1. What is the hybridization of the indicated atom in the following molecule?

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

A. sp\(^3\)  B. sp\(^2\)  C. sp  D. not hybridized

2. Name the functional groups in the following molecule (in order from left to right).

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

A. Secondary alcohol, ketone, secondary amine, ether  
B. Primary alcohol, ketone, secondary amine, ester  
C. Secondary alcohol, amide, ketone, ether  
D. Primary alcohol, amide, ester

3. Which of the following is the strongest acid?

A. \[ \text{OH} \]
B. \[ \text{C}_6\text{H}_5\text{C}≡\text{C} \]
C. \[ \text{C}_6\text{H}_5\text{COOH} \]
D. \[ \text{C}_6\text{H}_5\text{NH}_2 \]

4. The following is an example of a:

\[
\begin{array}{c}
\text{C} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{C} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{C}_6\text{H}_5 \\
\end{array}
\]

A. homopolymer  B. block copolymer  
C. random copolymer  D. graft copolymer
5. Give the IUPAC name of:

![Chemical structure](image)

A. (2R,3R,4S)-3,4-dichloro-2-pentene
B. (1R,3S)-1,2-dichloro-1methyl-3-butene
C. (3S,4S)-3,4-dichloro-1-pentene
D. (3R,4S)-3,4-dichloro-1-pentene

6. Which of the following statements is true about this reaction?

![Reaction](image)

A. The product will have R configuration.
B. A racemic mixture is produced.
C. The product will have S configuration.
D. The product is not optically active.

7. What is the IUPAC name of this compound?

![Chemical structure](image)

A. cis-2,3-dimethyl-3-hexene
B. trans-2,3-dimethyl-3-hexene
C. (Z)-2,3-dimethyl-3-hexene
D. (E)-2,3-dimethyl-3-hexene
8. What is the major organic product of the following reaction?

\[
\begin{array}{c}
\text{Br} \\
\text{KOH} \\
\text{heat}
\end{array}
\]

A. \[
\begin{array}{c}
\text{Br} \\
\text{KOH} \\
\text{heat}
\end{array}
\]
B. \[
\begin{array}{c}
\text{Br} \\
\text{KOH} \\
\text{heat}
\end{array}
\]
C. \[
\begin{array}{c}
\text{Br} \\
\text{KOH} \\
\text{heat}
\end{array}
\]
D. \[
\begin{array}{c}
\text{Br} \\
\text{KOH} \\
\text{heat}
\end{array}
\]

9. What is the major organic product of the following reaction?

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

A. \[
\begin{array}{c}
\text{Cl}_2 \\
\text{CH}_3\text{OH}
\end{array}
\]
B. \[
\begin{array}{c}
\text{Cl}_2 \\
\text{CH}_3\text{OH}
\end{array}
\]
C. \[
\begin{array}{c}
\text{Cl}_2 \\
\text{CH}_3\text{OH}
\end{array}
\]
D. \[
\begin{array}{c}
\text{Cl}_2 \\
\text{CH}_3\text{OH}
\end{array}
\]

10. Arrange these hydrogens by acidity, listing the most acidic first.

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

A. \[
\begin{array}{c}
\text{O}
\end{array}
\]
B. \[
\begin{array}{c}
\text{O}
\end{array}
\]
C. \[
\begin{array}{c}
\text{O}
\end{array}
\]
D. \[
\begin{array}{c}
\text{O}
\end{array}
\]
11. Which of the following compounds would produce both of these ketones in an ozonolysis reaction?

\[ \text{Ketone 1} \quad \text{and} \quad \text{Ketone 2} \]

A. 
B. 
C. 
D. 

12. Which of the following is the least stable radical?

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

13. Which of the following reactions would form 1-bromo-3-methylbutane from 3-methyl-1-butene?

A. Reaction with HBr 
B. Reaction with HBr in presence of peroxides 
C. Reaction with NBS in presence of light 
D. Reaction with Br\(_2\) in presence of light

14. A solution that has 0% ee can be:

A. enantiomerically pure 
B. a racemic mixture 
C. optically active 
D. chiral
15. Which conformer has torsional strain and steric strain?

