1. Choose the major product of the following reaction.

![Reaction Diagram]

A) \( \text{CH}_3 \)  
B) \( \text{CH}_3 \)  
C) \( \text{CH}_3 \)  
D) \( \text{CH}_3 \)  
E) \( \text{CH}_3 \) 

2. Choose those reactions that will give 3-bromochlorobenzene as a major product.

![Reaction Diagrams]

A) \( \text{Br}_2 \)  
B) \( \text{Br}_2 \)  
C) \( \text{Br}_2 \)  
D) \( \text{Br}_2 \)  
E) \( \text{Br}_2 \) 

3. Choose the major product of the following reaction.

![Reaction Diagram]

A) \( \text{A} \)  
B) \( \text{B} \)  
C) \( \text{C} \)  
D) \( \text{D} \)  
E) \( \text{E} \)
4. Choose the major product of the following reaction sequence.

\[
\begin{align*}
\text{Ph-} & \text{NH}_2 \\
\text{2 equivalents} \\
\overset{\text{OEt}}{\text{OEt}} \\
\text{1. } & \text{OH} \\
\text{2. } & \text{H}_3\text{O}^+ \text{ heat}
\end{align*}
\]

\[
\begin{align*}
\text{A} & \quad \text{Ph-} \quad \text{N} \quad \text{C} \\
\text{B} & \quad \text{Ph} \quad \text{N} \quad \text{C} \\
\text{C} & \quad \text{Ph-} \quad \text{N} \quad \text{C} \\
\text{D} & \quad \text{Ph} \quad \text{N} \quad \text{C} \\
\text{E} & \quad \text{Ph-} \quad \text{N} \quad \text{C}
\end{align*}
\]

5. Choose the reactants that would give the following compound by a Mannich reaction.

\[
\begin{align*}
\text{Mannich Reaction} \\
\overset{\text{H}^+}{\text{?}} \\
\text{O-} \\
\text{O}
\end{align*}
\]

\[
\begin{align*}
\text{1} & \quad \text{2} \\
\text{3} & \quad \text{4} \\
\text{5}
\end{align*}
\]

\[
\begin{align*}
A & = 2 + 4 + 5 \\
B & = 1 + 4 \\
C & = 2 + 3 \\
D & = 1 + 3 + 5 \\
E & = 1 + 3
\end{align*}
\]

6. Choose the order that has the following compounds correctly arranged with respect to increasing acidity.

\[
\begin{align*}
i & \quad \text{H}_3\text{C-} \quad \text{C-} \quad \text{S-} \quad \text{CH}_3 \\
ii & \quad \text{H}_3\text{C-} \quad \text{C-} \quad \text{N-} \quad \text{CH}_3 \\
iii & \quad \text{H}_3\text{C-} \quad \text{C-} \quad \text{O-} \quad \text{CH}_3
\end{align*}
\]

\[
\begin{align*}
i & < ii < iii \\
ii & < iii < i \\
ii & < iii < i \\
ii & < i < iii \\
iii & < i < ii
\end{align*}
\]

\[
\begin{align*}
A & \quad \text{A} \quad \text{B} \\
B & \quad \text{B} \quad \text{C} \\
C & \quad \text{C} \quad \text{D} \\
D & \quad \text{D} \quad \text{E} \\
E & \quad \text{E} \quad \text{A}
\end{align*}
\]

7. Choose the order that has the following carbonyl groups correctly arranged with respect to increasing $K_{eq}$ of their hydration (the compound with the greatest % of the gem diol is on the right).

\[
\begin{align*}
\text{R} & \quad \text{R}_1 \\
\overset{\text{H}_2\text{O}}{\text{K}_{eq}} \\
\text{HO} & \quad \text{OH} \\
\text{H}_3\text{C} & \quad \text{H}_3\text{C} \\
\text{CH}_3 & \quad \text{CH}_3 \\
\text{CF}_3
\end{align*}
\]

\[
\begin{align*}
A & \quad i < ii < iii \\
B & \quad i < iii < ii \\
C & \quad ii < i < iii \\
D & \quad ii < iii < i \\
E & \quad iii < i < ii
\end{align*}
\]
8. Which of the following is least likely to be an intermediate in the Heck reaction.

\[
\text{Ph-Br} + \text{CH}_3\text{COO-CH}_3 \xrightarrow{\text{PdL}_2, \text{Et}_3\text{N}} \text{Ph-CH}_2\text{COO-CH}_3
\]

\[
\text{L = ligand}
\]

A

B

C

D

9. Choose the compound that will cyclize the following ketal.

? \xrightarrow{\text{H}^\ominus, \text{-H}_2\text{O}}

A

B

C

D

E

10. Choose the reactant whose aldol reaction will give the following compound.

? \xrightarrow{\Theta, \text{alcohol}}

A

B

C

D

E
11. Choose the major product of the following reaction.

\[
\begin{align*}
\text{CH}_3\text{MgBr} & \quad 1. \text{H}_2\text{O}^+ \\
\text{CH}_3 & \quad 2. \text{H}_3\text{O}^+
\end{align*}
\]

\[
\begin{align*}
\text{A} & \quad \text{B} & \quad \text{C} & \quad \text{D} & \quad \text{E}
\end{align*}
\]

12. Choose the major product of the following reaction sequence.

\[
\begin{align*}
\text{HNO}_3/\text{H}_2\text{SO}_4 & \quad 1. \quad \text{Br}_2/\text{FeBr}_3 \\
\end{align*}
\]

\[
\begin{align*}
\text{A} & \quad \text{B} & \quad \text{C} & \quad \text{D} & \quad \text{E}
\end{align*}
\]

13. Choose the true statements about the reaction coordinate shown on the right.

1. The energy difference between species E and A can be used to calculate the equilibrium constant.
2. The energy difference between C and A can be used to calculate the rate of the reaction.
3. Species C represents a transition state.

