1. Which of the following is the structure of succinic acid?

A. A
B. B
C. C
D. D

2. Where does the OH proton of a carboxylic acid appear in $^1$H NMR?

A. 3800-3000 cm$^{-1}$
B. 1-6 ppm
C. 10-12 ppm
D. 60 ppm

3. What structure is consistent with the following $^1$H NMR spectrum?

A. benzoic acid
B. benzyl alcohol
C. 2,2-dimethylpropanoic acid
D. pentanoic acid
4. What reagent would you use for the following reaction?

![Reaction Diagram]

A. LiAlH$_4$
B. FeCl$_3$
C. Br$_2$, light
D. KMnO$_4$

5. What is the pKa of water?

A. 0
B. 7
C. 15
D. 20

6. Rank the following from most to least acidic.

![Chemical Structures]

A. A, B, C
B. A, C, B
C. B, C, A
D. B, A, C
E. C, B, A
F. C, A, B
7. How could you separate the following compounds?

A. React with KMnO₄
B. Make a basic aqueous solution, then extract with an organic solvent
C. Make an acidic aqueous solution, then extract with an organic solvent
D. Hydrogenate

8. What is the major form of serine at pH 7?

A. A
B. B
C. C

9. Rank the labeled protons in order of decreasing acidity.

A. H₋b, H₋c, H₋a
B. H₋b, H₋a, H₋c
C. H₋a, H₋b, H₋c
D. H₋a, H₋c, H₋b
E. H₋c, H₋a, H₋b
10. What is the product?

\[
\begin{align*}
\text{CO}_2\text{H} & \quad \text{Na}_2\text{CO}_3 \\
\text{CO}_2\text{Na} & \quad \text{CO}_2\text{H} \\
\text{Na} & \quad \text{OH} \\
\end{align*}
\]

A. A  
B. B  
C. C  
D. D

11. What reagent would you use to reduce an acid chloride to an aldehyde?

A. NaBH\(_4\)  
B. LiAlH(OtBu)\(_3\)  
C. LiAlH\(_4\)  
D. FeCl\(_3\)

12. What reagent would you use to reduce an amide to an amine?

A. NaBH\(_4\)  
B. LiAlH(OtBu)\(_3\)  
C. LiAlH\(_4\)  
D. FeCl\(_3\)
13. What will be the product of the following reaction (before any aqueous work-up)?

\[
\text{PhCOH} \xrightarrow{\text{MeMgBr}} \]

A. A
B. B
C. C
D. D

14. What is the product?

\[
\text{CH}_3\text{COCH}_3 \xrightarrow{\text{EtMgBr (xs)}}
\]

A. A
B. B
C. C
D. D
15. What is the product?

\[
\begin{align*}
\text{OMe} & \quad \text{MeMgBr (xs)} \\
\end{align*}
\]

A. A  
B. B  
C. C  
D. D

16. What is the missing reagent in the reaction below?

\[
\begin{align*}
\text{O} & \quad \text{OH} \\
\to & \quad \text{OH} \\
\end{align*}
\]

A. \( \text{NaBH}_4 \)  
B. \( \text{H}_2, \text{Pd/C} \)  
C. \( \text{LiAlH}_4 \)  
D. \( \text{MeMgBr} \)

17. Which is the most reactive carbonyl compound?

\[
\begin{align*}
\text{A} & \quad \text{B} & \quad \text{C} & \quad \text{D} \\
\end{align*}
\]

A. A  
B. B  
C. C  
D. D
18. What is the structure of benzophenone?

A. A
B. B
C. C
D. D

19. Using IR spectroscopy, how can you tell the difference between a ketone and an aldehyde?

A. A ketone has no carbonyl stretch at 1720 cm\(^{-1}\)
B. An aldehyde has a carbonyl stretch at 1820 cm\(^{-1}\)
C. An aldehyde has a C-H stretch (one or two) between 2700-2830 cm\(^{-1}\)
D. A ketone has no C-H stretches

20. What compound is consistent with the following \(^1\)H NMR spectrum?

A. acetone
B. propanal
C. cyclobutanone
D. 2-butanone

21. What is the driving force for the Wittig reaction?

A. The formation of an alkene
B. The deprotonation of a phosphonium salt
C. The elimination of triphenylphosphine oxide
D. The formation of a phosphonium salt
22. What is the product?

A. A
B. B
C. C
D. D

23. What is the missing reagent in the reaction below?

A. ethyl amine, mild acid
B. diethylamine, mild acid
C. diethylamine, strong acid
D. diethylamine, NaOMe

24. Which of the following products is formed by Wittig reaction of CH₃CH₂CH₂CHO with P₃CH?

A. A only
B. B only
C. C only
D. A and B would both be formed.
E. A, B, and C would all be formed.
25. How would the following compounds be distinguishable using IR and NMR spectroscopy?

![Compounds 1 and 2](image)

A. The NMR of compound 1 will have two singlets.
B. The C==O absorption in the IR spectrum of compound 1 will be at a higher wave number than that of compound 2.
C. The NMR of compound 2 will have one triplet at a chemical shift of about 4.
D. The NMR of compound 1 will have two singlets AND the C==O absorption in the IR spectrum of compound 1 will be at a higher wave number than that of compound 2.
E. The NMR of compound 1 will have two singlets, the C==O absorption in the IR spectrum of compound 1 will be at a higher wave number than that of compound 2 AND the NMR of compound 2 will have one triplet at a chemical shift of about 4.

26. Which of the following is a lactam?

![Lactam structures](image)

A. A  
B. B  
C. C  
D. D

27. What would you see in the IR spectrum of a carboxylic acid?

A. A flat line (carboxylic acids are not IR active)  
B. A sharp line at 2250 cm\(^{-1}\)  
C. A broad peak from 3800-2800 cm\(^{-1}\)  
D. A broad peak from 800-600 cm\(^{-1}\)
28. Where do the carbonyl signals appear in the $^{13}$C NMR spectrum of carboxylic acid derivatives?

A. 1700 cm$^{-1}$  
B. 180-160 ppm  
C. 2.5-3.0 ppm  
D. 100-80 ppm

29. Which structure is consistent with the following $^1$H NMR spectrum?

![NMR Spectrum]

A. ethyl acetate  
B. 2-propanone  
C. 3,3-dimethylpentanone  
D. Ethyl 2,2-dimethylpropionate

30. Will the following reaction occur?

![Reaction]

A. Yes  
B. No

31. How can you convert a carboxylic acid into an acid chloride?

A. Heat with hydrochloric acid  
B. React with thionyl chloride ($\text{OSCl}_2$)  
C. React with sodium chloride  
D. Fuse with sodium chloride