Answer all 23 questions (150 pts).

1. (2.5) True or False? An acetal "protects" an aldehyde from reaction with nucleophiles.

2. (2.5) True or False? The molecule shown below could undergo a substitution reaction with a nucleophile.

3. (2.5) True or False? Reactions between anhydrides and good nucleophiles are typically carried out in the presence of an acid catalyst to speed up the reaction.

4. (2.5) True or False? The first step of the reaction between a Grignard and an acyl halide involves loss of the halide.

5. (2.5) True or False? A primary amine reacts with a ketone to form a product with a C=C bond.

6. (12) For each of the following molecules, indicate the number of different types of hydrogen and the number of different types of carbon present.

   a) 
   \[
   \begin{array}{c}
   \text{Cl} \\
   \text{H}_3\text{C} \\
   \text{Cl} \\
   \text{Cl} \\
   \text{CH}_3
   \end{array}
   \]

   b) 
   \[
   \begin{array}{c}
   \text{O} \\
   \text{O} \\
   \text{O} \\
   \text{O}
   \end{array}
   \]

   c) 
   \[
   \begin{array}{c}
   \text{O} \\
   \text{O}
   \end{array}
   \]

7. (3) The molecule shown would have which \(^1\)H-NMR spectrum?

   A. A singlet at ~3.5 \(\delta\), a quartet at ~3 \(\delta\) & a doublet at ~1.5 \(\delta\)
   B. A singlet at ~1.75 \(\delta\), a quartet at ~4 \(\delta\) & a triplet at ~1.5 \(\delta\)
   C. A singlet at ~1.5 \(\delta\), a doublet at ~1.5 \(\delta\) & a septet at ~4 \(\delta\)
   D. A singlet at ~7 \(\delta\), a quartet at ~6 \(\delta\) & a triplet at ~4 \(\delta\)

8. (3) The molecule shown would have which \(^1\)H-NMR spectrum?

   A. A doublet at ~7.5\(\delta\), a doublet at ~7.3\(\delta\) & a singlet at ~2\(\delta\)
   B. A doublet at ~7.5\(\delta\), a triplet at ~7.3\(\delta\) & a singlet at ~2\(\delta\)
   C. A doublet at ~7.5\(\delta\), a doublet at ~7.3\(\delta\) & a singlet at ~4\(\delta\)
   D. A singlet at ~7.5\(\delta\), a singlet at ~7.3\(\delta\) & a singlet at ~1.5\(\delta\)

9. (8) **Circle** all compounds below which are predicted to be aromatic, draw a large X through those which are not aromatic.

   a) 
   \[
   \begin{array}{c}
   \text{N} \\
   \text{N} \\
   \text{N}
   \end{array}
   \]

   b) 
   \[
   \begin{array}{c}
   \text{N} \\
   \text{N}
   \end{array}
   \]

   c) 
   \[
   \text{N} \quad +
   \]

   d) 
   \[
   \text{N}
   \]
10. (17.5) From the list given, choose the best reagent for each transformation shown. Write the appropriate letter above the reaction arrow. It is possible to use the same reagent more than once.

A. PhMgBr then H_3O^+  
B. Ph_2CuLi then H^+  
C. LiAlH_4 then HCl  
D. NaH then EtI  
E. H_2 / Pd  
F. NaBH_4 then H_3O^+  
G. CrO_3, H_2SO_4  
H. Et_2NH / H^+  
I. NEt_3 / Me_3SiCl  
J. EtNH_2 / H^+  
K. HOCH_2CH_2OH, H^+  
L. EtCOCl / AlCl_3

11. (9) Show the first step (complete) of the arrow-pushing mechanism for the reaction between each of the following. You need not show the consequence of your arrows.

a) \[
\text{PhCOCH}_3 \quad \rightarrow \quad \text{PhCH}_2\text{CHOH, H}^+ \]
b) \[ \text{H}_3\text{C} \quad \text{H}_3\text{C} - \equiv \quad \text{O} \quad + \quad \text{H-Cl} \quad \text{H}_2\text{O} \]

c) \[ \text{H}_2\text{O} \quad + \quad \text{H}_2\text{O} \]

12. (36) Show reasonable products or missing reactants from the following reactions.

a) \[ \text{PPh}_3^- \quad \text{+} \quad \text{PPh}_3^- \quad \text{H}^+ \quad \text{cat.} \quad \rightarrow \quad \text{H}_2\text{O} \]

b) \[ \text{H}_3\text{C} \quad \text{H}_3\text{C} - \equiv \quad \text{O} \quad + \quad \text{H-Cl} \quad \text{H}_2\text{O} \]

c) \[ \text{H}_2\text{O} \quad + \quad \text{H}_2\text{O} \]

f) \[ \text{H}_3\text{C} \quad \text{H}_3\text{C} - \equiv \quad \text{O} \quad + \quad \text{H-Cl} \quad \text{H}_2\text{O} \]

g) \[ \text{H}_3\text{C} \quad \text{H}_3\text{C} - \equiv \quad \text{O} \quad + \quad \text{H-Cl} \quad \text{H}_2\text{O} \]
13. (8) For each of the following compounds, indicate by yes or no whether or not they contain conjugated systems. If you think that there is a conjugated part to the molecule, put a circle around it.

a) 

b) 

c) 

14. (6) In each of the following pairs, circle the compound which will react more readily with the reagent indicated. You need not explain why.

a) 

and 

with \( \text{CH}_3\text{COCl} / \text{AlCl}_3 \)

b) 

and 

with \( \text{PhMgBr} \)

c) 

and 

with \( \text{NaBH}_4 \)

15. (2.5) True or False? Using only the functional groups & their locations discussed in class, it would be easy to tell the difference between the following two compounds using only their infrared spectra?

16. (6) The 2 molecules shown below could be distinguished easily by their \(^{13}\text{C}\)-NMR spectra. Explain briefly, but clearly, why.

17. (5) Draw the different alkene products which would result from the following reaction. Additionally, circle the major product.

18. (3) Why do you suppose that accidental overlap of signals is much more common in \(^1\text{H}\)-NMR than in \(^{13}\text{C}\)-NMR? Explain briefly.

19. (3) The anti-periplanar conformation is required for an E2 reaction because:

A. Planar molecules are more stable
B. E2 reactions give products with an anti arrangement
C. This conformation leads to more stable (E) alkenes
D. This conformation allows the base and leaving group to be far apart
20. (8) Draw structures for:

   a) 5-bromo-2-fluoro-3-nitrotoluene

   b) 3-propoxy-1-cycloheptene

21. (2.5) True or False? The compound shown would have only 2 small peaks (along with other peaks) in its C-13 NMR spectrum.

22. (2.5) True or False? The IR spectrum of the above compound would have peaks at 3100 and 2900 cm\(^{-1}\) (along with other peaks in other locations).

23. (2.5) True or False? The \(^1\)H-NMR spectrum of the compound shown in question 21 would have one singlet at around 7-8 δ (along with other peaks in other locations).