1. Consider the $S_{N2}$ reaction of butyl bromide with $\text{OH}^-$ ion.

$$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{Br}^-$$

Assuming no other changes, what effect on the rate would result from simultaneously doubling the concentrations of both butyl bromide and $\text{OH}^-$ ion?

A) No effect.
B) It would double the rate.
C) It would triple the rate.
D) It would increase the rate four times.
E) It would increase the rate six times.

2. Consider the $S_{N2}$ reaction of 2-iodopentane with $\text{CH}_3\text{CO}_2^-$ ion.

![Equation Diagram]

Assuming no other changes, what effect on the rate would result from simultaneously doubling the concentrations of both 2-iodopentane and $\text{CH}_3\text{CO}_2^-$ ion?

A) No effect.
B) It would double the rate.
C) It would triple the rate.
D) It would increase the rate four times.
E) It would increase the rate six times.

3. Consider the $S_{N2}$ reaction of 1-chloro-5-methylhexane with $\text{CN}^-$ ion.

$$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3\text{Cl} + \text{NaCN} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CN} + \text{NaCl}$$

Assuming no other changes, what effect on the rate would result from simultaneously doubling the concentrations of both 1-chloro-5-methylhexane and $\text{CN}^-$ ion?

A) No effect.
B) It would double the rate.
C) It would triple the rate.
D) It would increase the rate four times.
E) It would increase the rate six times.
4. The major product of the following reaction would be:

\[
\begin{array}{c}
\text{H}_3\text{CO} \quad \text{CH}_2\text{OH} \\
\text{CH}_3 \quad \text{CH}_3 \\
\text{I} \quad \text{II} \\
\text{III} \quad \text{IV}
\end{array}
\]

A) I  
B) II  
C) III  
D) IV  
E) An equimolar mixture of I and II.

5. A true statement about the transition state(s) of an SN2 reaction is:

A) the two transition states are of unequal energy.  
B) the transition states precede and follow an unstable reaction intermediate.  
C) the single transition state represents the point of maximum free energy of the reaction.  
D) existence of this transition state implies an exothermic reaction.  
E) the transition state will always have a net charge of -1.

6. The rate equation for a nucleophilic substitution reaction of a tertiary alkyl bromide (R-Br) with I- ion would be:

A) Rate = k [RBr]  
B) Rate = k [I-]  
C) Rate = k [RBr][I-]  
D) Rate = k [RBr]^2[I-]  
E) Rate = k [RBr][I-]^2
7. Consider the reaction of 2-chloro-2-methylpentane with sodium iodide.

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl} + \text{NaI} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{I} + \text{NaCl}
\]

Assuming no other changes, how would it affect the rate if one simultaneously doubled the concentration of 2-chloro-2-methylpentane and sodium iodide?
A) No effect
B) It would double the rate.
C) It would triple the rate.
D) It would quadruple the rate.
E) It would increase the rate five times.

8. The hybridization state of the charged carbon in a carbocation is
A) \(sp^4\)
B) \(sp^3\)
C) \(sp^2\)
D) \(sp\)
E) \(s\)

9. The p orbital of a methyl cation, \(\text{CH}_3^+\), contains how many electrons?
A) 1
B) 2
C) 3
D) 4
E) 0

10. The p orbital of the charged carbon in the isopropyl cation, \((\text{CH}_3)_2\text{CH}^+\), contains how many electrons?
A) 1
B) 2
C) 3
D) 4
E) 0

11. Which of the following reactions proceeds with inversion of configuration at the carbon bearing the leaving group?
A) \(S_N2\)
B) \(S_N1\)
C) \(E2\)
D) \(E1\)
E) All of these
12. Consider the substitution reaction that takes place when (R)-3-bromo-3-methylhexane is treated with methanol. Which of the following would be true?

A) The reaction would take place only with inversion of configuration at the stereogenic center.
B) The reaction would take place only with retention of configuration at the stereogenic center.
C) The reaction would take place with racemization.
D) No reaction would take place.
E) The alkyl halide does not possess a stereogenic center.

13. Consider the substitution reaction that takes place when (R)-3-bromo-3-methylhexane is treated with sodium methoxide. Which of the following would be true?

A) An $S_{N}2$ reaction would take place with inversion of configuration at the stereogenic center.
B) An $S_{N}1$ reaction would take place with retention of configuration at the stereogenic center.
C) An $S_{N}1$ reaction would take place with racemization of configuration at the stereogenic center.
D) An $S_{N}1$ reaction would take place, accompanied by an E1 reaction, affording a complex mixture of products.
E) An E2 reaction would take place, during which the stereogenic center is lost.

14. Consider the substitution reaction that takes place when (R)-3-iodo-3-methylheptane is treated with sodium acetate ($\text{CH}_3\text{CO}_2\text{Na}$). Which of the following would be true?

