All answers should be written CLEARLY in the space provided. (If it’s not clear, it’s wrong).

You may raise your hand to ask a question if you are unsure what a question is asking of you.
1. (3 points) Give the chemical structure for tert-butyl ethyl ether.

2. (3 points) Provide the name for the following compound:

3. (3 points) Diethyl ether and 1-butanol are isomers of C₄H₁₀O, and thus have the same molecular weight. However, 1-butanol has a much higher boiling point (118°C vs. 35°C). Explain why.

   H-bonding

4. (3 points) Explain why the amine shown below is optically inactive.

5. (4 points) Rank each of the following alkyl halides in order of their relative reactivity in SₐN₂ reactions (1 = most reactive, 5 = least reactive)

6. (6 points) Circle the better nucleophile in each of the following pairs:
   a) H₂O or H₂S
   b) CH₃S⁻ or CH₃SH
   c) I⁻ or Cl⁻
7. (6 points) If a molecule is capable of reacting with itself either intramolecularly or intermolecularly, the two process can sometimes compete. For example, consider the following two reactions:

a) 

\[
\begin{array}{c}
\text{Cl} \\
\text{Cl}
\end{array}
\quad \leadsto \quad \begin{array}{c}
\text{O} \\
\text{O}
\end{array} + \text{Cl}^-
\]

b) 

\[
\begin{array}{c}
\text{Cl} \\
\text{Cl}
\end{array}
\quad \rightarrow \quad \begin{array}{c}
\text{O} \\
\text{O}
\end{array}
\begin{array}{c}
\text{O} \\
\text{O}
\end{array} + \text{Cl}^-
\]

Which of the two reactions has a higher $\Delta S$, and explain why. Would you expect this reaction to become more favorable at higher temperature, or less favorable? Why?

\[
\begin{align*}
\Delta S & > 0 \\
\Delta G & = \Delta H - T\Delta S \\
\uparrow T & \rightarrow \text{Lesser negative value} \\
\therefore & \text{Hi T favours rxn}
\end{align*}
\]

8. (8 points) Explain why $S_{n2}$ reactions proceed with inversion of stereochemistry. Hint: show the reaction mechanism and invoke molecular orbitals in your explanation (a picture is worth a thousand words).

\[
\begin{array}{c}
\text{Nu} \quad \sigma^* \quad \text{C} \quad \sigma \quad \text{Nu} \\
\text{R}^1 \quad \text{R}^2 \quad \text{R}^3
\end{array}
\rightarrow
\begin{array}{c}
\text{Nu} \quad \text{O} \quad \text{C} \quad \text{Nu} \\
\text{R}^1 \quad \text{R}^2 \quad \text{R}^3
\end{array}
\]

- backside attack trajectory ①
- mention $\sigma^*$ of C-X bond ①
9. (10 points) A reaction coordinate diagram for the following reaction is shown below. Use it to answer the following questions:

\[
\begin{align*}
\begin{array}{ccc}
\text{Cl}^+ & \text{KOT-Bu} & \text{DMSO} \\
\text{A} & \rightarrow & \text{B} + \text{C}
\end{array}
\end{align*}
\]

\[
\text{E} \\
\begin{array}{ccc}
\text{A} & \rightarrow & \text{B} \\
\text{C}
\end{array}
\]

Reaction Coordinate

a) (2 points) The energy level for the reactant A has been included for you in the diagram. Indicate the relative energies of the two products on the diagram, using the labels “B” and “C”.

b) (4 points) Which product is the thermodynamic product? Explain how you determined this.

C. Zaitsev: more subst. alkene more stable

C

(c) (4 points) Which product is the kinetic product? Explain how you determined this.

