Final Review: New Material after Midterm 2

1. Complete the following reactions, showing the major product expected in each case. Clearly show stereochemistry where important. If a racemic mixture is formed, show both enantiomers. If no reaction occurs, or the equilibrium is unfavorable, write NR.

   a. \[ \text{CH}_3\text{OH} \xrightarrow{\text{NaN}_3, \text{DMSO}} \text{H}_3\text{C} \square \text{H} \quad \text{Cl} \]

   b. \[ \text{CH}_3-\text{C-Br} \xrightarrow{\text{NaSH, CH}_3\text{CH}_2\text{OH}} \]

   c. \[ \text{EtOH} \xrightarrow{\text{EtO}^-, \text{EtOH}} \]

   d. \[ \text{EtOH} \xrightarrow{\text{BrCH}_2, \text{NaSH, 1 equivalent, HCN(CH}_3)_2, \text{(DMF)}} \]

2. For the following energy diagram, circle the correct answers in the questions that follow:

   a. Which step is the rate-determining step in the forward direction: B \(\rightarrow\) D, or D \(\rightarrow\) G?
   b. Which step is the rate-determining step in the reverse direction: G \(\rightarrow\) D, or D \(\rightarrow\) B?
   c. Is the second step exothermic or endothermic?
   d. For the overall reaction is \(\Delta H^\circ\) (-) or (+)?
   e. If all steps are reversible, which will be favored at equilibrium, B, D, or G?
3. Rank following compounds in order of decreasing nucleophilicity in aqueous solution. (1 =
best nucleophile). You can consult the $pK_a$ table at the end of this exam.

   \[
   \begin{array}{c}
   \text{CH}_3\text{OH} \quad \text{CH}_3\text{C} \quad \text{CH}_3\text{O} \quad \text{Ph} \quad \text{CH}_3\text{NH}_2 \\
   \square & & \square & & \square \\
   \end{array}
   \]

4. Which would you expect to be a stronger nucleophile? Circle the correct answer for each set.
   a. CH$_3$S$^-$ or CH$_3$SH?
   b. (CH$_3$)$_3$P or (CH$_3$)$_3$N in acetone?
   c. (CH$_3$)$_3$P or (CH$_3$)$_3$N in methanol?

5. The following questions refer to Vildagliptin, sold under the trade name Zomelis™. 
   Vildagliptin is an oral anti-hyperglycemic drug used to treat type 2 diabetes.

   \[
   \text{Vildagliptin (Zomelis™)}
   \]

   a. Excluding sp$^3$-CH bonds, indicate the four main absorptions above 1500 cm$^{-1}$ expected
      for Vildagliptin, by using an arrow to point to the specific bond, and writing an
      approximate absorption (using the IR chart provided.)
   b. Circle the carbon expected to be the most deshielded in $^{13}$C-NMR.
   c. Comparing carbon a & carbon b, which do you expect have the largest chemical shift in
      $^{13}$C-NMR? Give a one-sentence explanation for your answer.

6. (12 points) Complete the following:

   \[
   \begin{array}{c}
   \text{Cl} - \text{C} - \text{C} - \text{CH}_3 \\
   \text{H} \quad \text{D} \\
   \square & & \square \\
   \end{array}
   \quad \quad 
   \begin{array}{c}
   \text{H} - \text{N(CH}_3)_2 - \text{CH}_2\text{OCH}_3 \\
   \square & & \square \\
   \end{array}
   \quad \quad 
   \begin{array}{c}
   \text{Cl} - \text{C} - \text{CH}_2\text{Br} \\
   \text{H} - \text{H} \\
   \square & & \square \\
   \end{array}
   \]

   # H signals: 
   # C signals: 
   multiplicity of signal from H* 
   (singlet, doublet, doublet of doublets, etc.)

   CIRCLE HYDROGEN THAT IS FURTHEST DOWNFIELD IN EACH COMPOUND.
7. For the following energy diagram, circle the correct answers in the questions that follow:

![Energy Diagram](image)

d. Which step is the rate-determining step in the forward direction: B → D, or D → G?
e. Which step is the rate-determining step in the reverse direction: G → D, or D → B?
f. Is the second step exothermic or endothermic?
d. For the overall reaction is $\Delta H^\circ (-)$ or (+)?
e. If all steps are reversible, which will be favored at equilibrium, B, D, or G?

8. How would you use $^1$HNMR to distinguish between the following pairs of compounds? Pick one signal for each set that could be used, and write the approximate chemical shift, splitting, and integration for each.

- a. \( \text{CH}_3\text{CH}_2\text{C}=\text{CH} \) \( \text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2 \)
- b. \( \text{H}_3\text{C}\text{O}-\text{H} \) \( \text{CH}_3\text{CH}_2\text{C}=\text{CH}_2\text{CH}_3 \)
- c. \( \text{CH}_3\text{C}=\text{O} \) \( \text{CH}_3\text{CH} \text{C}=\text{CH}_3 \)
- d. \( \text{H}_3\text{C}\text{O}-\text{CH}_3 \) \( \text{H}_3\text{C}\text{O}-\text{CH}_2\text{CH}_3 \)

For 8a & b, how would you use IR spectroscopy to distinguish between the two pairs? 8c & d cannot be easily distinguished by IR spectroscopy.