A.  
B.  
C.  
D.  

16. Which description is correct for the following compound?

A. Achiral
B. Meso
C. Optical active
D. It is not superimposable on its mirror image

17. Which one is the best synthetic route to obtain the following compound?

A.  
B.  
C.  
D.  

OCH₃CH₃

+ CH₃CH₂OH

+ CH₃CH₂O⁻

+ CH₃CH₂Br

+ CH₃CH₂Br

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18. What is/are the major organic product(s) of the following reaction?

\[
\text{Br} \quad \overset{\text{NaOCH}_3}{\underset{\text{HOCH}_3}{\longrightarrow}} \]

A. \[
\text{\includegraphics[width=0.2\textwidth]{diagram1.png}}
\]
B. \[
\text{\includegraphics[width=0.2\textwidth]{diagram2.png}} \quad \text{and} \quad \text{\includegraphics[width=0.2\textwidth]{diagram3.png}}
\]
C. \[
\text{\includegraphics[width=0.2\textwidth]{diagram4.png}}
\]
D. \[
\text{\includegraphics[width=0.2\textwidth]{diagram5.png}} \quad \text{and} \quad \text{\includegraphics[width=0.2\textwidth]{diagram6.png}}
\]

19. Which is the correct set of reagents/conditions to carry out the following reaction?

\[
\text{\includegraphics[width=0.2\textwidth]{diagram7.png}} \quad \overset{?}{\longrightarrow} \quad \text{\includegraphics[width=0.2\textwidth]{diagram8.png}}
\]

A. Hg(OAc)_2, H_2O, then NaBH_4
B. BH_3-THF, then H_2O_2/OH
C. H_3O^+, H_2O, heat
D. Cold KMnO_4, H_2O, HO^-

20. Which would be the best way to carry out the following synthesis?

\[
\text{\includegraphics[width=0.2\textwidth]{diagram9.png}} \quad \overset{?}{\longrightarrow} \quad \text{\includegraphics[width=0.2\textwidth]{diagram10.png}}
\]

A. (1) Br_2/heat; (2) (CH_3)_3COK/(CH_3)_3COH; (3) cold KMnO_4, H_2O, HO^-
B. (1) Br_2/heat; (2) KOH/CH_3OH; (3) cold KMnO_4, H_2O, HO^-
C. (1) Br_2/CCl_4; (2) (CH_3)_3COK/(CH_3)_3COH; (3) C_6H_5COO0H; H_3O^+
D. (1) Br_2/CCl_4 (2) KOH/CH_3OH /(CH_3)_3COH; (3) C_6H_5COO0H; H_3O^+
21. In the molecule shown below, arrange by bond dissociation energy, largest BDE first.

![Molecule Diagram]

A. \(a > c > b > d\)  
B. \(a > c > d > b\)  
C. \(c > a > d > b\)  
D. \(c > a > b > d\)

22. What is the major organic product of the following reaction?

\[
\text{OH} \quad \xrightarrow{\text{H}_2\text{SO}_4, \text{heat}} \quad \text{O-SO-H}
\]

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

23. What is the major organic product of the following reaction?

\[
\text{Cyclohexene} \quad \xrightarrow{\text{HBr}} \quad \text{Cyclohexyl bromide}
\]

- A. 
- B. 
- C. 
- D.
24. Which base/conjugate acid pair is correct?

A. \[
\begin{array}{c}
\text{H} \\
\text{N} \\
\end{array}
\]
B. \[
\begin{array}{c}
\text{H} \\
\text{O} \\
\end{array}
\]
C. \[
\begin{array}{c}
\text{H} \\
\text{N} \\
\end{array}
\]
D. \[
\begin{array}{c}
\text{O} \\
\end{array}
\]

25. Which reagent(s) are most suitable to accomplish the following reaction?

\[
\begin{array}{c}
\text{C} \rightarrow \text{C} \\
\end{array}
\]

A. \(\text{NH}_3\) then ethyl bromide  
B. Ethyl bromide then \(\text{NH}_3\)  
C. \(\text{NaNH}_2\) then ethyl bromide  
D. Ethyl bromide then \(\text{NaNH}_2\)

26. Which carbocation is likely to undergo a 1,2-hydride shift?

A. \[
\begin{array}{c}
\text{\textsuperscript{+}} \\
\end{array}
\]
B. \[
\begin{array}{c}
\text{\textsuperscript{+}} \\
\end{array}
\]
C. \[
\begin{array}{c}
\text{\textsuperscript{+}} \\
\end{array}
\]
D. \[
\begin{array}{c}
\text{\textsuperscript{+}} \\
\end{array}
\]