A) An $S_{N}2$ reaction would take place with inversion of configuration at the stereogenic center.
B) An $S_{N}1$ reaction would take place with retention of configuration at the stereogenic center.
C) An $S_{N}1$ reaction would take place with racemization of configuration at the stereogenic center.
D) An $S_{N}1$ reaction would take place, accompanied by an E1 reaction, affording a complex mixture of products.
E) An E2 reaction would take place, during which the stereogenic center is lost.
15. By analyzing the starting material and the product(s), the following reaction is an example of what type of mechanism?

\[ \text{Br} \quad \text{SN1} \quad \rightarrow \quad \text{N}_3 \]

A) $S_N1$
B) $S_N2$
C) $E1$
D) $E2$
E) More than one of the above

16. By analyzing the starting material and the product(s), the following reaction is an example of what type of mechanism?

\[ \text{Br} \quad \rightarrow \quad \text{OH} \]

A) $S_N1$
B) $S_N2$
C) $E1$
D) $E2$
E) None of the above

17. By analyzing the starting material and the product(s), the following reaction is an example of what type of mechanism?

\[ \text{I} \quad \rightarrow \quad \text{OH} \]

A) $S_N1$
B) $S_N2$
C) $E1$
D) $E2$
E) None of the above

18. The Hammond-Leffler postulate, when applied to nucleophilic substitutions and elimination reactions, states that:
A) a negatively-charged nucleophile is stronger than its conjugate acid.
B) polar aprotic solvents strongly accelerate the rate of $S_N2$ processes.
C) bimolecular nucleophilic substitutions are $2^{nd}$ order kinetically.
D) the transition state for an endergonic reaction step (one accompanied by an increase in free energy) resembles the product of that step.
E) elimination reactions will always compete with nucleophilic substitution reactions.
19. When 1,4-diodo-2,2-dimethylbutane (0.10 mol) is treated with 0.10 mol of NaCN in dimethyl sulfoxide at 30°C, the product formed is:

A)  
```
    NC
   /   /
  I---I
```

B)  
```
   CN
  / /
 I---I
```

C) both A) and B).

D)  
```
    NC
   /   /
  I---I
```

E)  
```
    CN
   / /
  I---I
```

20. Which is a true statement concerning the transition state of the rate-determining step of an SN1 reaction?
   A) Structurally, it closely resembles the carbocation intermediate.
   B) Both covalent bond-breaking and bond-making are occurring.
   C) Formation of the transition state is an exothermic reaction.
   D) Necessarily, the transition state has zero charge overall.
   E) More than one of the above.

21. By analyzing the starting material and the product(s), the following reaction is possibly an example of what type of mechanism?

```
    Br
   /   
  I---I
  +  
   /   
   N_3
```

A) SN1
B) SN2
C) E1
D) E2
E) More than one of the above
22. Which alkyl chloride, though primary, is essentially unreactive in S_N2 reactions?

A)  

B)  

C)  

D)  

E)  

23. Which alkyl halide would be most reactive in an S_N1 reaction?

I  Br  II  Br  III  Br

A)  I  
B)  II  
C)  III  
D)  IV  
E)  V  

24. Which alkyl halide would you expect to undergo an S_N2 reaction most slowly?

A)  1-bromohexane  
B)  1-bromo-2-methylpentane  
C)  1-bromo-3-methylpentane  
D)  1-bromo-4-methylpentane  
E)  1-bromo-2,2-dimethylbutane
25. Identify the nucleophile in the following reaction:

\[ 2 \text{H}_2\text{O} + \text{RX} \rightarrow \text{ROH} + \text{H}_3\text{O}^+ + \text{X}^- \]

A) X-
B) H_3O^+
C) ROH
D) H_2O
E) RX

26. Which of the following is not a nucleophile?

A) H_2O
B) CH_3O^-
C) NH_3
D) NH_4^+
E) All are nucleophiles.

27. Which is the strongest nucleophile?

A) OH^-
B) CH_3CH_2O^-

C) CH_3CO^-
D) CH_3CH_2OH
E) H_2O

28. Which S_N2 reaction would you expect to take place most rapidly? Assume that the concentrations of the reactants and the temperature are the same in each instance:

A) CH_3S^- + CH_3I \rightarrow CH_3SC\text{H}_3 + I^-  

B) CH_3SH + CH_3I \rightarrow \text{H}_3\text{C}^+\text{S}^-\text{CH}_3 + I^-  

C) CH_3O^- + CH_3I \rightarrow CH_3O\text{CH}_3 + I^-  

D) CH_3OH + CH_3I \rightarrow \text{H}_3\text{C}^+\text{O}^-\text{CH}_3 + I^-  

E) CH_3S^- + CH_3Cl \rightarrow CH_3SC\text{H}_3 + Cl^-
29. Which is not a polar aprotic solvent?