A. 1  B. 2  C. 3  D. 1+2  E. 2+3
14. Choose the major product of the following reaction sequence.

\[
\begin{align*}
\text{O} & \quad \text{N} \\
\text{O} & \quad \text{N}_3 \\
\text{CH}_3\text{OH} \quad \text{heat (-N}_2) \quad 1. \text{LiAlH}_4 \quad \text{2. H}_2\text{O} \\
\end{align*}
\]

15. Choose the structure of the polymer produced by ring-opening metathesis polymerization.

16. Choose the correct statement(s) about the α-D-glucopyranose and β-D-glucopyranose shown below.

1. They both react with NaBH₄ to give the same compound.
2. They both have the same optical rotation.
3. They both react with CH₃-I in the presence of base to give the same pentamethyl derivative.

A. 1       B. 2       C. 3       D. 1+2       E. 2+3
17. Choose the major product of the following reaction sequence.

\[
\begin{align*}
&\text{O} \\
&\text{C} \\
&\text{N} \\
\end{align*}
\]

\[
\text{1. LiAlH}_4 \\
\text{2. H}_2\text{O}
\]

A  B  C  D  E

18. Treatment of fructose with base gives two aldohexoses. From the data on the front cover choose the structures of these two aldohexoses.

\[
\begin{align*}
\text{CH}_2\text{OH} & \\
& \text{O} \\
& \text{H} \\
& \text{H} \\
\text{H} & \\
& \text{OH} \\
& \text{CH}_2\text{OH} \\
\text{fructose}
\end{align*}
\]

A. 1+2  B. 3+4  C. 4+5  D. 5+6  E. 7+8

19. Choose the best synthesis for toluidine.

A  B  C  D  E

20. Using the data on the cover page, choose the structure of the D-aldohexose with the following properties:
(a) Oxidation with HNO\textsubscript{3} gives an optically inactive aldonic acid.
(b) Ruff degradation to the D-aldopentose followed by oxidation with HNO\textsubscript{3} gives an optically active aldonic acid.

A. 1  B. 2  C. 5  D. 6  E. 7
Short Answer Questions. 80 points.

21. Predict the products of the following reactions. 10 pts
   (a) Aseriscanolide workshop.
   \[
   \text{[Structure of Aseriscanolide]} \xrightarrow{LDA, Et_3N, \text{Claisen Rearrangement}} \text{[Predicted products]}
   \]

   (b) Tamiflu workshop.
   \[
   \text{[Structure of Tamiflu]} \xrightarrow{\text{heat}, \text{NH}_3, \text{heat}} \text{[Predicted product C7H11NO]}
   \]

22. Predict the products of the following reactions. 10 pts
   (a) Salvinorin A workshop
   \[
   \text{[Structure of Salvinorin A]} \xrightarrow{\text{OH, CH}_3\text{OH}} \text{[Predicted products]}
   \]

   (b) \[
   \text{[Structure of Compound]} \xrightarrow{\text{D}^+ / \text{D}_2\text{O}} \text{[Predicted products]}
   \]

23. A student was asked to perform the hydrolysis of diethyltoluamide (DEET). Unfortunately, the student stopped the reaction before all of the reactant had been consumed. Analysis showed that only \(\frac{1}{2}\) of the DEET had reacted but the student worked up the reaction anyway using the following separation procedure.

   Identify the chemical species, in addition to water and ether, the student found in flasks A, B, C and D. 10 pts

   \[
   \text{[Diagram of separation procedure]} \quad \text{A} \quad \text{B} \quad \text{C} \quad \text{D}
   \]

   \[
   \text{[Structure of DEET]} \xrightarrow{\text{H}_2\text{O, heat}} \text{[Products]} \xrightarrow{\text{[Separation procedure]}} \text{[Species found in A, B, C, D]}\]
24. Propose structures for compounds A-D in the following reaction sequence. 10 pts

\[
\begin{align*}
\text{A} & \quad \text{Ph}_3\text{P}=\text{CH}_2 \\
\text{B} & \quad \text{H}_3\text{O}^+ \\
\text{C} & \quad \text{MgBr} \\
\text{D} & \quad \text{PCC}
\end{align*}
\]

Dihydrotagetone

25. Give a synthesis for the following compound from benzene, compounds containing four carbon atoms or less and any other necessary reagents. 10 pts

\[
\begin{align*}
\text{Cl} & \quad \text{CH}_3
\end{align*}
\]

26. Cineol is a terpene with a camphoraceous odor found in *Eucalyptus globulus*. Using the curved arrow formalism show the bond making and bond breaking that occur in the conversion of geranyl pyrophosphate to cineol. 10 pts

\[
\begin{align*}
\text{H}_2\text{O} + \text{OPP} & \quad \text{biosynthesis} \quad \text{H}^+ \\
\text{HOPP} & \quad \text{H}_2\text{O} + \text{OPP}
\end{align*}
\]

27. Using the curved arrow formalism show the bond making and bond breaking that occurs in the following transformation. 10 pts

\[
\begin{align*}
\text{Ph} & \quad \text{BrMg—Ph} \\
\text{Ph} & \quad \text{1. BrMg—Ph} \\
\text{Ph} & \quad \text{2. H}^+/\text{H}_2\text{O}
\end{align*}
\]

28. Using the curved arrow formalism show the bond making and bond breaking that occurs in the following transformation. 10 pts

\[
\begin{align*}
\text{H}_2\text{C} & \quad \text{H}_2\text{C}—\text{S—CH}_3 \\
\text{H}_2\text{C} & \quad \text{H}_2\text{C}—\text{S—CH}_3 \\
\text{N} & \quad \text{N}
\end{align*}
\]