1. (3) True or False? An acetal "protects" an alcohol from reaction with bases.

2. (3) True or False? The molecule shown below would react with a primary amine to give a product containing a C=C bond.

3. (3) The first step of a reaction between a ketone and a Wittig reagent is:
   a) Attack by the Wittig P atom on the C of the ketone C=O
   b) Attack by the ketone O upon the P of the Wittig reagent
   c) Attack by the Wittig C anion on the C of the ketone C=O
   d) Loss of an alkene
   e) Protonation of the ketone O

4. (3) The first step of a reaction between an epoxide (cyclic ether) and H_3O^+ is:
   a) Attack by the epoxide O upon the O of H_3O^+
   b) Addition of H anion to the epoxide O
   c) Loss of water
   d) Attack by water upon a ring C
   e) Protonation of the epoxide O

5. (6) Draw the structure of 2-ethyl-4-fluoro-3-isopropyl-5-methylheptanoic acid.

6. (3) The aldehyde proton appears in its NMR spectrum at about:
   a) 7-8 δ
   b) 1-2 δ
   c) 3-4 δ
   d) 9-10 δ
   e) 11-12 δ

7. (2.5) True or False? The carbonyl oxygen in a carboxylic acid is sp^2 hybridized.

8. (4) Which one of the following reagents could not act as a nucleophile?
   a) LiAlH_4  b) Zn / Hg, H^+  c) NaBH_4  e) Me_2CuLi
9. (10) For each of the following, indicate with an asterisk (*) the atom most likely to attack an acid such as sulfuric acid.

a) \( \text{\includegraphics{image1}} \)

b) \( \text{\includegraphics{image2}} \)

c) \( \text{\includegraphics{image3}} \)

d) \( \text{\includegraphics{image4}} \)

e) \( \text{\includegraphics{image5}} \)

10. (10) For each of the molecules shown below, indicate with an asterisk (*) the atom or atoms which could be attacked by a nucleophile / base (without the addition of any catalyst). Note: there could be more than one site in a molecule.

a) \( \text{\includegraphics{image6}} \)

b) \( \text{\includegraphics{image7}} \)

c) \( \text{\includegraphics{image8}} \)

11. (4) In reactions of ketones or aldehydes with alcohols it is common to add a small amount of acid. The purpose of the acid is:
   a) to polarize the carbonyl group to make it more electrophilic
   b) to convert the ketone or aldehyde to an intermediate carboxylic acid
   c) to make the alcohol a better electrophile
   d) all of the above

12. (4) The first step of the reaction between an acyl chloride (RCOCl) and MeMgBr involves:
   a) attack by Me\(^-\) upon the C=O carbon
   b) attack of the C=O oxygen upon the Mg
   c) initial protonation of the C=O oxygen
   d) attack of the C-O oxygen upon the Mg
   e) attack by Me\(^-\) upon the C=O oxygen

13. (4) Give two different ways that the equilibrium shown below could be forced to the right:

\[
\begin{align*}
\text{boiling point:} & \quad 155^\circ C & 198^\circ C & 171^\circ C & 100^\circ C \\
\text{H}^{+} \quad \text{H}^{+} \quad \text{H}^{+} \quad \text{H}^{+} \\
\end{align*}
\]

14. (4) The reaction of a ketone with an amine is enhanced by the addition of acid down to a pH of \(~4.5\). However, at even lower pH's the reaction slows considerably because:
   a) strong acids are fully ionized and the anion interferes
   b) the ketone O is more protonated and, so, the reaction slows
   c) the amine N is more protonated and, so, the reaction slows
   d) there is no electrophile at low pH
   e) all of the above

15. (2.5) True or False. An alcohol would have a lower boiling point than a carboxylic acid of similar size.
*16. (39.5) Fill in the missing products or reactants in each of the following reactions.

a) [Diagram of reaction]

b) [Diagram of reaction]

c) [Diagram of reaction]

d) [Diagram of reaction]

e) [Diagram of reaction]

f) [Diagram of reaction]

*17. (10) In each of the following pairs circle the compound which is more acidic.

a) NaCl or H$_3$O$^+$

b) HCN or MeOH

c) Me$_2$CuLi or MeOH

d) FCH$_2$CO$_2$H or BrCH$_2$CH$_2$CO$_2$H

*18. (2.5) True or False? After attack of a nucleophile upon the C of a C=O, the double bond will reform only if there is a potential leaving group attached to the nucleophilic atom.

*19. (2.5) True or False? The first step of the reaction between a Grignard reagent and an epoxide involves attack of the R’ of the Grignard upon the C of the C-O in the epoxide.
**20. (3)** Reaction of the species shown with a secondary amine would lead to:

\[ \text{Ph} \quad \text{O} \quad \text{H} \]

- a) formation of an enamine
- b) formation of a species containing a C=N
- c) displacement of the Ph
- d) conjugate addition
- e) formation of an amino alcohol

**21. (7)** 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) ![Reaction 1](image1)

b) ![Reaction 2](image2)

**22. (6)** In each of the following pairs, assign an appropriate infrared C=O stretching vibration value (choose from the numbers to the right) to each molecule.

a) ![Infrared A](image3) and ![Infrared B](image4)

b) ![Infrared C](image5) and ![Infrared D](image6)

**23. (7.5)** Circle each molecule in the following that could undergo a substitution reaction.

- ![Substitution A](image7)
- ![Substitution B](image8)
- ![Substitution C](image9)
- ![Substitution D](image10)

**24. (6)** For each of the following, choose which route, a) Grignard + CO\(_2\) then acid or b) ¬CN then H\(_3\)O\(^+\) would be the most appropriate for the preparation shown. You need not explain your answer.

a) ![Route A](image11)

b) ![Route B](image12)