A) \( \text{H}_3\text{C} \equiv \text{C} \equiv \text{N} \)
B) \( \text{H}_3\text{C} \equiv \text{C} \equiv \text{N} \)
C) \( \text{H}_3\text{C} \equiv \text{S} \equiv \text{CH}_3 \)
D) \( \text{H}_3\text{C} \equiv \text{N} \equiv \text{CH}_3 \)
E) \( \text{H}_3\text{C} \equiv \text{C} \equiv \text{OH} \)

30. Which is a polar aprotic solvent?
A) 2-methylhexane
B) \( \text{CCl}_4 \)
C) \( \text{NH}_2(\text{I}) \)
D) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{CH}_3 \)
E) 2-methyl-2-propanol

31. Which is the weakest nucleophile in polar aprotic solvents?
A) \( \text{I}^- \)
B) \( \text{Br}^- \)
C) \( \text{Cl}^- \)
D) \( \text{F}^- \)
E) All of the above are equally strong nucleophiles, regardless of the type of solvent used

32. Which is the weakest nucleophile in polar protic solvents?
A) \( \text{I}^- \)
B) \( \text{Br}^- \)
C) \( \text{Cl}^- \)
D) \( \text{F}^- \)
E) All of the above are equally strong nucleophiles, regardless of the type of solvent used.
33. Which ion is the strongest nucleophile in aqueous solution?
   A) F⁻  
   B) Cl⁻  
   C) Br⁻  
   D) I⁻  
   E) All of these are equally strong.

34. Which ion is the strongest nucleophile in an aprotic solvent such as dimethylsulfoxide?
   A) I⁻ 
   B) Br⁻  
   C) Cl⁻  
   D) F⁻  
   E) These are all equal.

35. Which alkyl halide would you expect to react most slowly when heated in aqueous solution?
   A) (CH₃)₂C-F  
   B) (CH₃)₂C-Cl  
   C) (CH₃)₂C-Br  
   D) (CH₃)₂C-I  
   E) They would all react at the same rate.

36. Which is the most reactive nucleophile in DMF (structure shown below)?

   ![Structure Image]

   A) F⁻  
   B) Cl⁻  
   C) Br⁻  
   D) I⁻  
   E) They are all equally reactive.

37. Which S_n 2 reaction will occur most rapidly in a mixture of water and ethanol?
   A) I⁻ + CH₃CH₂-Br → CH₃CH₂-I + Br⁻  
   B) I⁻ + CH₃CH₂-Cl → CH₃CH₂-I + Cl⁻  
   C) I⁻ + CH₃CH₂-F → CH₃CH₂-I + F⁻  
   D) Br⁻ + CH₃CH₂-Cl → CH₃CH₂-Br + Cl⁻  
   E) Br⁻ + CH₃CH₂-F → CH₃CH₂-Br + F⁻
38. Which $S_N2$ reaction will occur most rapidly in aqueous acetone solution? Assume concentrations and temperature are the same in each instance.

A) $\text{HO}^- + \text{CH}_3\text{Cl} \rightarrow \text{CH}_3\text{OH} + \text{Cl}^-$
B) $\text{HO}^- + \text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{Cl}^-$
C) $\text{HO}^- + (\text{CH}_3)_2\text{CH-Cl} \rightarrow (\text{CH}_3)_2\text{CHOH} + \text{Cl}^-$
D) $\text{HO}^- + (\text{CH}_3)_2\text{CH-Cl} \rightarrow (\text{CH}_3)_2\text{COH} + \text{Cl}^-$
E) $\text{HO}^- + (\text{CH}_3)_3\text{CCH}_2\text{Cl} \rightarrow (\text{CH}_3)_3\text{CCH}_2\text{OH} + \text{Cl}^-$

39. The relative nucleophilicities of species do not necessarily parallel the relative basicities of the same species because:

A) not all nucleophiles are bases, and vice versa.
B) experimental measurements of sufficient accuracy are not available to make the comparisons.
C) nucleophilicity is a thermodynamic matter; basicity is a matter of kinetics.
D) basicity is a thermodynamic matter; nucleophilicity is a matter of kinetics.
E) Actually, the relative values do parallel one another.

