1. (10 pts) Complete each of the following acid-base reactions and, using your knowledge of $pK_a$, work out the approximate $K_a$ for the reaction and indicate which side will be favored in each.

\[
\begin{align*}
\text{OH} + \text{CH}_3\text{CH}_2\text{ONa} & \quad \longrightarrow \\
\text{OH} + \text{NaNH}_2 & \quad \longrightarrow \\
\text{Li} + \text{H}_2\text{O} & \quad \longrightarrow \\
\text{O} + \text{NaOCH}_3 & \quad \longrightarrow \\
\text{O} + \text{NaOiPr} & \quad \longrightarrow
\end{align*}
\]

2. (9 pts) Give all significant resonance forms for each of the following species.

\[
\begin{align*}
\begin{array}{c}
\text{NO}_2 \\
\text{O}^\ominus \\
\text{N} \\
\text{H}_2\text{S}
\end{array}
\end{align*}
\]
3. (10 pts) Substrate A below proceeds to give a substitution (solvolyis) product whereas substrate B does not. Explain this difference in terms of the possible mechanisms that could operate.

![Substrate A and B reactions](image)

4. (6 pts) Indicate which of the following species should be aromatic and explain your choices in terms of Hückel’s rule.

![Aromatic species](image)

5. (5 pts) Indicate the hybridization of each C, N and O atom in the following Taxol molecule.

![Taxol molecule](image)
6. (10 pts) Label the indicated chiral centers in the Taxol molecule below (i.e. the ones with wedges and dashes given) as being either (R) or (S).

7. (10 pts) For the molecule CH₃CH(OH)CH(OH)CH(OH)CH₃ draw all of the different possible stereoisomers as Fisher projections and show the relationships between each of them (i.e. enantiomers or diastereomers).
8. (10 pts) Give products for the following reactions indicating any stereochemical changes that may have occurred.

a. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{\text{EtO}_2C-N=N-CO_2\text{Et}} \\
\text{PhCO}_2\text{H}, \text{PPh}_3 & \quad \text{THF}
\end{align*}
\]

b. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{1. \text{CH}_3\text{SO}_2\text{Cl}, \text{pyridine}} \\
2. \text{NaN}_3, \text{DMF} & \\
\end{align*}
\]

c. 
\[
\begin{align*}
\text{OTMS} & \quad \xrightarrow{(n-\text{Bu})_4\text{NCN}} \\
\text{THF} & \quad \text{CH}_2\text{Cl}_2
\end{align*}
\]

d. 
\[
\begin{align*}
\text{I} & \quad \xrightarrow{\text{NaBr, acetone}}
\end{align*}
\]

e. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{\text{HBr, RT}}
\end{align*}
\]
9. (10 pts) Give a complete mechanism, using arrows to show the making and breaking of bonds, for the following Mitsunobu reaction.

\[
\begin{align*}
\text{CO}_2\text{H} & \quad \text{EtO}_2\text{C-} \equiv \text{N-} \equiv \text{CO}_2\text{Et} \\
\text{PPh}_3, \text{THF} & \quad \text{OH} \\
\text{PPh}_3, \text{THF} & \quad \text{OH}
\end{align*}
\]

10. (6 pts) Put the missing (formal) charges on the appropriate atoms in each of the following species.

\[
\begin{align*}
\text{N} & \quad \text{O} \\
\text{O} & \quad \text{O} \\
\text{O} & \quad \text{HNNN} \\
\text{H}_2\text{C-} \equiv \text{N} \\
\text{O} & \quad \text{O}
\end{align*}
\]
11. (6 pts) Draw diagrams for the following:
   
a. *cis*-1-isopropyl-2-methylcyclohexane in its lowest energy chair form.

   b. *(Z)*-1-bromo-2,3-dimethyl-2-hexene

   c. Two different resonance forms for diazomethane (CH$_2$N$_2$)

12. (8 pts) Rank the following in order of increasing acidity (1 = weakest acid, 4 = strongest) and explain your choices in detail.

   ![Diagrams]