The first 10 questions are worth 3 points each.

The Heck reaction is a valuable synthetic reaction.

\[
\text{Br-Br} + \text{CO}_2\text{Me} \xrightarrow{\text{Pd(Ph}_3\text{)}_2, \text{NE}_3} \text{CO}_2\text{Me}
\]

A proposed catalytic mechanism for this reaction is shown below. Use it to answer the next four questions.

1. Which of the labeled steps of the mechanism is a ligand insertion reaction?

2. Which of the labeled steps of the mechanism is a β-hydride elimination reaction?

3. What is the electron count of compound X?

   A 12   B 14   C 15   D 16   E 17   F 18

4. What is the electron count of compound Y?

   A 12   B 14   C 15   D 16   E 17   F 18
5. Which of the above compounds is the most acidic? (Which has the lowest pKₐ?)

6. Which of the above compounds is the least acidic? (Which has the highest pKₐ?)

7. Which of the above compounds is an acetal?

8. Which of the above compounds is a lactone?

Which of the compounds above is the main product of each of the following two reaction sequences?

9.

10.
The next 4 questions are worth 5 points each.

11. Predict the product of the following reaction sequence.

\[
\text{CH}_3\text{CHO} + \text{NH}_3 \xrightarrow{\text{H}^+} \text{CN} \xrightarrow{\text{H}_2\text{O}} \text{NH}^+\text{CN} \xrightarrow{\text{H}^+\text{H}_2\text{O}} \text{NH}_2\text{CN}
\]

A. 
B. 
C. 
D. 
E. 
F. 

12. Predict the main product of the following reaction sequence.

\[
\text{O} \xrightarrow{(\text{C}_8\text{H}_8\text{P})} \text{O} \xrightarrow{\text{PCC}} \text{CO}_2\text{Et} \xrightarrow{\text{Na}^+} ?
\]

A. 
B. 
C. 
D. 
E. 
F. 

13. Select the worst method to produce the following ester.

\[
\text{O}
\]

A. \[
\text{A} \xrightarrow{\text{NaOCH}_3, \text{CH}_3\text{OH}} \text{O}
\]

B. \[
\text{B} \xrightarrow{\text{H}^+, \text{CH}_3\text{OH}} \text{O}
\]

C. \[
\text{C} \xrightarrow{\text{H}^+, \text{CH}_3\text{OH}} \text{O}
\]

D. \[
\text{D} \xrightarrow{\text{CH}_3\text{OH}} \text{CH}_3\text{OCH}_3 \xrightarrow{\text{DCC}} \text{O}
\]

E. \[
\text{E} \xrightarrow{\text{NaOCH}_3, \text{CH}_3\text{OH}} \text{O}
\]

F. 


14. Which of the substituted benzaldehyde derivatives shown below would you predict to most readily form a hydrate? (Which would have the greatest $K_{eq}$ for the hydration reaction?)

\[
\begin{align*}
\text{RCHO} & \rightleftharpoons \text{RCHO}_2^\text{H} \quad K_{eq} = ?
\end{align*}
\]

A \quad B \quad C

D \quad E \quad F

The next 5 questions are worth 10 points each.

15. The reaction scheme shown below shows a synthesis of Brevicomin, the sex attractant of the western pine beetle.

\[
\begin{align*}
\text{X} & \xrightarrow{\text{NaOH}} \xrightarrow{1. \text{OH}} \xrightarrow{2. \text{H}^+} \text{Y} \xrightarrow{1. \text{OsO}_4} \xrightarrow{2. \text{NaHSO}_3} \text{Z} \xrightarrow{\text{H}^+} \text{Brevicomin} + \text{enantiomer}
\end{align*}
\]

Identify the starting material X and the intermediate compounds Y and Z.
16. The following reaction sequence outlines a synthesis of the tranquilizer phenaglycodol.

\[
\begin{align*}
&\text{Cl} \quad \text{Cl} \\
\textbf{O} &\text{Cl} \quad \text{AlCl}_3 \\
\textbf{Cl} &\text{O} \quad \text{HCN} \\
\textbf{W} &\text{1. NaOH} \\
&\text{2. HCl} \\
&\text{EtOH} \\
&\text{1. CH}_3\text{MgBr (excess)} \\
&\text{2. H}^+ \\
&\text{phenaglycodol} \\
&\text{C}_{11}\text{H}_{15}\text{ClO}_2
\end{align*}
\]

Draw the structure of the intermediate \textbf{W} and the structure of phenaglycodol.

The following two step sequence yields a cyclopropylketone.

\[
\begin{align*}
&\text{NaOEt/EtOH} \\
&\text{NaOH} \\
&\text{+ CO}_2
\end{align*}
\]

17. Give a curved arrow mechanism for the first step of the sequence. Clearly show all intermediates.

18. Give a curved arrow mechanism for the second step of the sequence. Clearly show all intermediates.
19. Propose an acetoacetic ester synthesis of the compound shown below. You should start with acetoacetic acid ethyl ester and any other carbon containing compounds of four carbons or less.