40. Which $S_N2$ reaction would take place most rapidly?

A) $\text{OH}^- + \text{CH}_3\text{Cl} \xrightarrow{\text{H}_2\text{O}, 25^\circ \text{C}} \text{CH}_3\text{OH} + \text{Cl}^-$
B) $\text{H}_3\text{C}^+\text{O}^- + \text{CH}_3\text{Cl} \xrightarrow{\text{H}_2\text{O}, 25^\circ \text{C}} \text{H}_3\text{COCH}_3 + \text{Cl}^-$
C) $\text{H}_2\text{O} + \text{CH}_3\text{Cl} \xrightarrow{\text{H}_2\text{O}, 25^\circ \text{C}} \text{CH}_3\text{OH}_2^+ + \text{Cl}^-$
D) $\text{CH}_3\text{OH} + \text{CH}_3\text{Cl} \xrightarrow{\text{CH}_3\text{OH}, 25^\circ \text{C}} \text{H}_3\text{C}^+\text{OCH}_3 + \text{Cl}^-$
E) $\text{SH}^- + \text{CH}_3\text{Cl} \xrightarrow{\text{H}_2\text{O}, 25^\circ \text{C}} \text{CH}_3\text{SH} + \text{Cl}^-$

41. Identify the leaving group in the following reaction.

$\text{SN}^+$ + $\text{I}^{-} \rightarrow \text{SN}^- + \text{Na}^+ + \text{I}^{-}$

A) $\text{C}_6\text{H}_5\text{S}^+$
B) $\text{Na}^+$
C) $\text{CH}_3\text{CH}_2\text{I}$
D) $\text{C}_6\text{H}_5\text{SCH}_2\text{CH}_3$
E) $\text{I}^{-}$
42. Which nucleophilic substitution reaction would be unlikely to occur?
   A) $\text{HO}^- + \text{CH}_3\text{CH}_2\text{-I} \rightarrow \text{CH}_3\text{CH}_2\text{-OH} + \text{I}^-$
   B) $\text{I}^- + \text{CH}_3\text{CH}_2\text{-H} \rightarrow \text{CH}_3\text{CH}_2\text{-I} + \text{H}^-$
   C) $\text{CH}_3\text{S}^- + \text{CH}_3\text{-Br} \rightarrow \text{CH}_3\text{S}-\text{CH}_3 + \text{Br}^-$
   D) All of the above would be unlikely to occur.
   E) None of the above would be unlikely to occur.

43. Which of the following would be most reactive in an $S_N2$ reaction?
   A)
   B)
   C)
   D)
   E)

44. Which of the following is the poorest leaving group?
   A) $\text{H}^-$
   B) $\text{CH}_3\text{O}^-$
   C) $\text{H}_2\text{O}$
   D) $\text{OH}^-$
   E) $\text{NH}_2^-$

45. Which of the following is not a good leaving group?
   A) $\text{C}_2\text{H}_5\text{O}^-$
   B) $\text{Cl}^-$
   C) $\text{I}^-$
   D) $\text{CH}_3\text{CO}_2^-$
   E) All of these are good leaving groups.
46. Which nucleophilic substitution reaction is not likely to occur?
   A) $\text{I}^- + \text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{CH}_3\text{CH}_2\text{I} + \text{Cl}^-$
   B) $\text{I}^- + \text{CH}_3\text{CH}_2\text{Br} \rightarrow \text{CH}_3\text{CH}_2\text{I} + \text{Br}^-$
   C) $\text{I}^- + \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{I} + \text{OH}^-$
   D) $\text{CH}_3\text{O}^- + \text{CH}_3\text{CH}_2\text{Br} \rightarrow \text{CH}_3\text{CH}_2\text{OCH}_3 + \text{Br}^-$
   E) $\text{OH}^- + \text{CH}_3\text{CH}_2\text{Cl} \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{Cl}^-$

47. Elimination reactions are favored over nucleophilic substitution reactions:
   A) at high temperatures.
   B) when tert-butoxide ion is used.
   C) when 3° alkyl halides are used as substrates.
   D) when nucleophiles are used which are strong bases and the substrate is a 2° alkyl halide.
   E) in all of these cases.

48. What would you expect to be the chief organic product(s) when tert-butyl bromide reacts with sodium acetylide, i.e.,

\[ \text{CH}_3\text{C} = \text{C}^\cdot + \text{HC} = \text{C}^- \text{Na}^+ \rightarrow ? \]

\[ \text{I} \quad \text{II} \quad \text{III} \]

\[ \left( \text{IV} + \text{HC} = \text{CCH} \right) \]

A) I
B) II
C) III
D) IV
E) None of these
49. What would you expect to be the chief organic product(s) when 2-bromo-2-methylpentane react(s) with sodium propynide, i.e.,

$$\begin{align*}
\text{Br} & + \text{C} : \text{Na}^+ \\
\text{I} & \\
\text{CH}_3 & + \text{HC} \equiv \text{CH} \\
\text{II} & \\
\text{CH}_3 & + \text{HC} \equiv \text{CH} \\
\text{III} & \\
\end{align*}$$

