1. Rank the following molecules from best (1) to worst (4) leaving group ability and basicity of the leaving group.

<table>
<thead>
<tr>
<th></th>
<th>LG:</th>
<th>Basicity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Br</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>OH</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>OH₂⁺</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>CH₃⁻</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

As basicity increases, leaving group ability decreases. \( \text{H}_2\text{O} \) is the best leaving group because it wants to be a neutral molecule due to its current positive charge. \( \text{Br}^- \) is the next best leaving group because it is the second weakest base (basicity increases going down the periodic table). \( \text{OH}^- \) is the second strongest base, making it a bad leaving group. \( \text{CH}_3^- \) is the best base making it the worst leaving group.

2. Identify the stronger nucleophile of the following molecules in a methanol solvent solution.
   a. I⁻ or Cl⁻
   b. F⁻ or CH₃⁻
   c. OH⁻ or NH₂⁻

As nucleophilicity increases, basicity increases. However, methanol is a polar protic solvent, thus the nucleophilicity trend increases down a column, even though basicity decreases. Polar protic solvents are capable of hydrogen bonds (hydrogen directly attached to oxygen) Nucleophilicity increases from right to left in either solvent.

3. Identify the mechanism that the following reaction will undergo in the box under the arrow. Predict the product(s) resulting from this reaction. Indicate stereochemistry is necessary.
The 2° alkyl halide can undergo $S_2$ or $S_N^1$. CH$_3$OH is a weak nucleophile, which means that this reaction will undergo $S_N^1$. The product will be a racemic mixture due to the planar carbocation transition state.

4. Identify the mechanism that the following reaction will undergo in the box under the arrow. Predict the product(s) resulting from this reaction. Indicate stereochemistry is necessary.

![Diagram of E2 mechanism]

The tertiary alkyl halide indicates an E2 mechanism, along with the strong base OH$^-$. There are two products due to the two different beta-hydrogen positions; one within the ring and the other on the methyl substituent. According to Zaitzev’s Rule, the major product is the more substituted alkene, therefore more stable.

5. Draw the arrow pushing mechanism for the following reaction and determine the product(s). Include any by-products resulting from the reaction.

![Diagram of dehydration reaction]

The secondary alcohol with a strong acid indicates a dehydration of an alcohol through an E1 mechanism.
6. Draw the arrow pushing mechanism for the following reaction and determine the product(s). Include any by-products resulting from the reaction.

The primary alcohol with a strong acid indicates another dehydration of an alcohol through an E2 mechanism.

7. Predict the starting material of the following reaction. Indicate the mechanism that this reaction will undergo in the box under the arrow.

The halide on the final product is a tertiary halide, meaning the starting product would be in a tertiary position. We learn that alcohols can become alkyl halides through a reaction with HX, thus making the starting product a tertiary alcohol. Tertiary and secondary alcohols undergo an S\textsubscript{N}1 reaction with hydro halides while primary alcohols undergo S\textsubscript{N}2.
8. Determine the starting material and draw the arrow pushing mechanism for the following reaction. Include any by-products resulting from the reaction.

\[
\text{byproducts:} \quad + \text{HCl} \quad + \text{SO}_2
\]

9. Draw the arrow pushing mechanism for the following reaction and determine the product(s). Include any by-products resulting from the reaction.

10. Determine the correct reagent(s) and solvent for this following reaction.
11. Of the following reagents, which of these produces an alkene?
Both KOC(CH₃)₃ and H₂SO₄ are reagents that produce alkenes. KOC(CH₃)₃ is the reagent used usually during E2 mechanisms as it is a strong bulky base. H₂SO₄ also produces alkenes through the dehydration of alcohols.

12. Based on the reagent and the starting material, what is the name of this addition reaction?
Draw the arrow pushing mechanism for the following reaction.

This reaction addition undergoes hydrohalogenation due to the fact that the reagent is a hydrogen halide with an alkene starting material. This certain reaction undergoes a 1,2 Hydride shift in order to get a more stable carbocation. The bromine anion then attacks the carbocation and the product is formed. If stereochemistry was needed, hydrohalogenation reactions produce enantiomers as the anion can be added through syn and trans addition.

13. Identify the reagents for the following reactions.
This reaction undergoes a hydration reaction. With hydration reactions, the reagents needed are $H_2O$ and $H_2SO_4$. If stereochemistry was noted, two products would be produced as the addition of H and OH undergoes both a syn and anti fashion.

14. Determine the starting materials and the reagent(s) that produce the following product.

By looking at the product, we see that there two chlorides, one of the only reactions that we know that adds two halides adjacent from each other is through halogenation. Halogenation, needs an alkene and as well as an addition of a halide.

15. Draw the product of the following reaction. Indicate stereochemistry if stereochemistry is applicable.

The reagent NBS coupled with DMSO and $H_2O$ undergoes a halohydrin formation. In terms of stereochemistry, halohydrins undergo an anti addition which means enantiomers are formed.
16. Determine if the following product shown is a possible hydroboration product? Why or why not.
   The product shown is not a possible hydroboration product. This is because the OH is added on the more substituted and the more hindered carbon. The following reaction shown below is the correct product. In this case, the OH is now added correctly on the less hindered carbon. The previous product would have been correct if the reagents were \( \text{H}_2\text{O} \) and \( \text{H}_2\text{SO}_4 \).

\[
\begin{align*}
\text{BH}_3 & \quad \text{H}_2\text{O}_2, \text{H}_2\text{O} \\
\end{align*}
\]

17. Of the following starting materials, which of the following produces an aldehyde through hydroboration oxidation?
   This is the only reactant that can produce an aldehyde through hydroboration oxidation because this is the only material that has a terminal alkyne.

