1. (30) Using provided boxes, answer the questions on mechanisms of the following reactions (15 each):

(a) \[ \text{OH} \xrightarrow{\text{H}_2\text{SO}_4, \text{heat}} \]

Using curved arrows and showing the structure of the oxonium intermediate, write the first step (protonation) in the reaction mechanism (5 pts):

Using curved arrow and showing the structure of the carbocationic intermediate, write the second step in the reaction mechanism (5 pts):
Using curved arrows and other essential species (H₂O), write the elimination step (E1) in the reaction mechanism (5 pts):

(b) \[
\begin{align*}
\text{phenyl} & \quad \text{C} = \text{CH} \\
\text{HBr} (1 \text{ equivalent}) & \quad \rightarrow \\
\text{phenyl} & \quad \text{C} = \text{CH}_2 \quad \text{Br}
\end{align*}
\]

Using curved arrows and showing the structure of the carbocationic intermediate, write the first step in the reaction mechanism (10 pts):

Using curved arrow and other essential species, write the final step in the reaction mechanism (5 pts):

2. (29) Finish drawings of the three-dimensional structures of major organic products in the followin reaction [your drawings must be in agreement with the stereochemistry of this reaction!] (10 pts). In the provided circles, write R,S configurations for all stereocenters in each of the products (8 pts). In the provided box, draw the structure of the bridged bromonium intermediate for this reaction (11 pts).
3. (36) Complete the following equations by drawing **three-dimensional structures** with the correct **stereochemistry** of the major organic products expected in each case (6 pts each).

\[
\text{C}_{2}H_{5} \quad \text{NaN}_{3} \quad \text{acetone} \quad \rightarrow \quad \text{C}_{2}H_{5} \quad \text{N}_{3} \quad \text{CH}_{3} \quad (-3 \text{ pts for wrong racemization})
\]

\[
\text{Ph} \quad \text{Br} \quad \text{Ph} \quad \text{H} \quad \text{CH}_{3} \quad \text{(CH}_{3}\text{)}_{3}\text{COK} \quad \text{(CH}_{3}\text{)}_{3}\text{COH} \quad \rightarrow \quad \text{Phi} \quad \text{Ph} \quad \text{Br} \quad \text{CH}_{3} \quad \text{or} \quad \text{Ph} \quad \text{Br} \quad \text{CH}_{3} \quad \text{or} \quad \text{Ph} \quad \text{Br} \quad \text{CH}_{3} \quad \text{(-3 pts for wrong stereochemistry)}
\]

\[
\text{H}_{3}\text{O} \quad \text{Ph} \quad \text{H}_{2}\text{O} \quad \rightarrow \quad \text{CH}_{3} \quad \text{Ph} \quad \text{Br} \quad \text{+CH}_{3} \quad \text{Ph} \quad \text{Br} \quad \text{(-3 pts for wrong stereochemistry)}
\]
4. (35) Complete the following equations by drawing structures of the major product(s) expected in each reaction (5 pts each).

\[
\text{HC≡CH} + \text{H}_2\text{O} \xrightarrow{\text{H}_2\text{SO}_4, \text{HgSO}_4} \text{CH}_3-\overset{\text{C}}{\text{=O}}
\]

\[
\text{C}_6\text{H}_5-\text{C} \xrightarrow{\text{HBr}} \text{CH}_3-\overset{\text{C}}{\text{=O}}
\]

\[
\text{C}_6\text{H}_{10} + \text{Br}_{\text{NCO}} \xrightarrow{\text{peroxide, heat, CCl}_4} \text{Br}
\]

\[
\text{CH}_2\text{OH} + \text{CH}_2\text{OH} \xrightarrow{1. \text{O}_3} \text{CH}_2\text{OH} \xrightarrow{2. (\text{CH}_3)_2\text{S}} \text{OH}
\]

\[
\text{Ph-CH}_2\text{OH} + \text{N}^+ \xrightarrow{\text{CrO}_3\text{Cl}^-} \text{OH}
\]

\[
\text{C}_6\text{H}_5-\text{CH}_2\text{OH} + \text{PBr}_3 \xrightarrow{\text{pyridine}} \text{CH}_2\text{Br}
\]

\[
\text{HC≡CNa} + \text{C}_6\text{H}_5-\text{CH}_2\text{Br} \rightarrow \text{HC≡C-CH}_2\text{Br}
\]
5. (30) Give the reagents on the arrow that can be used to convert the reactant to the indicated product in high yield (5 pts each).