A) I  \\
B) II  \\
C) III  \\
D) IV  \\
E) V

50. The major product(s) of the following reaction is(are):

$$\begin{align*}
\text{H} & \\
& \\
& \\
& \\
\text{CH}_3 & \\
\text{Cl} & \\
\text{NaI, CH}_3\text{CH}_2\text{OH} & \\
\text{25°C} & \\
\end{align*}$$

$$\begin{align*}
\text{H} & \\
& \\
& \\
& \\
\text{CH}_3 & \\
\text{I} & \\
\end{align*}$$

A) I  \\
B) II  \\
C) III  \\
D) IV  \\
E) Equal amounts of I and II
51. What would be the major product of the following reaction?

\[ \text{CH}_2\text{Cl} \text{H} \quad \text{OH}^- \quad \text{S}_\text{n}2 \]

\[ \text{I} \quad \text{II} \]

\[ \text{III} \quad \text{IV} \]

A) I  
B) II  
C) III  
D) IV  
E) An equimolar mixture of I and II

52. What would be the major product(s) of the following reaction?

\[ \text{CH}_3\text{CH}_2\text{CO}_2\text{Na} \quad \text{CH}_3\text{CH}_2\text{CO}_2\text{H} \]

\[ \text{I} \quad \text{II} \quad \text{III} \quad \text{IV} \]

A) I  
B) II  
C) III  
D) IV  
E) None of the above
53. What would be the major product(s) of the following reaction?

\[
\begin{array}{c}
\text{CH}_3\text{SNa} \\
\text{CH}_3\text{SH}
\end{array}
\]

\[
\begin{array}{cccc}
\text{I} & \text{II} & \text{III} & \text{IV}
\end{array}
\]

A) I  
B) II  
C) III  
D) IV  
E) More than one of the above

54. What would be the major product(s) of the following reaction?

\[
\begin{array}{c}
\text{NaI} \\
\text{Acetone}
\end{array}
\]

\[
\begin{array}{cccc}
\text{I} & \text{II} & \text{III} & \text{IV}
\end{array}
\]

A) I  
B) II  
C) III  
D) IV  
E) None of the above

55. Which of the following statements is (are) true of an \( S_n2 \) reaction of (R)-2-bromobutane with hydroxide ion?

A) Doubling the hydroxide ion concentration would double the rate of the reaction. (Assume that all other experimental conditions are unchanged.)
B) The major product would be (S)-2-butanol.
C) Doubling the concentration of (R)-2-bromobutane would double the rate of the reaction. (Assume that all other experimental conditions are unchanged.)
D) All of the above
E) Two of the above
56. The major product(s) for the following reaction would mainly be dictated by which mechanism?

\[
\text{NaN}_3 \xrightarrow{\text{CH}_3\text{CH}_2\text{OH}} \quad \text{SO}_2\text{CF}_3
\]

A) S\(_\text{n}1\)
B) S\(_\text{n}2\)
C) E\(_1\)
D) E\(_2\)
E) None of the above

57. Predict the product(s) for the following reaction sequence.

\[
\quad \xrightarrow{\text{THF, } \text{H}_3\text{C} = \text{Li}} \quad \xrightarrow{\text{H}_2 \text{ (excess), Pd/C, EtOH}}
\]

A) 
B) 
C) 
D) 
E) None of the above
58. Predict the product(s) for the following reaction sequence.

\[ \text{1. 1-bromobutane} \]
\[ \text{2. } \text{H}_2 (\text{excess}), \text{Pd/C}, \text{EtOH} \]

A)

B)

C)

D)

E) None of the above

59. The major product(s) for the following reaction would mainly be dictated by which mechanism?

\[ \text{O} \quad \text{CF}_3 \]
\[ \text{CH}_3\text{CH}_2\text{OLi} \]
\[ \text{CH}_3\text{CH}_2\text{OH} \]

A) Sn1
B) Sn2
C) E1
D) E2
E) None of the above
60. The product(s) for the following reaction would mainly be dictated by which mechanism?

\[
\text{Cl} \quad \xrightarrow{\text{EtOH, EtONa}} \quad \text{?}
\]

A) $S_N1$
B) $S_N2$
C) E1
D) E2
E) None of the above

61. Treating $(\text{CH}_3)_3\text{C-Cl}$ with a mixture of $\text{H}_2\text{O}$ and $\text{CH}_3\text{OH}$ at room temperature would yield:

A) $\text{CH}_2=\text{C(\text{CH}_3)_2}$
B) $(\text{CH}_3)_3\text{COH}$
C) $(\text{CH}_3)_3\text{COCH}_3$
D) All of these
E) None of these

62. Which would be formed in the following reaction?

\[
\text{H}_2\text{C} \quad \xrightarrow{\text{CH}_3\text{OH}} \quad 55^\circ\text{C} \quad ?
\]

\[
\text{H}_3\text{C} \quad \text{I} \quad \text{II}
\]

\[
\text{H}_3\text{C} \quad \text{III} \quad \text{IV}
\]

A) I
B) II
C) III
D) IV
E) All of the above
63. What would be the major product(s) of the following reaction?

