1. Predict the major product(s) of each of the following reactions then indicate which mechanism \((S_N 1 or S_N 2)\) will produce this product.

a. \(\text{HO-} + \text{Br} \xrightarrow{\text{KOH, DMF}} \)

b. \(\text{CH}_3 \xrightarrow{\text{NaCN, EtOH}} \)

c. \(\text{Br} \xrightarrow{\text{NaCN, DMF}} \)

d. \(\text{H} \xrightarrow{\text{conc. HBr}} \)

e. \(\text{OH} \xrightarrow{\text{dil. H}_2\text{SO}_4, \text{CH}_3^{16}\text{OH}} \)

f. \(\text{Cl} \xrightarrow{\text{cold NaOH}} \)

g. \(\text{H} \xrightarrow{\text{conc. HCl}} \)
2. Consider the following S<sub>\text{N}2</sub>-type reaction...

\[
\begin{align*}
\text{CH}_3\text{I} + \text{NO}_2^- & \rightarrow \text{CH}_3\text{NO}_2^- + \text{I}^-
\end{align*}
\]

a. Draw the most stable Lewis dot structure for the product, CH₃NO₂, showing formal charges and resonance structures where applicable.
b. Identify each of the following components of the above reaction: nucleophile, electrophile, Lewis acid, Lewis base, leaving group.
c. Is this reaction a first-order or second-order process? Based on your answer, provide a reasonable rate expression for the above reaction.
d. How does the rate of the above reaction change as a function of solvent? That is, does this reaction work better in a polar aprotic or polar protic solvent?

3. Consider the following S<sub>\text{N}1</sub>-type reaction...

\[
\begin{align*}
\text{CH}_3\text{I} + \text{HCO}_2^- & \rightarrow \text{CH}_3\text{CO}_2^- + \text{I}^-
\end{align*}
\]

a. Draw the most stable Lewis dot structure for the product, showing formal charges and resonance structures where applicable.
b. Identify each of the following components of the above reaction: nucleophile, electrophile, Lewis acid, Lewis base, leaving group.
c. Is this reaction a first-order or second-order process? Based on your answer, provide a reasonable rate expression for the above reaction.
d. How does the rate of the above reaction change as a function of solvent? That is, does this reaction work better in a polar aprotic or polar protic solvent?

4. The cis and trans stereoisomers of 4-chlorocyclohexanol (see below) give different products when treated with hydroxide ion (OH⁻).

\[
\begin{align*}
\text{Cl} & \quad \text{OH}^- \quad \text{OH}^- \\
\text{1} & \quad \text{3} + \text{4} & \quad \text{2} & \quad \text{3} + \text{5}
\end{align*}
\]

a. Using the curved-arrow formalism, provide a reasonable mechanism to account for the formation of compounds 3, 4, and 5 from 1 and/or 2 (where applicable).
b. Explain why compound 4 is not observed to form in the reaction of 2 with hydroxide ion (OH⁻).
5. Show how each of the following compounds may be prepared from an alkyl halide.

   a. CH₃CH₂CH₂SH
   b. CH₃CH₂CH₂OCH₃
   c. (CH₃)₂CHCH₂CH₂CN
   d. CH₃CH₂CH=CH₂
   e. CH₃CH₂CH₂CH₂N₃

6. Draw the line structure(s) corresponding to the major organic product(s) expected when isopentyl bromide (1-bromo-3-methylbutane) reacts with the following reagents. Be certain to indicate the mechanism (S₁N₁, S₂N₂, E₂, or E₁) that accounts for the formation of your predicted product(s)

   a. NaI in acetone
   b. KOH in ethanol
   c. KOtBu in tert-butyl alcohol
   d. CsF in DMF
   e. Sodium methoxide in methanol
   f. NaN₃ in DMSO

7. For each of the following pairs of reactions, indicate the mechanism at work (S₁N₁, S₂N₂, E₂, or E₁), then predict which one is faster. Explain your prediction.

   a. (CH₃)₂CHCH₂Cl + N₃⁻ → (CH₃)₂CHCH₂N₃ + Cl⁻
   (CH₃)₂CHCH₂I + N₃⁻ → (CH₃)₂CHCH₂N₃ + I⁻

   b. (CH₃)₂CBr → (CH₃)₂COH + HBr
   (CH₃)₂CHBr → (CH₃)₂CHOH + HBr

   c. CH₃CH₂CH₂Br + CN⁻ → CH₃CH₂CH₂CN + Br⁻
   CH₃CH₂CH₂Br + CH₃OH → CH₃CH₂CH₂CN + Br⁻

   d. t-BuBr → t-BuCH₂Br
   t-BuBr → t-BuCH₂Br