27. Which of the following reactions would most likely occur via an \(S_N1\) pathway?

A. \[
\begin{array}{c}
\text{Br} \\
\text{EtOH} \\
\end{array}
\]
B. \[
\begin{array}{c}
\text{Br} \\
\text{NaOEt} \\
\text{DMF} \\
\end{array}
\]
C. \[
\begin{array}{c}
\text{Br} \\
\text{EtOH} \\
\text{heat} \\
\end{array}
\]
D. \[
\begin{array}{c}
\text{Br} \\
\text{NaOEt} \\
\text{DMSO} \\
\end{array}
\]
28. Which set of reagents are needed to complete the following reaction?

\[
\begin{array}{c}
\text{?} \\
\text{OH} \\
\text{OH}
\end{array}
\rightarrow
\begin{array}{c}
\text{OH} \\
\text{OH}
\end{array}
\]

A. 1. RCO_3H; 2. H_2O, H_2O
B. 1. BH_3-THF; 2. H_2O_2, OH
C. 1. Hg(OAc)_2, H_2O; 2. NaBH_4
D. cold, dilute KMnO_4, OH

29. For the CO_2 molecule, what is the shape, bond angle, and hybridization of the carbon atom?

A. Bent, 109°, sp^2
B. Bent, 120°, sp^3
C. Linear, 180°, sp
D. Pyramidal, 120°, sp^4

30. Which reaction favors formation of the products?

A. \[
\begin{array}{c}
\text{H}_3\text{C} \text{--H} \\
\text{O} \\
\text{O}
\end{array}
\rightarrow
\begin{array}{c}
\text{O} \\
\text{OH}
\end{array}
\]

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

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

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

31. The compound that best fits the IR spectrum below is:

\[
\begin{array}{c}
\text{A. C}_6\text{H}_5\text{NH}_2 \\
\text{B. CH}_3\text{CH}_2\text{OH} \\
\text{C. CH}_3\text{CO}_2\text{CH}_2\text{CH}_3 \\
\text{D. CH}_3\text{CO}_2\text{H}
\end{array}
\]
32. What is the Hydrogen Deficiency Index for the compound with the highest boiling point?

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} & \quad \text{CH}_2=\text{CH}_2 \quad \text{CH}_3\text{CH}_2\text{OH} \quad \text{CH}_2=\text{CH}_2
\end{align*}
\]

A. 0  
B. 0.5  
C. 1  
D. 2

33. How many chirality centers (asymmetric carbons; stereocenters) does the following molecule have?

\[
\text{HO}
\]

A. 3  
B. 2  
C. 1  
D. 0

34. Use the following reaction and kinetic data to deduce the mechanism of the reaction:

\[
\text{BrBr} \quad \text{NaOH} \quad \text{BrBr} \quad \text{NaBr}
\]

\[
\begin{array}{ccc}
[R\text{Br}] & [\text{NaOH}] & \text{relative rate} \\
0.06 & 0.02 & 6 \\
0.03 & 0.02 & 3 \\
0.06 & 0.01 & 3 \\
\end{array}
\]

A. S_N1  
B. S_N2  
C. E1  
D. E2

35. The alkene that forms in the following alcohol dehydration reaction as the major product is:

\[
\text{OH} \quad \text{H}^+ 
\]

A. tetrasubstituted  
B. trisubstituted  
C. disubstituted  
D. monosubstituted
36. Which of the following is the best synthesis for 2,2-dibromopentane?

A. Addition of Br₂ in CCl₄ to 1-pentene.
B. Bromination of pentane using excess of Br₂ in the presence of light.
C. Addition of HBr to 1-pentyne in the presence of peroxides.
D. Addition of HBr to 1-pentyne.