\[
\begin{align*}
\text{H}_3\text{CC} & \equiv \text{CNa} & \text{CH}_3\text{Br} & \xrightarrow{3 \text{pt's}} & \text{2 pt's} & \text{Na}_2, \text{NH}_3 \\
& \text{(or CH}_3\text{I}) & & & & \\
& & & \text{2 CH}_3\text{OH} & & \\
& & & \text{(or NaOC}_2\text{H}_5) & & \\
& & & \text{(or NaNH}_2 & & \\
& & & \text{H}_2\text{O, H}_2\text{O}) & &
\end{align*}
\]

\[
\begin{align*}
\text{Br} & \text{Br} \text{BuOK} & \text{t} & \text{O}_3\text{O}_4 \\
& \text{(or NaOC}_2\text{H}_5) & & \text{(or H}_2\text{O, H}_2\text{O})
\end{align*}
\]

\[
\begin{align*}
\text{OH} & \xrightarrow{3 \text{pt's}} & \text{2 Br}_2 \\
& \text{H}_2\text{SO}_4(\text{heat}) & & \text{Br}_2 & \text{(or H}_3\text{PO}_4(\text{heat})
\end{align*}
\]

\[
\begin{align*}
\text{NBS} & \xrightarrow{3 \text{pt's}} & \text{2 NaCN} \\
& \text{(or Br}_2, \text{heat}) & & \text{(or CN}^{-})
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3\text{CH}_3 & \xrightarrow{3 \text{pt's}} & \text{2 NH}_3 \\
& \text{C}_2\text{H}_4, \text{hv} & & \text{CH}_3\text{CH}_2\text{NH}_3 & \text{Cl}^{-} \\
& \text{(or C}_2\text{H}_4, \text{heat}) & &
\end{align*}
\]

\[
\begin{align*}
\text{CH}_2\text{Cl} & \xrightarrow{3 \text{pt's}} & \text{2 PCC} \\
& \text{NaOH} & & \text{PCC} & \text{H}_2\text{O}
\end{align*}
\]

6. (40, 5 pts each) For each of the following questions (a)-(h) circle the item that is the correct answer.

(a) Which of the following compounds is the most reactive in \text{S}_N1\text{ reactions?}

1-chlorohexane 1-iodo-2-methylhexane 1-iodo-1-methylcyclohexane 1-iodohexane
2-hexyl tosylate 1-fluoro-4-methylhexane 1-hexyl tosylate 1-iodo-4-methylcyclohexane
methane ethane tert-butylcyclohexane methanol ethanol vinyl chloride
(b) Which of the following compounds is the most reactive in $S_N2$ reactions?

1-bromohexane 1-bromo-2-phenylhexane 3-bromocyclohexene iodomethane
2-iodohexane 3-bromocyclohexanol 4-bromo-1-phenylcyclohexene 1-bromo-2-phenylcyclohexane

(c) Which of the following compounds is the most reactive in radical reactions with NBS?

cyclohexane 1,1-dimethylcyclohexane ethylene chloromethane fluoromethane
methane ethane phenylcyclohexane 3-methylcyclohexanol dichloromethane butane

(d) Which one of the following compounds has the most acidic hydrogens?

methane ammonia 1-fluoropropane 2-butyne cyclohexanol 1-iodopropene
2-methylcyclohexene 3-methylcyclohexene tetrafluoromethane 1-chloropropane

(e) Which one of the following compounds has two stereoisomers?

2-iodo-3-chlorobutane methylcyclopentane 1-iodo-1-methylcyclopentane 1,1-dimethylcyclobutane
3-bromocyclohexanol 4-methylcyclohexanol 1,2-dibromocyclohexane 3,4-dichlorohexane

(f) Which one of the following compounds will have the highest boiling point?

propane acetic acid 2-chloropropane 1,2-dimethylcyclopropane
1-fluoropropane dimethyl ether 1-propanethiol propene propyne

(g) Which of the following compounds is the strongest base?

$\text{CH}_3\text{OCH}_3$ LiCl $\text{CH}_3\text{OH}$ LiI $\text{H}_2\text{O}$ LiF NaNH$_2$
\text{CH}_3\text{OLi}$\text{NH}_3$ $\text{CH}_3\text{NH}_2$ $t$-$\text{BuOH}$ $t$-$\text{BuOK}$ HCl

(h) Which of the following alkenes will be the major product in the acid-catalyzed dehydration of 3-methyl-2-butanol?

3-methyl-1-butene (E)-2-pentene (Z)-2-pentene 2-methyl-2-butene 2-methylbutane
(E)-2-butene (Z)-2-butene 1-butene 1-pentene dimethylacetylene 1-pentyne