1. Rank the designated protons by chemical shift ($\delta$), highest $\delta$ first.

A. IV > III > II > I  B. IV > II > III > I  C. III > IV > II > I  D. III > IV > I > II

2. What are the products, if any, expected from the following reaction?

$$\text{CH}_3\text{O}^-\text{Na}^+ + \text{CH}_3\text{S-H} \rightarrow \text{CH}_3\text{OCH}_3 + \text{NaHS}$$

A. CH$_3$OCH$_3$ + NaHS  B. CH$_3$SCH$_3$ + NaOH  C. CH$_3$O-H + CH$_3$S$^-\text{Na}^+$  D. No reaction

3. What is the IUPAC name for the following compound?

A. cis-1,2-cyclopentanediol  B. meso-1,2-cyclopentanediol  C. (1R,2R)-1,2-cyclopentanediol  D. (1R,2S)-1,2-cyclopentanediol

4. Which of the following explains why cyclohexanol has a $pK_a$ of 18 and phenol has a $pK_a$ of 10?

A. Phenolate is a stronger base than the conjugate base of cyclohexanol  
B. The conjugate base of cyclohexanol is resonance stabilized  
C. The conjugate base of phenol is resonance stabilized  
D. Phenol is a weaker acid than cyclohexanol
5. Predict the product for the following reaction.

\[
\begin{align*}
\text{CH}_3\text{MgBr} & \quad 1. \quad \text{CH}_3\text{MgBr} \\
\text{H}_2\text{O} & \quad 2. \quad \text{H}_2\text{O}
\end{align*}
\]

A.  
B.  
C.  
D.  

6. Which one of the following compounds is NOT a product of reaction between 1,3-butadiene and HBr?

A. (S)-3-bromo-1-butene  
B. (R)-3-bromo-1-butene  
C. (Z)-2-bromo-2-butene  
D. (E)-1-bromo-2-butene

7. Choose the reagents necessary to carry out the following conversion.

\[
\begin{align*}
\text{A. } \text{HBr, then NaOH/heat, then H}_3\text{O}^+, \text{then PCC} \\
\text{B. } \text{Br}_2/\text{light, then EtONa, then BH}_3, \text{then H}_2\text{O}_2/\text{NaOH, then PCC} \\
\text{C. } \text{Br}_2/\text{FeBr}_3, \text{then NaOH, then BH}_3, \text{then H}_2\text{O}_2/\text{NaOH, then CrO}_3/\text{H}_2\text{SO}_4 \\
\text{D. } \text{NBS/heat, then (CH}_3)_2\text{CONa, then H}_3\text{O}^+/\text{heat, then PCC}
\end{align*}
\]
8. Which one of the following compounds is aromatic?

A. \[
\begin{array}{c}
\text{H}_2 \\
\text{N} \\
\text{H} \\
\text{N} \\
\text{H}
\end{array}
\]

B. \[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

C. \[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

D. \[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

9. Predict the product for the following reaction.

\[
\begin{array}{c}
\text{OH} \\
\text{O} \\
\text{H}
\end{array}
\xrightarrow{\text{NaOH}}
\]

A. \[
\begin{array}{c}
\text{O} \\
\text{H}
\end{array}
\]

B. \[
\begin{array}{c}
\text{O} \\
\text{H}
\end{array}
\]

C. \[
\begin{array}{c}
\text{O} \\
\text{H}
\end{array}
\]

D. \[
\begin{array}{c}
\text{O} \\
\text{H}
\end{array}
\]

10. Predict the product for the following reaction.

\[
\begin{array}{c}
\text{Cl} \\
\text{C}
\end{array}
\xrightarrow{\text{CH}_3\text{CH}_2\text{OH}}
\]

A. ethyl-3-methylbutanoate

B. ethyl-2-methylpropanoate

C. isobutylethanoate

D. 5-methyl-3-hexanone
11. Rank the following carboxylic acid derivatives in decreasing order (most to least) of reactivity towards nucleophilic acyl substitution.

A. I > IV > III > II
B. II > III > I > IV
C. IV > I > III > II
D. III > I > II > IV

12. Predict the product for the following reaction sequence:

\[
\text{1. NaOCH}_2\text{CH}_3 \quad \xrightarrow{\text{H}_3\text{O}^+} \quad \text{2. CH}_3\text{CH}_2\text{I} \quad \Delta
\]

A.  
B.  
C.  
D.  

13. Amino acids are connected to each other by ___________.
A. an ether linkage
B. an acetal linkage
C. a ester linkage
D. an amide linkage
14. Predict the product for the following reaction.

\[
\text{\begin{align*}
\text{A} & \quad \text{B} & \quad \text{C} & \quad \text{D} \\
\begin{array}{c}
\text{\hspace{1cm} (\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \quad \text{HO} \quad \text{HO} } \\
\text{\hspace{1cm} \text{HO} \quad \text{HO} \quad \text{HO} \quad \text{HO} } \\
\text{\hspace{1cm} \text{HO} } \\
\text{\hspace{1cm} \text{HO} } \\
\end{array}
\end{align*}}
\]