37. How many bonds in this molecule are formed by an s-sp³ orbital overlap?

\[
\begin{align*}
\text{H₂N} & \quad \text{O} \\
\text{CH₂} & \quad \text{OH}
\end{align*}
\]

A. 4    B. 5    C. 6    D. 7

38. Rank the following bases in order of increasing base strength (weakest base first).

\[
\begin{align*}
\text{I} & \quad \text{II} & \quad \text{III} & \quad \text{IV} \\
\text{H₃C} & \quad \text{O} & \quad \text{N} & \quad \text{C} \\
\text{CH₃} & \quad & \text{N} & \quad \text{C} \\
\end{align*}
\]

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

39. What are the products of the reaction shown below?

\[
\text{CH₃C≡CNa + CH₃OH → ?}
\]

A. H₃COC≡CH + NaCH₃  
B. CH₃C≡CCH₃ + NaOH  
C. CH₃C≡CH + CH₃ONa  
D. CH₃C≡COCH₃ + NaOH

40. Which of the following alkenes gives off the least heat of combustion?

A. (CH₃)₂C=CHCH₂CH₃  B. CH₃CH=CHCH(CH₃)₂  
C. (CH₃)₂C=C(CH₃)₂  D. CH₂=C(CH₃)CH₂CH₂CH₃
41. Which reaction sequence would convert *cis*-2-butene to *trans*-2-butene?

A. Br₂/CCl₄; then 2 NaNH₂; then H₂/Ni  
B. Br₂/CCl₄; then 2 NaNH₂; then Li/NH₃  
C. H₃O⁺, heat; then cold dilute KMnO₄, HO⁻  
D. HBr; than NaNH₂; then H₂/Pt

42. What is the major product of the following reaction?

\[ \text{CH}_2=\text{CH}_2 \xrightarrow{1. \text{Hg(OAc)}_2, \text{THF}, \text{H}_2\text{O}} \xrightarrow{2. \text{NaBH}_4, \cdot \text{OH}} \]

\[ \text{A.} \quad \text{B.} \quad \text{C.} \quad \text{D.} \]

43. The free radical chlorination of 2,2-dimethylbutane produces how many monochlorinated products, including stereoisomers?

A. 2  
B. 3  
C. 4  
D. 5

44. Which of the following is a propagation step in the chlorination of methane?

A. Cl-Cl → 2 Cl⁺  
B. ·Cl + CH₄ → ·CH₃ + HCl  
C. ·CH₃ + H₃CCl → CH₄ + ·CH₂Cl  
D. ·CH₃ + ·CH₃ → CH₃CH₃
45. Determine formal charges of boron and oxygen in the following structure. Lone pairs are not shown, so use the octet rule to determine where they are:

\[
\begin{align*}
\text{A. } & \quad B = +1; \quad O = +1 \\
\text{B. } & \quad B = -1; \quad O = -1 \\
\text{C. } & \quad B = +1; \quad O = -1 \\
\text{D. } & \quad B = -1; \quad O = +1
\end{align*}
\]

46. What is wrong with the mechanistic arrow shown here?

A. It should start on the alkyne carbon-carbon triple bond and end at the nitrogen.
B. It should start on a hydrogen attached to the nitrogen.
C. It should start on a nitrogen unshared pair, end at the alkyne H, and a second arrow should start at the bond between the C and H on the alkyne and end on the alkyne terminal carbon.
D. There should be two arrows: one starts from a nitrogen unshared pair and ends at the alkyne H and one starts from the alkyne carbon and ends at the nitrogen.

47. What is the name of the following structure?

A. styrene  B. polystyrene  C. polybenzene  D. polyisobutylene
48. To perform this \( S_N2 \) reaction, what are the best nucleophile and solvent to use?

\[
\text{Br} \quad \rightarrow \quad \text{SCH}_3
\]

A. \( \text{CH}_3\text{SH} \)  
B. \( \text{CH}_3\text{SNa}, \text{CH}_3\text{SH} \)  
C. \( \text{CH}_3\text{SH}, \text{DMSO} \)  
D. \( \text{CH}_3\text{SNa}, \text{DMSO} \)

49. Which of the following compounds is/are the same as compound I?

\[
\begin{align*}
\text{I} & : \quad \text{H}_3\text{C} \quad \text{C} \quad \text{H}_3 \\
\text{II} & : \quad \text{H}_3\text{C} \quad \text{C} \quad \text{H}_3 \\
\text{III} & : \quad \text{H}_3\text{C} \quad \text{C} \quad \text{H}_3 \\
\text{IV} & : \quad \text{H}_3\text{C} \quad \text{C} \quad \text{H}_3
\end{align*}
\]

A. II  
B. III  
C. IV  
D. III and IV

50. Rank the following substrates from most to least reactive in an \( S_N2 \) reaction.

\[
\text{Br} \quad \text{Br} \quad \text{CH}_3\text{Br} \quad \text{Br}
\]

I  
II  
III  
IV

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