For questions 1-15, select the best answer and put it in the bubble sheet. You will not receive any credits if you select more than one answer. (3 pts each, 45 pts total)

1. Which one of the following molecules is a secondary alcohol with the molecular formula C₅H₁₀O.

a) \includegraphics[width=0.2\textwidth]{molecule1}  

b) \includegraphics[width=0.2\textwidth]{molecule2}  

c) \includegraphics[width=0.2\textwidth]{molecule3}  

d) \includegraphics[width=0.2\textwidth]{molecule4}  

e) \includegraphics[width=0.2\textwidth]{molecule5}

2. Which one of the following molecules does NOT have the same degree of unsaturation as a molecule with the formula C₄H₈O.

a) \includegraphics[width=0.2\textwidth]{molecule6}  

b) \includegraphics[width=0.2\textwidth]{molecule7}  

c) \includegraphics[width=0.2\textwidth]{molecule8}  

d) \includegraphics[width=0.2\textwidth]{molecule9}  

e) None of the choices given.

3. Which of the following alkenes is the LEAST stable among the structures shown?

a) \includegraphics[width=0.2\textwidth]{molecule10}  

b) \includegraphics[width=0.2\textwidth]{molecule11}  

c) \includegraphics[width=0.2\textwidth]{molecule12}  

d) \includegraphics[width=0.2\textwidth]{molecule13}  

e) \includegraphics[width=0.2\textwidth]{molecule14}

4. For the following reaction, if the concentrations of both reactants decreased to 1/3 of the original values, how will the rate of the reaction change?

\[
\text{Br} + \text{KO}^+\text{Bu} \rightarrow \text{Br} + \text{KBr} + \text{HO}^+\text{Bu}
\]

a) Unchanged;  

b) decrease to 2/3 of the original rate;  

c) decrease to 1/3 of the original rate;  

d) decrease to 1/9 of the original rate;  

e) None of the choices given.

5. For the following reaction, if the concentrations of both reactants tripled, how will the rate of the reaction change?

\[
\text{Br} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+\text{Br}^-
\]

a) Unchanged;  

b) increase by 3 folds;  

c) increase by 6 folds;  

d) increase by 9 folds;  

e) None of the choices given.

6. Assign the stereochemistry of the following two alkenes marked with an arrow.

a) Z, Z;  

b) Z, E;  

c) E, Z;  

d) E, E.
7. Which of the following reagent(s) will NOT convert hydroxyl group of an alcohol to a good leaving group?
   a) POCl$_3$ + pyridine;  b) PBr$_3$;  c) NaH;  d) H$_2$SO$_4$;  e) SOCl$_2$ + pyridine.

8. Which of the following carbocations would NOT likely undergo rearrangement?
   a)  
   b)  
   c)  
   d)  

9. Which of the following cation is the LEAST stable among the group?
   a)  
   b)  
   c)  
   d)  

10. What is the rate limiting step for the following reaction?
    
    a)  
    b)  
    c)  
    d) More than one step shown are the rate determining step for this reaction.

11. Which of the following compound will undergo E2 elimination with the lowest rate upon treatment with KO'Bu?
    a)  
    b)  
    c)  
    d)  

12. What will be the major organic products when 'butyl methyl ether was treated with only 1 eq of HBr?
    a)  
    b)  
    c)  
    d)  

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13. Which of the following reaction will NOT proceed as drawn?

a)  \[
\begin{align*}
\text{H}_2\text{SO}_4 & \quad \text{H}_2\text{O} \\
\text{HO} & \quad \text{H}_2\text{O} \\
\end{align*}
\]

b)  \[
\begin{align*}
\text{H}_2\text{SO}_4 & \quad \text{H}_2\text{O} \\
\text{Br} & \quad \text{Br} \\
\end{align*}
\]

c)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{Br} \\
\end{align*}
\]

d)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{Br} \\
\end{align*}
\]

e) More than one reaction drawn will not proceed.

14. What will be the product(s) for the following reaction?

a)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{OH} \\
\end{align*}
\]

b)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{OH} \\
\end{align*}
\]

c)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{OH} \\
\end{align*}
\]

d)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{OH} \\
\end{align*}
\]

e)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{OH} \\
\end{align*}
\]

15. Which of the following is NOT an ether?

a)  \[
\begin{align*}
\text{O} & \quad \text{O} \\
\text{O} & \quad \text{O} \\
\end{align*}
\]

b)  \[
\begin{align*}
\text{O} & \quad \text{O} \\
\text{O} & \quad \text{O} \\
\end{align*}
\]

c)  \[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OH} & \quad \text{OH} \\
\end{align*}
\]

d)  \[
\begin{align*}
\text{O} & \quad \text{O} \\
\text{O} & \quad \text{O} \\
\end{align*}
\]

e) More than one compound shown is not an ether.

