1. The best solvent for an S_N2 reaction is
   a. Dichloromethane, CH_2Cl_2
   b. DMSO, (CH_3)_2S=O
   c. Ethanol, CH_3CH_2OH
   d. Water, H_2O

2. Which substance below would serve as the best nucleophile in a substitution reaction at a primary carbon?
   a. HMPA
   b. Cl
   c. O-Tozyl
   d. OCH_3
   e. H_2O

3. A bimolecular nucleophilic substitution (S_N2) is
   a. A one-step process with retention of configuration.
   b. A one-step process with inversion of configuration.
   c. A two-step process in which a bond is broken then a new bond is formed and there is retention of configuration.
   d. A two-step process in which a bond is broken then a new bond is formed and there is inversion of configuration.
   e. A two-step process in which a bond is broken then a new bond is formed creating a racemic mixture with both retention and inversion of configuration.

4. Classify the following reaction as an oxidation, a reduction or neither.
   a. oxidation
   b. reduction
   c. neither

5. Which S_N2 reaction will proceed faster?
   a. 1-bromobutane
   b. 1-chlorobutane
   c. Both reactions will occur at the same rate.
6. Which $S_N2$ reaction will proceed faster?
   a. methyl $p$-tolyl sulfate
   b. Both reactions will occur at the same rate.

7. Consider the nucleophilic substitution shown below. The effect of doubling the amount of $CN^-$ would be to multiply the reaction rate by a factor of 3.
   a. $\frac{1}{4}$
   b. $\frac{1}{2}$
   c. 2
   d. 4
   e. 0 (No change in the rate of reaction.)

8. Name the following molecules:
   4-methyl-1-pentyne
   (Cis)-4-methyl-2-pentene

   $\text{H}_2$ Lindlar's Catalyst
10. Draw a mechanism showing the proper representation of the "flow" of electrons in this reaction?

What type of reaction would most likely occur (E1, E1cb, E2, S_N1, or S_N2)?  

\[ \text{OTs} \quad \text{CH}_3\text{CH}_2\text{CHCH}_3 \quad \text{CH}_3\text{CH}_2\text{O}^- \quad \text{CH}_3\text{CH}==\text{CHCH}_3 \]

\[ \text{CH}_3\text{-} \quad \text{H} \quad \text{CO}^{2-} \]

\[ \text{CH}_3\text{-} \quad \text{C} \quad \text{H}_3 \quad \text{C} \quad \text{CH}_3 \quad \text{H} \]

11. Which of the following two reactions would occur at the fastest rate?

E2 3°, Strong Base

a. H\text{H}C \quad H \quad H \quad H \quad H \quad \text{OH}^- \quad \text{H}_2\text{C}==\text{C} \quad \text{CH}_3 \quad \text{H}_2\text{C} \quad \text{H}_3 \quad \text{CH}_3

b. D\quad D\quad D\quad D\quad H\quad \text{Br} \quad \text{OH}^- \quad \text{H}_2\text{C}==\text{C} \quad \text{CH}_3 \quad \text{H}_2\text{C} \quad \text{H}_3 \quad \text{CH}_3

12. Which of the following choices best represent the reaction shown above?

a. S_N1  

b. S_N2  

c. E1  

d. E2

13. The reaction of RCl with CH\text{3CH}_2\text{OH} reacts according to an S_N1 mechanism. Which is the correct rate law expression for this reaction?

a. rate = k[RCl][CH\text{3CH}_2\text{OH}]  

b. rate = k[RCl][H\text{2O}][CH\text{3CH}_2\text{OH}]  

c. rate = k[RCl]  

d. rate = k[RCl][H\text{2O}]

15
14. Draw the mechanistic steps for the formation of 2-methyl-1-butene by dehydration of 3-methyl-2-butanol using sulfuric acid – similar to the reaction you did in lab. Draw each step individually so I can tell if it happens in 1, 2, 3, or 4 steps.

15. Draw all monochlorination products you would expect to obtain from radical chlorination of 2-methylbutane. Use the reactivity of primary as 1.0, secondary as 3.5 and tertiary as 5.0. What would be the approximate percentage of each product be?
For each of the following reactions, draw the major product(s) and identify the type of reaction that is taking place in each case (Sn2, E2, E1cb, or combination of Sn1 and E1)?

16. 

17. 

