1. Which one of the following four schemes (A-D) represents a step in the mechanism of the reaction in the box?

\[
\begin{array}{c}
\text{OTs} & \text{NaCl} & \text{Cl} \\
\text{CH}_3 & \text{DMSO} & \text{CH}_3
\end{array}
\]

2. What is the energy diagram for the reaction shown above in Question 1?

3. What type of mechanism the reaction shown in Question 1 has?

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

4. Which one of the following four schemes (A-D) represents a step in the mechanism of the reaction in the box?
5. What type of mechanism the reaction shown in Question 4 has?

A) Radical substitution  
B) Radical addition  
C) Electrophilic addition  
D) S_N1

6. What is the structure of an intermediate in the reaction shown in Question 4?

A)  
B)  
C)  
D)  

7. What is the rate equation for the reaction in the box?

A) Rate = k [CH_3OH] 
B) Rate = k [RBr] 
C) Rate = k [RBr][CH_3OH] 
D) Rate = k [RBr][CH_3ONa]

8. What is the energy diagram for the reaction shown above in Question 7?

A)  
B)  
C)  
D)  

9. What type of mechanism the reaction shown in Question 7 has?

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

10. Which of the following structures represents the major resonance contributor of molecule in the box?
11. Which of the following structures represents the **major** resonance contributor of molecule in the box?

![Resonance Structures]

A) \[ \text{Structure A} \]
B) \[ \text{Structure B} \]
C) \[ \text{Structure C} \]
D) \[ \text{Structure D} \]

12. Which of the following is **NOT** a resonance structure of the molecule shown in the box?

![Resonance Structures]

A) \[ \text{Structure A} \]
B) \[ \text{Structure B} \]
C) \[ \text{Structure C} \]
D) \[ \text{Structure D} \]

13. What is the IUPAC name of the major **product** for the reaction shown in the box?

![Reaction]

\[ \text{CH}_2=\text{CH}_2 + \text{Cl}_2 \rightarrow \text{Product} \]

A) \((E)-1\)-chloropropene  
B) 2-chloropropane  
C) 1,2-dichloropropane  
D) 3-chloropropene

14. What is the IUPAC name of the major **product** for the reaction shown in the box?

![Reaction]

\[ \text{CH}_2=\text{CH}_2 + \text{NBr} \rightarrow \text{Product} \]

\[ \text{hv} \rightarrow \text{Product} \]

A) \((E)-1\)-bromopropene  
B) 2-bromopropane  
C) 1,2-dibromopropane  
D) 3-bromopropene

15. What is the **IUPAC** name of the major **product** for the reaction shown in the box?
16. What is the main product of the reaction shown in the box?

\[
\begin{array}{c}
\text{CH}_3\text{CO}_2\text{H} \\
\text{CH}_2\text{Cl}_2
\end{array}
\rightarrow ?
\]

A) cis-3,4-dimethylepoxide  
B) trans-2,3-dimethyloxirane  
C) trans-2,3-dimethylepoxide  
D) cis-2,3-dimethyloxirane

17. What is the IUPAC name of the major product for the reaction shown in the box?

\[
\begin{array}{c}
\text{CH}_3 \\
\text{NaI} \\
\text{acetone}
\end{array}
\rightarrow ?
\]

A) (1S,2S)-1-iodo-2-methylcyclopentane  
B) (1R,2R)-1-iodo-2-methylcyclopentane  
C) (1S,2R)-1-iodo-2-methylcyclopentane  
D) (1R,2S)-1-iodo-2-methylcyclopentane

18. What is the IUPAC name of the major product for the reaction shown in the box?

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

A) (2S,3S)-2,3-dichlorobutane  
B) (2R,3S)-2,3-dichlorobutane  
C) (R)-1,2-dichlorobutane  
D) (S)-1,2-dichlorobutane

19. What is the IUPAC name of the major product for the reaction shown in the box?

\[
\begin{array}{c}
\text{TsO} \\
\text{H}_2\text{CC} \equiv \text{C} \text{Na}
\end{array}
\rightarrow ?
\]

A) (Z)-3-methyl-2-hepten-5-yne  
B) (E)-3-methyl-2-hepten-5-yne  
C) (Z)-3-methyl-2-octen-6-yne  
D) (E)-3-methyl-2-octen-6-yne

20. What is the IUPAC name of the major product for the reaction shown in the box?

\[
\begin{array}{c}
\text{1. BH}_3 \\
\text{2. H}_2\text{O}_2, \text{NaOH, H}_2\text{O}
\end{array}
\rightarrow ?
\]

A) cis-2-methylcyclopentanol  
B) trans-2-methylcyclopentanol  
C) 1-methylcyclopentanol  
D) 1-methylcyclopentene

21. What is the IUPAC name of the major product for the reaction shown in the box?
22. What is the IUPAC name of the major product for the reaction shown in the box?