![Chemical structure diagram]

A) I and II  
B) II and III  
C) I and III  
D) IV  
E) None of the above

64. Which of the following statements is (are) true of S_N1 reactions of alkyl halides in general?
A) The rate of an S_N1 reaction depends on the concentration of the alkyl halide.  
B) The rate of an S_N1 reaction depends on the concentration of the nucleophile.  
C) S_N1 reactions of alkyl halides are favored by polar solvents.  
D) Answers A) and C) only are true.  
E) Answers A), B) and C) are true.

65. Which of the following statements is (are) true of S_N1 reactions of alkyl halides in general?
A) The rate of an S_N1 reaction depends on the concentration of the alkyl halide.  
B) The rate of an S_N1 reaction depends on the concentration of the nucleophile.  
C) S_N1 reactions of alkyl halides occur faster in polar aprotic solvents (compared to protic solvents)  
D) Answers A) and C) only are true.  
E) Answers A), B) and C) are true.

66. S_N1 reactions of the type, Nu^− + RL → Nu−R + L^−, are favored:
A) when tertiary substrates are used.  
B) by using a high concentration of the nucleophile.  
C) when L^− is a strong base.  
D) by use of a non-polar solvent.  
E) by none of the above.
67. $S_N 1$ reactions of the following type:

$$\text{Nu}^- + \text{R-X} \rightarrow \text{R-Nu} + \cdot\text{X}^-$$

are favored:
A) by the use of tertiary substrates (as opposed to primary or secondary substrates).
B) by increasing the concentration of the nucleophile.
C) by increasing the polarity of the solvent.
D) by use of a strong base.
E) by more than one of the above.

68. $S_N 1$ reactions of the following type:

$$\text{Nu}^- + \text{R-X} \rightarrow \text{R-Nu} + \cdot\text{X}^-$$

are favored:
A) by the use of tertiary substrates (as opposed to primary or secondary substrates).
B) by increasing the concentration of the nucleophile.
C) by increasing the polarity of the solvent.
D) by use of a weak nucleophile.
E) Both A) and D)

69. Name the following compound:

\[
\begin{align*}
\text{OCH}_3 \\
\end{align*}
\]

A) (cis)-3-methoxyhex-3-ene
B) (Z)-4-methoxyhex-4-ene
C) (Z)-3-methoxyhex-3-ene
D) (E)-3-methoxyhex-3-ene
E) 3-methoxyhex-3-ene
70. Name the following compound:

\[
\begin{align*}
&\text{HO} \quad \text{C} \quad \text{C} \\
&\quad \text{C} \\
&\quad \text{C} \quad \text{C} \\
\end{align*}
\]

A) (E)-4-phenyl-4-methylbut-3-en-1-ol  
B) (E)-4-phenylpent-3-en-1-ol  
C) (Z)-4-phenylpent-3-en-1-ol  
D) (Z)-4-phenyl-4-methylbut-3-en-1-ol  
E) (E)-4-benzylpent-3-en-1-ol

71. Which structure represents (Z)-4-bromohexa-1,3-diene?

\[
\begin{align*}
&\text{Br} \\
&\text{C} \quad \text{C} \\
&\text{C} \quad \text{C} \\
&\text{C} \quad \text{C} \\
\end{align*}
\]

A)  
B)  
C)  
D)  
E) None of the above

72. A correct IUPAC name for the following compound is:

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

A) 3,3,5-trimethyl-2-hexene  
B) 3-isobutyl-3-isopropyl-2-propene  
C) 3-isobutyl-4-methyl-2-pentene  
D) 3-(1-methylethyl)-5-methyl-2-hexene  
E) None of the above
73. Select the structure of 4-ethyl-2,3-dimethyl-2-heptene.

A)  

B)  

C)  

D)  

E)  

74. The correct IUPAC name for the following compound is:

Cl
Br

A) (E)-2-Bromo-3-chloro-5-methyl-2-hexene  
B) (E)-2-Bromo-3-chloro-5-methyl-3-hexene  
C) (Z)-2-Bromo-3-chloro-5-methyl-3-hexene  
D) (Z)-2-Bromo-3-chloro-5-methyl-2-hexene  
E) (E)-2-Methyl-5-bromo-4-chloro-4-hexene

75. What is the major product for the following reaction?

\[
\begin{align*}
\text{CH}_3\text{CH}(\text{CH}_3)\text{CHCH}_2\text{CH}_2\text{CH}_3 & \quad \text{EtOH, EtONa} \\
& \quad \text{heat}
\end{align*}
\]