15. Rank the following compounds in decreasing order of basicity, strongest to weakest.

A. III > IV > I > II  
B. I > II > IV > III  
C. IV > III > I > II  
D. IV > I > II > III

16. Predict the product for the following reaction sequence:
17. Predict the product for the following reaction sequence:

18. Which of the following D-aldoses will produce an optically inactive product when treated with NaBH₄/H₂O?
19. What is the pI of the following amino acid?

\[
\begin{align*}
\text{O} & \quad \text{C} & \quad \text{N} \\
\text{H} & \quad \text{CH}_3 & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{pK}_{a1} = 1.88 & \quad \text{pK}_{a2} = 9.60 & \quad \text{pK}_{a3} = 3.65 \\
\end{align*}
\]

A. 2.76  B. 5.74  C. 6.62  D. 7.5

20. Which one of the following is the correct structure for polyisobutylene?

A.  
B.  
C.  
D.  

21. Please choose an appropriate oxidizing agent for the following rxn.

\[
\begin{align*}
\begin{array}{c}
\text{OH} \\
\end{array} & \quad \rightarrow & \quad \begin{array}{c}
\text{O} \\
\text{OH} \\
\end{array}
\end{align*}
\]

A. LiAlH₄  B. H₂/ Pt  C. PCC  D. H₂CrO₄

22. Which of these compounds best fits these data? It is soluble in water, and turns red litmus blue; has only one major IR band, at 2950 cm⁻¹, and has the following ¹H NMR spectrum: 2.7 ppm, 2H; 2.2 ppm, 6H; 1.0 ppm, 3H.

A. N,N-dimethylethanamine  B. propanoic acid  C. 2-propanol  D. 2-methylpropane
23. What is the major product for the following reaction?

![Reaction Diagram]

A. ![Product A]
B. ![Product B]
C. ![Product C]
D. ![Product D]

24. Which position is most likely to undergo an EAS reaction?

A. ![Compound A]
B. ![Compound B]
C. ![Compound C]
D. ![Compound D]

25. How would you convert an unsaturated fatty acid into a saturated fatty acid?

A. KMnO₄, OH⁻, heat
B. OH⁻, H₂O heat; then H₃O⁺
C. H₂, Ni, pressure
D. H₃O⁺, H₂O, heat
26. What structure has the following proton NMR spectrum?

\(^1\text{H NMR: doublet 6.6 ppm, 2 H}
\)
\(^1\text{H NMR: doublet 7.8 ppm, 2 H}
\)
\(^1\text{H NMR: broad singlet 4.2 ppm, 2 H}
\)
\(^1\text{H NMR: singlet 2.1 ppm, 3H}
\)

A. ![Structure A](image)
B. ![Structure B](image)
C. ![Structure C](image)
D. ![Structure D](image)

27. Which of the following is the correct synthesis of the compound shown?

A. ![Synthesis A](image)
B. ![Synthesis B](image)
C. ![Synthesis C](image)
D. ![Synthesis D](image)
28. Which one is the correct intermediate for the **major product** of following reaction?

![Reaction Diagram](image)

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

29. Which one is the correct synthesis of the compound shown, from benzene?

![Synthesis Diagram](image)

- A. \[ \text{Br}_2/\text{FeBr}_3 \rightarrow \text{Mg/Ether} \rightarrow \text{H}_2\text{C}=\text{O} \rightarrow \text{H}_3\text{O}^+ \]
- B. \[ \text{Br}_2/\text{FeBr}_3 \rightarrow \text{NaCN} \rightarrow \text{H}_3\text{O}^+ \rightarrow \text{H}_3\text{O} \]
- C. \[ \text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{Na}_2\text{Cr}_2\text{O}_7 \rightarrow \text{H}_3\text{O}^+ \rightarrow \text{H}_3\text{O} \]
- D. \[ \text{CH}_3\text{Cl} \rightarrow \text{Br}_2/\text{heat} \rightarrow \text{NaCN} \rightarrow \text{H}_3\text{O}^+ \]

30. Which of the following has the lowest boiling point?

- A. \( \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 \)
- B. \( \text{CH}_3\text{CH}_2\text{NHCH}_3 \)
- C. \( \text{(CH}_3)_2\text{N} \)
- D. \( \text{(CH}_3)_3\text{NHCl} \)
31. What is the major product for the following reaction?

\[ \text{H}_3\text{O}^+ \xrightarrow{\text{Cl}_2} \xrightarrow{\text{KOC(CH}_3)_3} \]

A.  
B.  
C.  
D.  

32. What is the IUPAC name for the following compound?

\[ \begin{array}{c}
\text{H} \\
| \\
\text{CH}_3 \\
\text{CH}_2 \\
\text{CH}_2 \\
\text{CH}_2 \\
\text{CH}_2 \\
\end{array} \]

A. 1-methyl-\(N\)-butyl-1-butanamine
B. 4-methyl-5-octanamine
C. 1-ethyl-\(N\)-propyl-1-pentanamine
D. \(N\)-propyl-2-pentanamine

33. A pentapeptide has the molecular formula: Arg, Glu, Ile, Phe, Leu. After partial hydrolysis, the fragments are: Glu-Ile, Leu-Arg, Phe-Leu, Arg-Glu. What is the sequence?