18. 

19. 

20. 

Sn1
21. Draw the structure of the major organic products(s) for each of the following reactions. Indicate the stereochemistry for each reaction when appropriate.
22. Write a detailed, stepwise mechanism for the following reaction. (Use curved arrows and label the initiation step, propagation step(s). Calculate $\Delta H^\circ$ for only the two propagation steps in this reaction. Draw an energy diagram. Is this reaction exothermic or endothermic.

\[
\text{Initiation} \quad \text{CH}_3\text{Cl} + \text{hv} \rightarrow 2 \cdot \text{Cl}^* \\
\text{CH}_3\text{H} + \cdot \text{Cl}^* \rightarrow \text{CH}_3\text{H} + \text{HCl} = -22 \\
\text{CH}_3\text{H} + \cdot \text{Cl}^* \rightarrow \text{CH}_3\text{H} + \cdot \text{Cl}^* = -96 \\
\text{CH}_3\text{H} + \cdot \text{Cl}^* \rightarrow \text{CH}_3\text{H} + \cdot \text{Cl}^* = -339 \\
\text{Energy Diagram:} \\
\text{Initiation: } -118 \\
\text{Propagation 1: } 22 \\
\text{Propagation 2: } 96 \\
\text{Total Energy Change: } -118 \\
\text{Exothermic Reaction}.
1. The best solvent for an S_N2 reaction is
   a. DMSO (CH_3)2S=O
   b. CHCl_3
   c. H_2O
   d. CH_3CH_2OH
   A

2. Which S_N2 reaction will proceed faster?
   a. The displacement by CN^- on 1-bromobutane.
   b. The displacement by CN^- on 1-chlorobutane.
   A

3. Which S_N2 reaction will proceed faster?
   a. The displacement by I^- on CH_3Cl.
   b. The displacement by I^- on CH_3OTos
   B

4. Which substance below would serve as the best nucleophile in a substitution reaction at a primary carbon.
   a. HMPA
   b. Cl^-
   c. O-Tosyl
   d. OH^-
   e. H_2O
   D

5. A bimolecular nucleophilic substitution (S_N2) is
   a. A one-step process with inversion of configuration.
   b. A one-step process with retention of configuration.
   c. A two-step process in which a bond is broken then a new bond is formed and there is inversion of configuration.
   d. A two-step process in which a bond is broken then a new bond is formed and there is retention of configuration.
   A

6. Classify the following reaction as an oxidation, a reduction or neither.

   H_3C—C≡C—CH_3 \xrightarrow{\text{H_2 \text{Lindlar's Catalyst}}} \text{H}_3\text{C} \quad \text{H}_3\text{C}

   a. oxidation
   b. reduction
   c. neither

7. Classify the following reaction as an oxidation, a reduction or neither.

   OH

   a. oxidation
   b. reduction
   c. neither

   Na_2Cr_2O_7 \xrightarrow{\text{H}_3\text{O}^+} \text{H}_2\text{O}^+
8. Consider the nucleophilic substitution shown below. The effect of doubling the amount of CH₃CH₂OH would be to multiply the reaction rate by a factor of

- a. ¼
- b. ½
- c. 2
- d. 4
- e. 0 (No change in the rate of reaction.)

9. What is the proper representation of the “flow” of electrons in this E2 reaction?

- a)
- b)
- c)
- d)
10. Which of the mechanistic steps shown is NOT a reasonable one in the mechanism to describe the formation of 2-methyl-1-butene by dehydration of 3-methyl-2-butanol?

a)

b)

b)

d)
11. A set of three nucleophilic displacement reactions is shown below:

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CHCH}_3 & \xrightarrow{\text{NaN}_3/\text{CH}_3\text{OH}} \text{S}_{\text{N}2} \text{ reaction} \\
\text{A, } X = \text{I} & \quad \text{B, } X = \text{Br} \\
\text{C, } X = \text{OH}
\end{align*}
\]

Which reaction proceeds the fastest?

a) A
b) B
c) C

12. Use the following information to identify the reaction type.

Both reactions occur at the same rate.