18. Determine the product for the following reaction and then draw the arrow pushing mechanism.
The alkyne attacks the epoxide at the least substituted side. Coupled with water, it protonates the oxygen in order to turn into alcohol.

19. Is the product shown the most favorable product that can be produced? Why or why not?
   The product shown on the blank is not the most favorable product that can be produced. The hydroxyl group can be turned into a ketone due to tautomerization. Equilibrium favors the ketone group more because the C=O bond is simply stronger than the C=C bond. The following reaction and product below would be the most favorable.

20. Determine the reagents for the following reaction.
First, we see that two bromines were added adjacent to each other, which means that halogenation is necessary for this. Second, we see that an alkyne is made during the second step. With two bromines, we can use a big bulky base in for elimination and in this case it would be a double elimination. Then we see that two sets of Cl added to the same carbon which infers a hydrohalogenation reaction. We would need two equivalents of this as it is added to an alkyne instead of an alkene.

21. Draw the product of the following reaction.

First, the alkyne attacks the H in HBr and adds in Markovnikov fashion to the least substituted carbon, forming a carbocation. The -Br attacks the carbocation and it is added to the alkyne. Then, another equivalent of HBr comes in, adds H to the least sub. C, and -Br attacks the carbocation.

22. Classify each reaction as oxidation, reduction, or neither.
   a. Oxidation. Going from an alkane to a ketone means there is an increase in the # of C-Z bonds and a decrease in the # of C-H bonds at a specific Carbon (Carbon #2 in this case).
b. Reduction. Going from a ketone to an alkane means there is an increase in the # of C-H bonds and a decrease in the # of C-Z bonds.

c. Oxidation. Alkyne → Carboxylic Acid = increase in # of C-Z bonds.

d. Neither. The alkene adds both a C-H and C-Cl bond.

23. Fill in the reagents in their respective boxes above the arrows for the following reactions.

\[
\begin{array}{c}
\text{H}_2 \\
Pd/C \\
\end{array} \quad \quad \Rightarrow \quad \quad \begin{array}{c}
\text{H}_2 \\
\text{Lindlar catalyst} \\
\end{array}
\]

More than one equivalent of H2 + Pd/C reduces the alkyne all the way to an alkane. H2 + Lindlar catalyst only reduces the alkyne to a cis-alkene. NaNH3 reduces an alkyne to a trans-alkene.

24. Draw the organic products in each of the following reactions.

a. The C=C gets replaced with C-H bonds adding in syn addition.

b. Both C-Z bonds get replaced with C-H bonds.

c. The epoxide is opened on by AlH4 attacking the least substituted side. An epoxide = 2 C-O bonds and now the product only has one C-O bond.
25. Draw an arrow pushing mechanism for the reaction below.

This is anti-dihydroxylation via an epoxide. First, we take our alkene and use mCPBA to turn it into an epoxide. Then, under acidic conditions, we open the epoxide and attack at the most substituted carbon. We are left with enantiomers as products. If OsO₄ was used instead, it would result in syn dihydroxylation.

26. Determine the product(s) from the following starting materials.

This is an ozonolysis reaction. Wherever we see a double bond, we should draw a line through them and replace the C=C bond with a C=O bond.
27. What alkene or alkyne yields each set of products after oxidative cleavage with ozone?

![Reaction diagram]

Terminal alkynes always produce carboxylic acid and carbon dioxide as products.
Internal alkynes produce two carboxylic acids.

28. Fill in the blanks:

<table>
<thead>
<tr>
<th>Oxidized to:</th>
<th>Reagents:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1º Alcohol</td>
<td>Aldehyde or Carboxylic Acid</td>
</tr>
<tr>
<td></td>
<td>To produce aldehyde: PCC</td>
</tr>
<tr>
<td></td>
<td>To produce carboxylic acid: 1. CrO3 and 2. H2O, H2SO4</td>
</tr>
<tr>
<td>2º Alcohol</td>
<td>Ketone</td>
</tr>
<tr>
<td></td>
<td>Both PCC and Jone’s reagent produce a ketone</td>
</tr>
<tr>
<td>3º Alcohol</td>
<td>No Reaction!</td>
</tr>
</tbody>
</table>

29. Fill in the intermediate reactants and/or products for the following synthesis:

![Synthesis diagram]
First, we take an alkane and brominate it via radical halogenation. Then, we perform an E2 elimination to get an alkene. Finally, we take the alkene and perform ozonolysis to get our product with two aldehyde functional groups.

30. Which alkane reacts fastest with Cl$_2$ and Δ, and what is/are the product(s)?

#1 reacts the fastest because the rate of halogenation increases with substitution/stability, similar to carbocations. In this fast reaction, there is no selectivity where the Cl adds, unlike Br, so multiple products are produced in a 1:1.