A) CH3CH2(CH2)C=CHCH3  
B) CH3CH2(CH2)CHCH=CH2  
C) CH3CH2(CH2)CHCH(OCH2CH3)CH3  
D) None of the above  
E) No reaction
76. What is the *major* product for the following reaction?

\[ \begin{array}{c}
\text{Cl} \\
\text{t-BuOH, t-BuOK} \\
\end{array} \]

A) \( \text{Ot-Bu} \)

B)

C)

D)

E)

77. What is the *major* product for the following reaction?

\[ \begin{array}{c}
\text{I} \\
\text{t-BuOH, t-BuOK} \\
\end{array} \]

A) \( \text{I} \)

B)

C)

D)

E) None of the above
78. What is the major product for the following reaction?

\[ \text{EtONa, EtOH} \]\n
\[ \text{heat} \]

A)  
B)  
C)  
D)  
E) None of the above
79. What is the major product for the following reaction?

\[
\begin{align*}
\text{Cl} & \quad \text{EtOH, EtONa} \quad \text{heat} \\
\text{A) } & \\
\text{B) } & \\
\text{C) } & \\
\text{D) } & \\
\text{E) } &
\end{align*}
\]
80. What is the major product for the following reaction?

\[ \text{Br} \quad \xrightarrow{t\text{-BuOK, } t\text{-BuOH}} \]

A) 

B) 

C) 

D) 

E)
81. What is the major product for the following reaction?

\[ \text{Br} \quad \text{EtONa, EtOH} \quad \text{heat} \]

A) 

B) 

C) 

D) 

E) More than one of the above

82. What is the major product for the following reaction?

\[ \text{Br} \quad \text{EtOH, EtONa} \quad \text{heat} \]

A) 

B) 

C) 

D) 

E) 

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83. What is the *major* product for the following reaction?

\[ \text{EtOH, EtONa} \]

\[ \text{heat} \]

A) \( \text{OEt} \)
B) 
C) 
D) 
E) 

84. What is the *major* product for the following reaction?

\[ 1. \text{NaI, acetone} \]

\[ 2. \text{t-BuOH, t-BuOK} \]

A) 
B) 
C) 
D) 
E)
85. What is the major product for the following reaction?

\[
\text{Cl} \quad \xrightarrow{1. \text{NaI, acetone}} \quad 1. \text{NaI, acetone} \\
2. t-\text{BuOH, } t-\text{BuOK}
\]

A)  

B)  

C)  

D)  

E)  

86. What is the major product for the following reaction?

\[
\text{Cl} \quad \xrightarrow{1. \text{NaI, acetone}} \quad 1. \text{NaI, acetone} \\
2. \text{NaOH, EtOH, heat}
\]

A)  

B)  

C)  

D)  

E)  
87. What is the major product for the following reaction?

\[
\begin{array}{c}
\text{Br} \\
\text{Iodoalkane} \\
\text{1. NaI, acetone} \\
\text{2. EtONa, EtOH, heat}
\end{array}
\]

A) 
B) 
C) 
D) 
E) 

88. Zaitsev's rule states that:
A) In electrophilic addition of an unsymmetrical reagent to an unsymmetrical alkene, the more positive portion of the reagent will become attached to the carbon of the double bond bearing the greater number of hydrogen atoms.
B) An equatorial substituent in cyclohexane results in a more stable conformation than if that substituent were axial.
C) E2 reactions occur only if the β-hydrogen and leaving group can assume an anti-periplanar arrangement.
D) When a reaction forms an alkene, and several possibilities exist, the more (or most) stable isomer is the one which predominates.
E) The order of reactivity of alcohols in dehydration reactions is 3° > 2° > 1°.

89. What is the major product of the reaction,

\[
\begin{array}{c}
\text{Br} \\
\text{Iodoalkane} \\
\text{(CH}_3)_2\text{COK} \\
\text{(CH}_3)_2\text{COH} \\
\text{heat}
\end{array}
\]

A) \((\text{CH}_3)_2\text{C} \equiv \text{C} \text{CH}_3\)
B) \((\text{CH}_3)_2\text{C} \equiv \text{CH} \equiv \text{CH}_2\)
C) \((\text{CH}_3)_2\text{C} \equiv \text{CHCH}_3\)
D) \((\text{CH}_3)_2\text{C} \equiv \text{CHCH}_2\text{CH}_3\)
E) None of these
90. Which compound would be the major product?

\[ \begin{aligned}
\text{Br} & \quad \text{(CH}_3\text{)}_3\text{CO}\text{K} \quad \text{(CH}_3\text{)}_3\text{COH} \\
\text{heat} & \quad \text{?}
\end{aligned} \]

A)  
B)  
C)  
D)  
E)  

91. Which statement(s) is/are true of acid-catalyzed alcohol dehydrations?

A) Protonation of the alcohol is a fast step.
B) Formation of a carbocation from the protonated alcohol is a slow step.
C) Rearrangements of less stable carbocations to more stable carbocations are common.
D) Loss of a proton by the carbocation is a fast step.
E) All of the above
92. Which product(s) would be produced by acid-catalyzed dehydration of 2-methyl-2-pentanol?