Which of the following choices best represent this reaction?

a. S_{N1} 

b. S_{N2}

c. E1

d. E2

13. The reaction of RCl with CH₃CH₂OH reacts according to an S_{N1} mechanism. Which is the correct rate law expression for this reaction?

a. rate = k[RCl][CH₃CH₂OH]

b. rate = k[RCl][H₂O][CH₃CH₂OH]

c. rate = k[RCl]

d. rate = k[RCl][H₂O]
14. Draw the structures for X, Y, and Z.

\[ \text{\begin{align*}
\text{\text{C}_3\text{H}_5} & \xrightarrow{\text{NH}_3^-} \text{X} \\
\text{\text{C}_3\text{H}_5} & \xrightarrow{\text{H}_2, \text{Lindlar's Catalyst}} \text{Y} \\
\text{\text{C}_3\text{H}_5} & \xrightarrow{\text{CH}_2\text{CH}_2\text{CH}_2\text{H}_2} \text{Z}
\end{align*}} \]

For each of the following reactions, draw the major product(s) and identify the type of reaction that is taking place in each case (S_N2, E2, or combination of S_N1 and E1)?

15. \[
\text{C}_6\text{H}_5\text{C}_3\text{H}_5\text{O} \xrightarrow{\text{CH}_3\text{OH}} \text{S_N1}
\]

16. \[
\text{CH}_3\text{CH}_2\text{CH}_3\text{Cl} \xrightarrow{\text{CH}_3\text{OCH}_2\text{CH}_3, \text{CH}_3\text{CH}_2\text{OH}} \text{E2}
\]

17. \[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \xrightarrow{\text{NaOCH}_3, \text{CH}_3\text{OH}} \text{S_N2}
\]

18. \[
\text{\text{C}_6\text{H}_5}\text{Cl} + \text{H}_2\text{O} \xrightarrow{} \text{E1, S_N1}
\]
19. Name the following molecule.

4-methyl-2-pentyne

20. The two reactants shown below are combined to bring about a nucleophilic substitution reaction.

\[
\text{CH}_3 - \text{CH}_2 - \text{C} - \text{CH}_3 + \text{Cl}^- \rightarrow \]

\[
\begin{align*}
\text{H} & \\
\text{H} & \\
\text{H} & \\
\text{H} & \\
\end{align*}
\]

e. OH  
ii. H₂O  
iii. none  
iv. CH₃OH  
v. HCl  
g. Cl⁻  
j. H₃O⁺

Which letter designates the electrophilic carbon at which substitution occurs? B

Which letter corresponds to the leaving group? H

Which letter designates the nucleophile? G

21. Draw all monochlorination products you would expect to obtain from radical chlorination of butane. Use the reactivity of primary as 1.0, secondary as 3.5 and tertiary as 5.0. What would the approximate percentage of each product be?

\[
\begin{align*}
\text{Cl} & \quad 30\%  \\
\text{H} - \text{C} - \text{CH}_2 \text{CH}_2 \text{CH}_3 & \quad 70\%
\end{align*}
\]

1° (3) 3/10

2° (3.5) 7/10
22. Draw the structure of the major organic products(s) for each of the following reactions. Indicate the stereochemistry for each reaction when appropriate.
23. Write a detailed, stepwise mechanism for the following reaction. (Use curved arrows and label the initiation step, propagation step(s). Calculate $\Delta H^\circ$ for only the two propagation steps in this reaction. Draw an energy diagram. Is this reaction exothermic or endothermic.

\[
\begin{array}{c}
\text{CH}_3 \\
\text{H} - \text{C} - \text{CH}_3 + \text{Cl}_2 \xrightarrow{\text{light}} \text{Cl} - \text{C} - \text{CH}_3 + \text{HCl}
\end{array}
\]

Initiation: \[\text{Cl}_2 \rightarrow 2 \cdot \text{Cl}^-\]

\[
\text{CH}_3
\]

\[
\begin{array}{c}
\text{CH}_3 \\
\text{H} - \text{C} - \text{CH}_3 \rightarrow \text{H} - \text{C}^- + \cdot \text{C} - \text{CH}_3 \\
\end{array}
\]

$404 \quad -431 \quad -27$

\[
\text{CH}_3
\]

\[
\begin{array}{c}
\text{CH}_3 \\
\text{H}_3 - \text{C} \rightarrow \text{CH}_3 - \text{C} - \text{CH}_3 + \cdot \text{Cl}^- \\
\end{array}
\]

$243 \quad -331 \quad -88$

Exothermic

\[
-115
\]

\[
-88
\]