Multiple Choice Questions: 90 points

Below is the structure of procaine, more commonly known as novocaine. Use this structure to answer questions 1 – 3.

1. Choose the correct molecular formula for procaine.
   A  $C_{12}H_{18}N_2O_2$  B  $C_{13}H_{20}N_2O_2$  C  $C_{13}H_{22}N_2O_2$  D  $C_{13}H_{24}N_2O_2$  E  $C_{14}H_{22}N_2O_2$

2. Select the correct number of $sp^2$ hybridized atoms in procaine.
   A  6  B  7  C  8  D  9  E  10  F  11

3. Choose the answer that best describes the geometry at the indicated carbon atom in procaine.
   A  linear  B  bent  C  tetrahedral  D  trigonal pyramidal  E  trigonal planar

4. Select the major product of the following reaction.

   ![Reaction structure]  

5. Choose the order that has the following amines correctly arranged with respect to increasing solubility in water.

\[
\text{A: } i \rightarrow ii \rightarrow iii; \quad \text{B: } i \rightarrow iii \rightarrow ii; \quad \text{C: } ii \rightarrow i \rightarrow iii; \quad \text{D: } ii \rightarrow iii \rightarrow i; \quad \text{E: } iii \rightarrow ii \rightarrow i; \quad \text{F: } iii \rightarrow i \rightarrow ii.
\]

6. Choose the structure that is not a contributing structure of the other four structures.

\[
\text{A: } \text{O=C=O; } \quad \text{B: } \text{O=C=O; } \quad \text{C: } \text{O=C=O; } \quad \text{D: } \text{O=C=O; } \quad \text{E: } \text{O=C=O.}
\]

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

\[
\text{A: } i \rightarrow ii \rightarrow iii; \quad \text{B: } i \rightarrow iii \rightarrow ii; \quad \text{C: } iii \rightarrow ii \rightarrow i; \quad \text{D: } iii \rightarrow ii \rightarrow i; \quad \text{E: } ii \rightarrow i \rightarrow iii; \quad \text{F: } ii \rightarrow iii \rightarrow i.
\]

8. Select the correct isomer of 2-bromo-4-isopropyl-1-methylcyclohexane that, when subjected to ethoxide followed by hydrogenation, would yield a single isomer of 4-isopropyl-1-methylcyclohexane.

\[
? + \text{CH}_3\text{CH}_2\text{O}^+ \xrightarrow{\text{Pd-C}} \text{H}_2 \rightarrow \text{one major product}
\]

\[
\text{A: } \quad \text{B: } \quad \text{C: } \quad \text{D: } \quad \text{E: }
\]

9. Select the major product from the following reaction sequence.

\[ \text{Br} \quad \rightarrow \quad \text{O}^\Theta \quad \rightarrow \quad \text{OH} \quad \rightarrow \quad ? \]

- \[ + \text{enantiomer} \quad \text{A} \]
- \[ + \text{enantiomer} \quad \text{B} \]
- \[ + \text{enantiomer} \quad \text{C} \]
- \[ + \text{enantiomer} \quad \text{D} \]
- \[ + \text{enantiomer} \quad \text{E} \]

10. Select the correct oxidation state of carbon in carbonic acid.

\[ \text{HO}_2\text{COH} \]

- \[ -3 \quad \text{A} \]
- \[ -1 \quad \text{B} \]
- \[ 0 \quad \text{C} \]
- \[ +1 \quad \text{D} \]
- \[ +3 \quad \text{E} \]
- \[ +4 \quad \text{F} \]

11. Choose the correct number of isomers with the molecular formula \( \text{C}_4\text{H}_9\text{Cl} \).

- \[ 3 \quad \text{A} \]
- \[ 4 \quad \text{B} \]
- \[ 5 \quad \text{C} \]
- \[ 6 \quad \text{D} \]
- \[ 7 \quad \text{E} \]
- \[ 8 \quad \text{F} \]

12. Select the choice that best describes the relationship between the following two structures.

- \[ \text{A} \quad \text{conformers} \]
- \[ \text{B} \quad \text{constitutional isomers} \]
- \[ \text{C} \quad \text{diastereomers} \]
- \[ \text{D} \quad \text{enantiomers} \]
13. Choose the major product of the following reaction that involves a deuterium-labeled reagent.

\[
\text{1. NaBD}_4 \\
\text{2. H}_2\text{O} \\
\text{K} \rightarrow ?
\]

\[\text{HO} \quad \text{H} \quad \text{DO} \quad \text{H} \quad \text{HO} \quad \text{D} \quad \text{DO} \quad \text{D} \quad \text{D} \quad \text{D} \]

A B C D E

14. Choose the correct intermediate formed from the following 1,2-alkyl shift, based on the following curved arrow.

\[\text{?} \rightarrow \text{?} \]

A B C D E

15. Choose the order that has the following compounds correctly arranged with respect to increasing reactivity with CH\textsubscript{3}MgBr.

\[\text{i} \quad \text{H} \quad \text{ii} \quad \text{ii} \quad \text{iii} \]

A B C D E

\[\text{A} \quad \text{B} \quad \text{C} \quad \text{D} \quad \text{E} \quad \text{F} \]