B. \( \Delta G^\dagger \) lower
10. (30 points) Give the major organic product(s) for the following reactions, including stereochemistry if applicable. Hint: for $S_N2$ and E2 reactions, show one major product; for $S_N1$ and E1 reactions, show all the possible products but circle the major alkene product if more than one alkene can be formed.

a) \[
\text{CH}_3\text{CH}_2\text{CH}_2\text{I} + \text{C}_6\text{H}_5\text{SO}_3^- \rightarrow \text{CH}_3\text{CH}(_2\text{CH}_2\text{S})\text{CH}_3 \] E2 \(\Box\)

b) \[
\text{CH}_3\text{CH}_3 \xrightarrow{\text{KOT-Bu}} \text{CH}_2=\text{CH}_2 \] $S_N2$ \(\Box\)

c) \[
\text{CH}_3\text{CH}(_2\text{Br})\text{CH}_2\text{CH}_3 \xrightarrow{\text{NaOCH}_3} \text{CH}_3\text{CH}(_2\text{CH}_3)\text{CH}=\text{CH}_2 \] $S_N2$ w/ inversion \(\Box\), w/o \(\Box\) non-Bertrand \(\Box\)

d) \[
\text{CH}_3\text{CH}(_2\text{OTs})\text{CH}_3 \xrightarrow{\text{NaBr}} \text{CH}_3\text{CH}(\text{Br})\text{CH}=\text{CH}_2 \] Stereo wrong \(\Box\) Elimination \(\Box\)

e) \[
\text{CH}_3\text{C}_6\text{H}_4\text{I} \xrightarrow{\text{H}_2\text{O}} \text{CH}_3\text{C}_6\text{H}_4\phi + \text{CH}_3\text{C}_6\text{H}_4=\text{CH} \] \(\frac{1}{2}\) each

f) \[
\text{CH}_3\text{CH}(_2\text{Br})\text{CH}_3 \xrightarrow{\text{H}_2\text{O}} \text{CH}_3\text{CH}(_2\text{OH}) + \text{CH}_3\text{CH}=\text{CH}_2 \] \(\frac{1}{2}\) eq. \(\Box\)

if \(\phi\) also and no major, \(\Box\)

if \(\phi\) is major, \(\Box\)

g) \[
\text{C}_6\text{H}_5\text{Cl} \xrightarrow{\text{NaOH}} \text{C}_6\text{H}_5\text{C}_6\text{H}_4\text{CH}=\text{CH}_2 (\text{or } \text{C}_6\text{H}_5\text{O}^-) \] \(\Box\)

h) \[
\text{CH}_3\text{CH}(_2\text{Br})\text{CH}_3 \xrightarrow{\text{NaOMe}} \text{CH}_3\text{CH}(_2\text{CH}(_2\text{CH}(_2\text{CH}(_2\text{OH}) \] \(\Box\)
11. (18 points) Provide reagents that will effect the following transformations:

a) \( \text{Br} \) + \( \text{Mg} \) → \( \text{MgBr} \) → \( \text{H}_2\text{O} \) or other \( \text{H}^+ \) source → \( \text{Cl}^- \)

b) \( \text{OH} \) + \( \text{SOCl}_2 \) or \( \text{HCl} \) or \( \text{TeCl}_7/\text{pyr} \) then \( \text{Cl}^- \)

c) \( \text{Br} \) + \( \text{N}_3 \) → \( \text{N}_3^- \)

d) \( \text{I} \) + \( \text{Me}_3\text{N} \) → \( \text{N}^+\text{CH}_3 \) \( \text{H}_3\text{C} \) \( \text{CH}_3 \) \( \text{I}^- \)

e) \( \text{OTs} \) + \( \text{Ac}_2\text{O} \) \( \text{(neutral acid} \text{)} \) → \( \text{Ac}^- \)

12. (6 points) Choose one of the following two synthesis problems below. Show how you can make the final product from the given starting material. The synthesis will require more than one chemical step.
If you show work on more than one problem, CLEARLY indicate which of the two you want graded; otherwise the first one on the page will count for credit.

a)

\[ \text{H}_3\text{CO}-\text{Cl} \xrightarrow{?} \text{HO}-\text{N}^{\text{CH}_3} \]

b)

\[ \text{OH} \xrightarrow{?} \text{CN} \]

See AM Key.