16. Name the following compounds. Clearly describe the stereochemistry in the name if applicable (2 pts each, 6 pts total).

\[
\begin{align*}
(3R, 5R) \text{-3-ethyl-2-methyl-nonanol} \\
(2E) \text{-3-octyl-octadiene} \\
3,3\text{-dimethyl-cyclohexene}
\end{align*}
\]
17. Provide an explanation for the following observations. Also explain why B was the minor product in reaction 2.

When compound A was treated with NaOCH₂CH₃, only one alkene product B was obtained (reaction 1). In contrast, when A was heated with very dilute base in HOCH₂CH₃, a mixture of alkenes B and C were produced with B being the minor product (reaction 2) (4 pts).

**Reaction 1**

```latex
\begin{align*}
3,2,1,6,5,4-Br & \xrightarrow{\text{NaOCH}_2\text{CH}_3} \quad \text{B} \\
\text{dilute base} & \quad \text{HOCH}_2\text{CH}_3 \\
& \quad \text{B} + \quad \text{C}
\end{align*}
```

**Reaction 2**

**Rxn 1:** E₂ elimination, which requires a trans arrangement of H and Br. The only β-H trans to Br is from carbon-6. In this run, B is the only alkene product.

**Rxn 2:** E₁ elimination. No trans requirement, it can lose β-H from either carbon-2 or 6. B is the minor alkene product since it is less substituted.

18. Provide the missing info for the following reactions. Clearly draw out stereochemistry if applicable. If there are multiple stereoisomers formed, draw out the structures of all stereoisomers. (3 pts each, 30 pts total).

a) 

\[
\begin{align*}
\text{Cl} & \quad \xrightarrow{2 \text{ eq. KO'Bu}} \quad \equiv -t\text{Bu} \\
\text{Cl} & \\
\text{t-Bu}
\end{align*}
\]

Draw two possible organic products from the substitution reaction. Clearly label the major product.

b) 

\[
\begin{align*}
\text{HCl} & \xrightarrow{\text{HCl}} \\
\text{Cl} & + \quad \text{Cl}
\end{align*}
\]

Provide the major organic product(s) structure.

c) 

\[
\begin{align*}
\text{1) 9-BBN} & \text{ 2) H}_2\text{O}, \text{OH}^- \\
\text{H} & + \quad \text{H}
\end{align*}
\]

Provide the major organic product(s) structure.

-1 for missing an isomer; -2 for wrong regiochemistry.

It is OK if they draw out both, but **Br should be labeled major.**
c) \[ \text{Cyclohexene} + \text{Br}_2 \rightarrow \]

Provide the major organic product structures

-1 for missing an isomer
-2 if not drawing stereochemical or organic dot

f) \[ \text{Missing reagent structure} \]

Major organic product structure

-1 for missing an isomer

-2 if wrong regiochem

Missing reagent structure

-1 pt for each peptide

h) \[ \text{Br} \rightarrow \text{KO}^+\text{Bu} \rightarrow \]

Major organic product structure

All alkene product structures

-1 pt for each peptide

i) \[ \text{Cyclohexanol} \rightarrow \text{NaH} \rightarrow \]

Major organic product structure

-0.5 for wrong stereochemistry

-1 for wrong stereochemistry

j) \[ \text{HBr} \rightarrow \]

Major organic product structure

-2 for wrong stereochemistry
19. Provide a reasonable synthesis of the following compound starting from the molecules shown. You may use any other reagents. The synthesis can be more than one synthetic steps (15 pts total).

Full credit as long as they are reasonable

1) 

2)
3) \[ \text{Cl} \xrightarrow{\text{KOTBu}} \xrightarrow{\text{Br}_2, \text{H}_2\text{O}} \text{Br} \]

4) \[ \text{OH} \xrightarrow{\text{BH}_3 \text{ or } 9\text{-BBN}} \xrightarrow{\text{H}_2\text{O}_2, \text{OH}^-} \text{Br} \]

4 pts