Page 4
16. Using the clues given in the following roadmap, select the correct structure for unknown compound Z.

\[ X \xrightarrow{\text{1. } \text{KMnO}_4, \text{OH}^-, \text{heat}} \xrightarrow{\text{2. } \text{H}_3\text{O}^+} \]

\[ c_8h_{16}o_2 \]

\[ Y \xrightarrow{\text{H}_2\text{CrO}_4, \text{H}_2\text{O, acetone}} Z \]

1. OsO₄
2. NaHSO₃

\[ A \quad B \quad C \]

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

\[ \begin{align*}
\text{HO} & \quad \text{COO} \\
\text{HO} & \quad \text{COO} \\
\text{HO} & \quad \text{COO} \\
\text{HO} & \quad \text{COO}
\end{align*} \]

\[ \begin{align*}
\text{HO} & \quad \text{COO} \\
\text{HO} & \quad \text{COO} \\
\text{HO} & \quad \text{COO} \\
\text{HO} & \quad \text{COO}
\end{align*} \]

17. Choose the major product of the following reaction.

\[ \text{CH}_3\text{S}^- \xrightarrow{\text{DMSO}} \]

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

\[ A \quad B \quad C \quad D \quad E \quad F \]
18. Select the cation that is most likely not an intermediate formed in the following reaction.

\[
\text{Cation A} \quad \overset{\text{H}_2\text{SO}_4}{\xrightarrow{\text{heat}}} \quad \text{Cation B} + \text{H}_2\text{O}
\]

A. \[\text{Cation A}\]
B. \[\text{Cation B}\]
C. \[\text{Cation C}\]
D. \[\text{Cation D}\]
E. \[\text{Cation E}\]

**Short Answer Questions: 90 points**

19. Draw the structure of the major product of the following reaction. 5 pts

\[
\begin{align*}
\text{Cation} & \quad \xrightarrow{\text{H}^+} \quad \text{Product} \\
\text{[C}_4\text{H}_9\text{O}_2] & \quad \text{\oplus}
\end{align*}
\]

20. Draw the structure of the major product of the following reaction sequence. 5 pts

\[
\begin{align*}
\text{C}_{10}\text{H}_{18}\text{O}_3 & \quad \xrightarrow{1. \text{LiAlH}_4} \quad \text{Product} \\
\text{C}_{10}\text{H}_{18}\text{O}_3 & \quad \xrightarrow{2. \text{H}_2\text{O}} \quad \text{Product} \\
\text{Product} & \quad \xrightarrow{\text{PCC}} \quad \text{Product}
\end{align*}
\]
21. Draw the most stable chair conformation of cis-1-isopropyl-3-methylcyclohexane. Clearly label each substituent as being axial or equatorial. 5 pts

22. Aside from carbonyl compounds, lithium aluminum hydride can also reduce epoxides. Based on your knowledge of LiAlH₄ and on your knowledge of epoxides, determine and draw the structure of the major product of the following reaction. 5 pts

\[ \text{Epoxide} \xrightarrow{\text{LiAlH}_4} \text{Product} \xrightarrow{\text{H}_2\text{O}} ? \]

23. Draw the structures of A and B, based on the following reaction sequence. 8 pts

\[ \text{Epoxide} \xrightarrow{\text{CH}_3\text{MgBr, ether}} \text{A} \xrightarrow{\text{CH}_3\text{I, } [\text{C}_6\text{H}_11\text{O}]} \text{B} \]

24. Compounds C through E are three isomeric cyclopropanes with the molecular formula C₄H₇Br. Based on the information given below, determine and clearly draw the structures of C, D and E, indicating stereochemistry where appropriate, using wedges and dashes. 10 pts

a. Treatment of compounds C and D with NaCN in DMF followed second-order kinetics, with compound C reacting at a faster rate.

b. Compound E does not undergo the S₂ reaction under the given conditions.

c. Compounds C and E were found to be achiral.

d. Compound D was found to be optically active containing two chirality centers, each having R configuration.
25. Compound **F** has a molecular formula of C₈H₁₆. Ozonolysis of **F** gives 2-methylpropanal. Compound **G** is a racemic mixture. Clearly draw the structures of compounds **F** and **G**, indicating stereochemistry where appropriate, using wedges and dashes. You only need to draw one enantiomer for **G**. 10 pts

26. Using the curved arrow formalism, show all the bond making and bond breaking steps of the following reaction. 8 pts

27. Propose a synthesis of the following compound starting from any compound(s) containing four carbon atoms or less. Your synthesis must lead to the racemic mixture. 10 pts
28. Using the curved arrow formalism, show all the bond making and bond breaking steps of the following reaction. 12 pts

\[
\begin{align*}
\text{OH} & \quad \xrightarrow{\text{HCl}} \\
\text{Cl} & \quad \text{CH}_2=\text{CH}_2
\end{align*}
\]

29. Propose a synthesis of the following compound starting from any compound(s) containing four carbon atoms or less (using TBDMS-Cl as a reagent is acceptable even though it contains more than four carbon atoms). 12 pts

\[
\begin{align*}
\text{O} & \quad \xleftarrow{} \\
\text{CH}_2=\text{CH}_2 & \quad \text{O}
\end{align*}
\]