A. Phe-Leu-Arg-Glu-Ile
B. Ile-Glu-Arg-Leu-Phe
C. Arg-Glu-Ile-Phe-Leu
D. Phe-Leu-Glu-Ile-Arg
34. Predict the product for the following reaction.

\[
\begin{align*}
\text{1. } \text{O}_3 \\
\text{2. } \text{Zn, H}_3\text{O}^+ \\
\end{align*}
\]

A.  
B.  
C.  
D.  

35. What is the product of the following reaction?

\[
\begin{align*}
\text{KOH} & \quad \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} & \quad \text{H}_3\text{O}^+, \text{H}_2\text{O} \\
\text{heat} & \\
\end{align*}
\]

A.  
B.  
C.  
D.  

36. Which of the following compounds is able to undergo a self-aldol condensation?

A. phenylethanal  
B. formaldehyde  
C. benzaldehyde  
D. 2,2-dimethylpropanal
37. The best synthesis of \[
\begin{align*}
\text{HNO}_3, \text{H}_2\text{SO}_4
\end{align*}
\]
is

A. Benzene \[
\begin{align*}
\text{CH}_3\text{Cl with 2 AlCl}_3
\end{align*}
\]
B. Toluene \[
\begin{align*}
\text{CH}_3\text{Cl with AlCl}_3
\end{align*}
\]
C. P-xylene \[
\begin{align*}
\text{CH}_3\text{Cl with AlCl}_3
\end{align*}
\]
D. M-nitrotoluene \[
\begin{align*}
\text{CH}_3\text{Cl with AlCl}_3
\end{align*}
\]

38. Which of these is the most reliable way to make 3-heptene?
A. \[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CHBrCH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{NaOCH}_3, \text{heat}
\end{align*}
\]
B. \[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CH} = \text{O} + \text{Ph}_3\text{P=CHCH}_2\text{CH}_2\text{CH}_3
\end{align*}
\]
C. \[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CHOHCH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{SO}_4, \text{heat}
\end{align*}
\]
D. \[
\begin{align*}
\text{CH}_3\text{CH}_2\text{C} = \text{CCH}_2\text{CH}_2\text{CH}_3 + \text{H}_2/\text{Pt}
\end{align*}
\]

39. Predict the major product for the following reaction.
\[
\begin{align*}
\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4/\text{H}_2\text{O}
\end{align*}
\]

\[
\begin{align*}
\text{Br}_2/\text{PB}_3, \text{2 H}_2\text{O}
\end{align*}
\]

A. \[
\begin{align*}
\text{Br}
\end{align*}
\]
B. \[
\begin{align*}
\text{Br}
\end{align*}
\]
C. \[
\begin{align*}
\text{Br}
\end{align*}
\]
D. \[
\begin{align*}
\text{Br}
\end{align*}
\]
40. Please indicate the # of signals in the $^{13}$C NMR and $^1$H NMR spectra for the following compound:

\[ \text{compound structure} \]

A. 4 $^{13}$C NMR and 4 $^1$H NMR  
B. 10 $^{13}$C NMR and 7 $^1$H NMR  
C. 6 $^{13}$C NMR and 4 $^1$H NMR  
D. 8 $^{13}$C NMR and 5 $^1$H NMR

41. What is the major product of this reaction?

\[ \text{reaction structure} \]

A.  
B.  
C.  
D.  

42. Predict the product of the following reaction:

\[ \text{reaction structure} \]

A.  
B.  
C.  
D.  
43. Which step is not part of the base-catalyzed aldol condensation mechanism?

A. 
B. 
C. 
D.
44. What is the IUPAC name for

A. 5-hydroxy-2-phenyl-3-hexanone  
B. 2-hydroxy-5-phenyl-4-hexanone  
C. 2-hydroxypropyl-1-phenylethylketone  
D. 5-hydroxy-3-keto-2-phenylhexane

45. What is the major product of this reaction?

46. A compound with the molecular formula C₈H₁₄O₄ shows an IR peak at 1740 cm⁻¹ but not 2500-3300 cm⁻¹. Its proton NMR spectrum consists only of a triplet at 1.3 ppm, a triplet at 2.6 ppm and a singlet at 4.2 ppm. The most likely structure is:
47. Predict the product(s) for the following reaction.

\[
\text{A} \quad \text{B} \quad \text{C} \quad \text{D} + \text{enantiomer}
\]

48. Rank the reactivity order of the following dienes with maleic anhydride, starting with the fastest.

A. IV > I > II > III     B. III > IV > II > I
C. III > II > I > IV     D. IV > III > II > I

49. Which is true for aromatic but not antiaromatic compounds?

A. Are cyclic and planar  
B. Are monocyclic  
C. Have a conjugated system with p orbital at every vertex  
D. Satisfy Hückel’s rule

50. How many pi electrons are there in the following aromatic compound?

A. 14  B. 16  C. 12  D. 18