A) 

B) 

and

C) 

and

D) 

E) 

93. Which one of the following alcohols would dehydrate most rapidly when treated with sulfuric acid?

I

II

III

IV

V

A) I
B) II
C) III
D) IV
E) V
94. Which mechanistic step in the acid-catalyzed dehydration of 3,3-dimethyl-2-butanol is the rate determining step?

Step 1:
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{OH} + \text{H}_3\text{O}^+ \rightleftharpoons \text{CH}_3\text{CH}_2\text{CHCH}_2\text{H} + \text{H}_2\text{O}
\]
A)

Step 2:
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{H} + \text{OH}_2 \rightleftharpoons \text{CH}_3\text{CH}_2\text{CHCH}_2\text{OH} + \text{H}_2\text{O}
\]
B)

Step 3:
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{H} \rightleftharpoons \text{CH}_3\text{CH}_2\text{CHCH}_2\text{H}
\]
C)

Step 4a:
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}_2\text{CHCH}_2\text{H} + \text{H}_3\text{O}^+
\]
D)

Step 4b:
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}_2\text{CHCH}_2\text{H} + \text{H}_3\text{O}^+
\]
E)

95. Which alcohol would be most easily dehydrated?

A)
\[
\text{CH}_3\text{CH}_2\text{CCH}_2\text{CH}_3
\]

B)
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{H}
\]

C)
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{CH}_2\text{OH}
\]

D)
\[
\text{HOCH}_2\text{CHCH}_2\text{CH}_2\text{CH}_3
\]

E)
\[
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{CH}_3
\]
96. Which alcohol would be most easily dehydrated?

A) I  
B) II  
C) III  
D) IV  
E) V

97. Which alcohol would initially produce the most stable carbocation when treated with concentrated H₂SO₄?

A)  
B)  
C)  
D)  
E)
98. Which of the following carbocations would NOT be likely to undergo rearrangement?

\[
\begin{align*}
\text{A)} & \quad \text{CH}_3
\end{align*}
\]
\[
\begin{align*}
\text{CH}_3 & \\
\text{CH}_3 & \\
\text{CH}_3 & +
\end{align*}
\]
\[
\begin{align*}
\text{B)} & \quad \text{CH}_3 \\
\text{CH}_3 & \\
\text{CH}_3 & \\
\text{C)} & \\
\text{CH}_3 & \\
\text{CH}_3 & +
\end{align*}
\]
\[
\begin{align*}
\text{D)} & \quad \text{CH}_3 \text{CH}_2^+ \\
\text{CH}_3 & \\
\text{CH}_3 & \\
\text{E)} &
\end{align*}
\]

99. Rearrangements are likely to occur in which of the following reaction types?

A) \( \text{S}_\text{N}1 \) reactions
B) \( \text{S}_\text{N}2 \) reactions
C) \( \text{E}_1 \) reactions
D) \( \text{E}_2 \) reactions
E) Both \( \text{S}_\text{N}1 \) and \( \text{E}_1 \) reactions

100. Upon catalytic hydrogenation, a compound \( \text{C}_6\text{H}_6 \) absorbs four moles of hydrogen. Select a structure for \( \text{C}_6\text{H}_6 \).

\[
\begin{align*}
\text{I} & \\
\text{II} & \\
\text{III} & \\
\text{IV} & \\
\text{V} &
\end{align*}
\]

A) I, II
B) III
C) II, III
D) IV, V
E) I, IV, V
101. On hydrogenation, a compound C₉H₁₂ absorbs 2 mol of hydrogen. Which of the following is a possible structure for the compound?

- A) I
- B) II
- C) III
- D) IV
- E) V

102. Predict the major product(s) for the following reaction sequence.

\[
\begin{align*}
\text{Br} & \quad \xrightarrow{1. \text{NaI, acetone}} \\
\text{OH} & \quad \xrightarrow{2. \text{H}_2\text{O, 20 °C}} \\
\end{align*}
\]

- A)
- B)
- C)
- D)
- E) A 1:1 mixture of A) and B)
Answer Key

1. D
2. D
3. D
4. B
5. C
6. A
7. B
8. C
9. E
10. E
11. A
12. C
13. E
14. D
15. B
16. B
17. A
18. D
19. B
20. A
21. A
22. E
23. D
24. E
25. D
26. D
27. B
28. A
29. E
30. D
31. A
32. D
33. D
34. D
35. A
36. A
37. A
38. A
39. D
40. E
41. E
42. B
43. D
44. E