The exam consists of this cover sheet, which contains an extra credit problem, which is optional. There are 10 problems to solve. The time limit for this exam is 2 hours. Please read problems carefully so that you understand the entire problem. *No work = no credit.*

**OPTIONAL EXTRA CREDIT (4 points):**

Starting with 2-butene, show how you could make 2,2-dichlorobutane. No reaction mechanism will be required, but, you must show, step-by-step reactions for this germinal dichlorobutane could be produced. There might be something like five or six or so actual reactions necessary for this conversion. Since this is extra credit, don’t even think about it until you have done the rest of the exam because you will lose no points, if you do not work on this problem, but if you don’t have enough time to do the rest of the exam, you definitely will lose points there.

\[
C-\overset{\text{H}}{\text{C=}}C-C + Br_2 \rightarrow C-\overset{\text{H}}{\text{C=}}C-C-\overset{\text{H}}{\text{C}}-C-\overset{\text{H}}{\text{C}}\underset{\text{Br}}{\text{Br}} \\
C-\overset{\text{H}}{\text{C=}}C-C \overset{\text{H}}{\text{Br}} \rightarrow C-\overset{\text{H}}{\text{C=}}C-\overset{\text{H}}{\text{C}}\underset{\text{Br}}{\text{Br}} \rightarrow C-\overset{\text{H}}{\text{C=}}C-\overset{\text{H}}{\text{C}}\underset{\text{Br}}{\text{Br}}
\]
9 1. (i) Chiral carbons are common in biochemistry. For each of the compounds below, show both R- and S- structures, which would represent enantiomers. Show only in correct Fischer Projections.

a. Alanine (which is 2-aminopropanoic acid)

b. Glyceraldehyde (2,3-dihydroxypropanal)

c. Define optical rotation and why enantiomers have equal optical rotation, but in opposite directions (one is positive and the other is negative rotation).

8 2. (i) Starting with 2-butyne show how you could produce cis-2-butene and trans-2-butene. Be sure to include any and all reagents necessary for these conversions from 2-butyne.
12 3. It is generally understood that dehydrohalogenation (E2 mechanism) requires strong base. On the other hand, substitution reactions can proceed using neutral conditions for S_N2. (i) Suppose you start with 2-bromobutane, show complete reaction mechanism for E2 elimination (6 pts). (ii) If you have methyl alcohol in neutral conditions, show the mechanism by which S_N2 occurs (6 pts).

12 4. (i) Show the reaction mechanism for a S_N1 substitution of 2-octanol by HCl (4 pts). (ii) Explain why you will not get an equal molar ratio of substitution products, which is what you might have expected going through a carbocation intermediate. That is, if you started with R(-)-2-octanol you ended with slightly more S-2-chlorooctanol (4 pts). (iii) Explain how a polarimeter is used to determine optical rotation (4 pts).

10 5. Explain how you could produce ethyl bromide starting with ethanol and phosphorus tribromide. Apply every reaction you have already encountered to come up with a plausible mechanism (oh yeah, you have to show a reaction mechanism) for this S_N2 reaction.
10. (i) If you wished to use sodium ethoxide for a reaction, explain, or show correct reaction, how you could produce this compound. If you show a reaction, make certain it is balanced (4 pts). (ii) Because the iodide ion is a great leaving group, alkyl iodide are often needed in the laboratory to make a reaction go faster. Suppose you started with butyl chloride and you carry out a substitution by adding NaI in order to get the butyl iodide. However, you realize that since the alkyl iodide is probably going to be converted right back to the butyl chloride since the iodide ion is such a good leaving group. How do you prevent the removal of the iodide, which placed onto the butyl chain (4 pts)?

\[
\begin{align*}
\text{C}_2\text{H}_5\text{CH}_3 + \text{NaI} &\rightarrow \text{NH}_3 + \text{C}_2\text{H}_5\text{I} + \text{Na}^+ \\
\text{C}_2\text{H}_5\text{CH}_3 + \text{Na}^+ &\rightarrow \text{acetone} + \text{C}_2\text{H}_5\text{I} + \text{Na}^+ \\
\end{align*}
\]

8. 7. Rank the following acids in correct order for increasing acid strength (1 is the weakest acid, and 8 is the strongest acid; put a number in the space after the compounds shown).

HI 8   HF 7   HOH 5   NH₃ 2   CH₄ 1
C₂H₂ (acetylene) 3   ethanol 4   methanol 6

8. 8. Using any reagents necessary, show how you could produce each of the following compounds (no reaction mechanism required, only starting and ending products).

2-bromobutane

\[
\text{C}_2\text{H}_5\text{CH}_3 + \text{HBr} \rightarrow \text{C}_2\text{H}_5\text{CH}_2\text{Br}
\]

2,2-dibromobutane

\[
\text{C}_2\text{H}_5\text{CH}_2\text{Br} + \text{HBr} \rightarrow \text{C}_2\text{H}_5\text{CH}_2\text{Br} + \text{C}_2\text{H}_5\text{CH}_2\text{Br}
\]

2,3-dibromobutane

\[
\text{Br}_2 + \text{C}_2\text{H}_5\text{CH}_2\text{Br} \rightarrow \text{Br}_2 + \text{C}_2\text{H}_5\text{CH}_2\text{Br}
\]

2,2,3,3-tetramethylbutane

\[
2\text{Br}_2 + \text{C}_2\text{H}_5\text{CH}_2\text{Br} \rightarrow 2\text{Br}_2 + \text{C}_2\text{H}_5\text{CH}_2\text{Br}
\]
10. The two parts of this question are not related. (i) Show how you could produce 3-hexyne using any reagents necessary, but you must use acetylene (ethyne) as one of your compounds.

(ii) Starting with any alcohol, show how you could produce an ester with sulfuric acid.

12. Starting with cyclopentanol, show how you could produce cyclopentyne using any combination of reactions, reagents, and reaction conditions, as long as they are valid. For every step, you must show a reaction mechanism. (You may have to go through substitution, elimination, halogenation, dehydrohalogenation, or other related reactions; any reaction is acceptable, as long as it is valid, and is done in the correct order. However, you can only produce a single product [no major and minor product allowed] for each reaction. In addition, the product of one reaction becomes the starting reactant for the next reaction, and so forth.)