![](image1)

A) cis-1-bromo-4-methylcyclohexane  B) cis-1-bromo-3-methylcyclohexane
C) trans-1-bromo-4-methylcyclohexane  D) trans-1-bromo-3-methylcyclohexane

23. What is the main product of the reaction shown in the box?

![](image2)

A) methylenecyclopentane  B) 3-methylcyclopentene
C) 4-methylcyclopentene  D) 1-methylcyclopentene

24. What is the main product of the reaction shown in the box?

![](image3)

A) (CH₃)₃C\(\text{CH}_{2}\)\(\text{CH}_{3}\)  B) (CH₃)₃C\(\text{CH}_{3}\)
C) (CH₃)₃C\(\text{CH}_{3}\)\(\text{CH}_{3}\)\(\text{OCH}_{3}\)  D) (CH₃)₃C\(\text{CH}_{2}\)\(\text{CH}_{2}\)\(=\text{CH}_{2}\)

25. What is the main product of the reaction shown in the box?

![](image4)

A) \(\text{TsO}, \text{pyridine}\)  B) \(\text{NaCN}, \text{DMSO}\)
C) \(\text{Na}, \text{OEt}\)  D) \(\text{CH}_{3}\text{COCH}_{3}\)

26. What is the main product of the reaction shown in the box?

![](image5)

A) \(\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}\)  B) \(\text{CH}_3\text{CH}(\text{OH})\text{CH}_3\)
C) \(\text{CH}_3\text{COCH}_3\)  D) \(\text{CH}_3\text{CH}_2\text{CHO}\)

27. What alkene when treated with ozone and then with (CH₃)₂S gives the products shown in the box?
28. What is the IUPAC name of the major product for the reaction shown in the box?

A) trans-1-methoxy-3-methylcyclopentane  B) cis-3-methoxycyclopentanol
C) cis-1-methoxy-3-methylcyclopentane  D) 3-methylcyclopentene

29. Which one of the following compounds is the strongest acid?

A) t-BuOH  B) CH₃CH₂Br  C) CH₃NH₂  D) CH₃CO₂H

30. Which one of the following compounds has the highest solubility in water?

A)  B)  C)  D)

31. Which molecule is the best substrate for S,1 reaction?

A)  B)  C)  D)

32. Which one of the following molecules is a meso compound?

A)  B)  C)  D)

33. Which of the following compounds is the strongest base?

A) NaN(CH₃)₂  B) NaF  C) NaOEt  D) NaI

34. Which one of the following molecules is chiral?

A)  B)  C)  D)

35. Which of the following molecules contains two chiral centers?

A)  B)  C)  D)
36. Consider the following **orders of priority** (highest to lowest). Which order is incorrect?

A) Cl > CH₂CH₃ > CH₃ > H  
B) Cl > CH=CH₂ > C(CH₃)₃ > H  
C) OH > CHO > CH₂CH₂OH > CH₃  
D) NH₂ > CH₂SH > CH₂OH > CH₃

37. Which sequence of **reagents** can be used for the reaction shown in the box?

A) (1) NBS, (2) NaN(CH₃)₂  
B) (1) HBr, (2) (CH₃)₂NH  
C) (1) Br₂, (2) (CH₃)₂NH  
D) (1) HBr, (2) NaNH₂

38. Which sequence of **reagents** can be used for the reaction shown in the box?

A) (1) HBr, (2) NaSCH₃  
B) (1) NBS, (2) NaSCH₃  
C) (1) Br₂, (2) NaSH  
D) (1) PBr₃, (2) NaSH

39. Which sequence of **reagents** can be used for the reaction shown in the box?

A) (1) Br₂, (2) NaNH₂, (3) Na  
B) (1) CH₃Br, (2) NH₃, (3) Na  
C) (1) CH₃Br, (2) NaNH₂, (3) H₂  
D) (1) NaNH₂, (2) CH₃Br, (3) Na

40. Which sequence of **reagents** can be used for the reaction shown in the box?

A) (1) H₃PO₄, (2) O₃  
B) (1) H₂SO₄, (2) OsO₄  
C) (1) CH₃CH₂ONa, (2) OsO₄  
D) (1) PCC, (2) H₂SO₄

41. Which sequence of **reagents** can be used for the reaction shown in the box?
42. Which sequence of reagents can be used for the reaction shown in the box?

