ stereogenic centers, and indicate whether the configuration is R or S.

+1 for each correct circle

+2 for each correct R/S
3. (26 points) Show the reagents required to convert the starting molecule to the indicated product. If necessary, be sure to differentiate clearly between distinct steps, by using "1)," "2)," etc. over the arrow.

(a)  
\[
\text{[Diagram of reaction]} \quad \text{1) } \text{O}_3 \text{ +4} \quad \text{2) (CH}_3\text{)_2S +4} \\
\]

(b)  
\[
\text{[Diagram of reaction]} \quad \text{1) NaNN}_2 \text{ +4} \quad \text{2) Br CH}_2\text{CH}_3 \text{ +4} \quad \text{[or C}_2\text{I or OTs]} \\
\]

(c)  
\[
\text{[Diagram of reaction]} \quad \text{2 equiv H}_2\text{O +6} \quad \text{[or "excess"]} \quad \text{(-2 if no stoichiometry indicated)} \\
\]

(d)  
\[
\text{[Diagram of reaction]} \quad \text{+3 if above} \\
\text{(-2 for extra R groups/weirdness)}
4. (6 points) Consider the two hydrogenation reactions below, both of which form the same product alkane, and both of which are exothermic (heat is released).

(a) CIRCLE the reaction that you expect to release MORE heat.

(b) Explain in ONE SENTENCE why you chose the circled reaction.

The starting material of the circled reaction is not aromatic and therefore less stable than the other starting material, which is aromatic.

5. (6 points) Show a mechanism (curved arrows) for the reaction below.
6. (20 points)

(a) The reaction shown below leads to two isomeric products. Draw those products.

![Chemical structure](image)

(Single enantiomer)

(b) Draw the most stable conformation of each product. (Note: A chlorine atom is smaller than a methyl group.)

![Chemical structure](image)

(−2 for each incorrect enantiomer)
7. (18 points) For each part below, draw the other side of the expected acid-base equilibrium. (Do not be concerned with which side is favored.) In each case the two species are present in 1:1 molar ratio.

(a) \( \text{H}_3\text{C}-\text{C}≡\text{CH} + \text{Na}^+\text{NH}_2^- \quad \leftrightarrow \quad \text{H}_3\text{C}-\text{C}≡\text{C}^-\text{Na}^+ + \text{NH}_3^+ \)

(b) \( \text{NH}_2^- + \text{BF}_3^- \quad \leftrightarrow \quad \text{N}_\text{H}_{\text{H}}^+ + 6^\text{O} \)

(c) \( \text{HO}-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} + \text{Na}^+\text{NH}_2^- \quad \leftrightarrow \quad \text{HO}-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CO}^-\text{Na}^+ + \text{NH}_3^+ \)
8. (26 points) Provide a mechanism (curved arrows) for each reaction shown below. Be sure to show intermediates and all important resonance structures.

(a) 

(b) 

+2 for each Cl resonance structure and +1 for each protonated ether intermediate, +0 for charge on protonated ether.
9. (30 points) When the starting material below is allowed to react under the conditions shown, two isomeric products result, $X$ and $Y$. $Y$ is chiral and racemic; $X$ is not chiral. When compound $X$ reacts with $\text{Cl}_2$ in water, two isomeric products are formed, $X-1$ and $X-2$; neither is chiral. When $Y$ reacts with $\text{Cl}_2$ in water, two different products are formed; each is chiral and racemic. Give structures for all six molecules in the appropriate boxes.

$X = \begin{align*}
\text{(-i for missing Cl}_5\text{) or stereochm} \\
\text{(i) for missing H}_5
\end{align*}$

$Y = \begin{align*}
\text{(-i) for undig/dash} \\
\text{(i) for missing Me} \\
\text{L-3 psi if missing Me}
\end{align*}$

$X-1 = \begin{align*}
\text{OH} \\
\text{Cl}_2
\end{align*}$

$X-2 = \begin{align*}
\text{Swap} \\
\text{ok}
\end{align*}$

$Y-1 = \begin{align*}
\text{(i)} \\
\text{OH}
\end{align*}$

$Y-2 = \begin{align*}
\text{(i)} \\
\text{OH}
\end{align*}$

$+5$ each

$+10$, if also draw an incorrect structure in box.

$+2$ each, if missing structure, or incorrect structure.
10. (20 points) Devise a synthetic route from the indicated starting material to the indicated target in each of the two cases below. Each route should be as short and as selective as possible. You may use any other organic molecules and any inorganic reagents in your synthetic plans. Show the expected product after each step in each synthetic route. (Do not provide mechanistic information.)

(a) 

Starting material = 

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Target = 

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\[ D_2, \text{poisoned catalyst} \]

\[ D_2 + H_2 \text{ can be reversed} \]

\[ H_2, Pd/C \]
Name

10. (cont.)

Starting material = \( \text{C}_{n}\text{H}_{2n+1}\text{Br} \)

Target = \( \text{C}_{n}\text{H}_{2n+1}\text{O} \)

1. \( \text{Mg, Et}_2\text{O} \)

2. \( \text{H}_2\text{O} \) [Not required]

3. \( \text{Na}_2\text{C}_2\text{O}_4, \text{H}_2\text{O}, \text{H}_2\text{SO}_4 \) [Any Cr(III) reagent ok]

- 1 pt per error in reagent

4 pts other with 6 pts if all right but not selective many extraneous steps