\[
\begin{align*}
\text{Ph} & \xrightarrow{\text{reagent (1)}} \text{Ph} \\
\text{OH} & \xrightarrow{\text{pyridine}} \text{N}_3
\end{align*}
\]

A) (1) TsCl, (2) NaN₃  
B) (1) SOCl₂, (2) NaCN  
C) (1) TsCl, (2) NH₃  
D) (1) PCC, (2) NaN₃

43. Which sequence of reagents can be used for the reaction shown in the box?

\[
\begin{align*}
\text{CH}_2=\text{CH} & \xrightarrow{\text{reagent (1)}} \text{CH}_2=\text{CH} \\
\text{OH} & \xrightarrow{1. \text{ reagent (2)}} \text{OH} \\
& \quad \text{2. H}_2\text{O}
\end{align*}
\]

A) (1) Br₂, (2) NaCN  
B) (1) HBr, (2) NaCN  
C) (1) RCO₂H, (2) NaN₃  
D) (1) RCO₂H, (2) HC≡C⁻ Na⁺

44. Which is the least stable alkene?

A) 2-methyl-2-pentene  
B) \textit{trans}-2-pentene  
C) 1-pentene  
D) 2,3-dimethyl-2-pentene

45. Arrange the compounds in the box in order of decreasing boiling point.

I) butane  II) 2-chloropropane  III) isopropanol

A) (highest) I > II > III  
B) (highest) III > II > I  
C) (highest) II > III > I  
D) (highest) II > I > III

46. Which of the following represents the order of increasing acidity for compounds the box?

(1) CH₃Br  (2) CH₃CO₂H  (3) CH₃CH₂OH  (4) FCH₂CO₂H  (5) HI

A) 1 (strongest) > 2 > 4 > 3 > 5 (weakest)  
B) 5 (strongest) > 4 > 2 > 3 > 1 (weakest)  
C) 4 (strongest) > 1 > 2 > 3 > 5 (weakest)  
D) 5 (strongest) > 1 > 4 > 2 > 3 (weakest)

47. Which species is NOT a Lewis acid?

A) B(CH₂CH₃)₃  
B) BH₃  
C) AlH₄⁻  
D) AlBr₃

48. Which one of the following structures has the lowest diaxial interactions?
49. Which of the following is a tertiary alcohol?

A) 3-buten-1-ol  
B) (R)-2-methyl-1-butanol  
C) (R)-3-buten-2-ol  
D) 2-methyl-3-buten-2-ol

50. Which of the following molecules contains both an acid AND an alcohol functional group?

A) \( \text{CH}_3\text{CH}_2\text{COOH} \)  
B) \( \text{CH}_3\text{CH}_2\text{COOCH}_3 \)  
C) \( \text{CH}_3\text{CHCOOH} \)  
D) \( \text{CH}_3\text{CHCHO} \)

**PLEASE MARK YOUR ANSWERS IN THE APPROPRIATE BOX ON THE BACK OF THE SCANTRON FORM (50 points total):**

**Question 51 (30 pts):** Consider the molecule shown below and answers the following questions. Indicate your answers by marking the appropriate number in boxes 51-60 on the back of the Scantron form (3 pts each).

Box 51: Number of \( \sigma \) bonds formed by overlap of \( sp^2 \) and \( sp^3 \) orbitals

Box 52: Number of \( \pi \) bonds formed by overlap of \( sp \) and \( sp \) orbitals

Box 53: Number of \( \sigma \) bonds formed by overlap of \( sp^2 \) and \( sp \) orbitals

Box 54: Number of \( \sigma \) bonds formed by overlap of \( s \) and \( sp^3 \) orbitals

Box 55: Number of \( \sigma \) bonds formed by overlap of \( sp^3 \) and \( sp^3 \) orbitals

Box 56: Number of \( \pi \) bonds formed by overlap of \( sp^2 \) and \( sp^2 \) orbitals

Box 57: Number of \( \sigma \) bonds formed by overlap of \( sp^2 \) and \( sp^2 \) orbitals

Box 58: Total number of \( \sigma \) bonds

Box 59: Total number of \( \pi \) bonds

Box 60: Total number of non-bonding electrons in this molecule

(Continued on the next page)

**Question 52 (20 pts):** Please write your answers in boxes 66-70 on the back of the Scantron form. Provide the reagents that give indicated products in high yield (4 pts each):
1. peroxides

2. $\text{H}_2\text{O}$, $\text{NaOH}$, $\text{H}_2\text{O}$