1. (6) Draw the best Lewis structure for the compound known as allyl isothiocyanate, one of the substances in wasabi, that tasty horseradish-like condiment served with sushi at a Japanese restaurant. The atom-atom connectivity is as follows:

```
H   H   H
H--C--C--N--C--S
   \   \   \  
    H   H   H
```

2. (4) Expand the following condensed structures to show all the covalent bonds and nonbonding pairs of electrons.

\[ \text{CH}_3\text{NHCH}_2\text{CH}_3 \]

\[ (\text{CH}_3)_3\text{CCCH}_2\text{OH} \]
3. (6) (a) Estimate the equilibrium constant (\(K_{eq}\)) for the following reaction:

\[
\text{CH}_3\text{OH} + \text{NH}_2^{\ominus} \rightleftharpoons \text{CH}_3\text{O}^{\ominus} + \text{NH}_3
\]

(b) If you were asked to carry out an E2 reaction where \(\text{CH}_3\text{O}^-\) was the desired base, would the treatment of methanol with \(\text{NaNH}_2\) generate the methoxide ion in a suitable amount? Explain.

4. (4) Which of the following molecules would you expect to have a dipole moment?

\[\text{CCl}_4 \quad \text{NH}_3 \quad \text{CH}_3\text{O} \text{--CH}_3 \quad \text{H}_2\text{C=}\text{CH}_2\]
5. (3) Draw a structure for each of the following compounds:

pentyl bromide

isopropyl alcohol

sec-butyl chloride

6. (3) Give a systematic name for each of the following molecules:

(CH₃)₂CHCH₂CH(CH₃)₂

CH₃CH₂CHClC(CH₃)₃

Br₂CH₂CH₂CH₂CH₃

7. (4) (a) Draw any hydrocarbon (a molecule containing only carbon and hydrogen!) where all the hydrogens are considered to be 1° (primary).

(b) Draw any hydrocarbon that contains all of the following types of carbons: 1°, 2°, 3°, and quaternary.
8. (2) Rank the following isomeric hydrocarbons in order of increasing boiling point:

9. (2) Rank the following compounds in order of decreasing solubility in water:

10. (6) For n-pentane:

   (a) Draw a Newman projection looking down the C2–C3 bond of the most stable conformation.

   (b) Draw a Newman projection looking down the C2–C3 bond of the least stable conformation.
11. (4) Concisely draw cyclohexane in a chair conformation along with all twelve of the hydrogens. Label each hydrogen as axial or equatorial.

12. (4) The two chair conformations of \textit{trans}-1,2-dichlorocyclohexane have different stabilities. Draw both conformations and indicate the one that is more stable.

13. (2) Draw and name the only molecule with formula C$_5$H$_{10}$ with \textit{E} configuration.
14. (2) For which reaction will $\Delta S^\circ$ be more significant?

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

15. (4) Write the correct mechanism for the reaction below:

\[
\begin{align*}
\text{C} = \text{C} & \quad +\quad \text{H-X} \quad \rightarrow\quad \text{C} - \text{C} \\
\end{align*}
\]

16. (2) Rank the carbocations below in order of stability (use 1 for the most stable and 3 for the least):

\[
\begin{align*}
1 & \quad \text{for the most stable} \\
3 & \quad \text{for the least} \\
\end{align*}
\]

\[
\begin{align*}
\text{1} & \quad \text{2} & \quad \text{3} \\
\end{align*}
\]

17. (2) According to the Hammond postulate, the _____________ will be more similar in structure to the species that it is _____________ similar to in energy.

A. starting material and less
B. transition state and more
C. product and less
D. none of the above
18. (10) Draw the major product(s) or the best starting material:

- **First Reaction:**
  - **Reagents:** CH\(_2\)Cl\(_2\), Cl\(_2\)
  - **Products:** (CH\(_3\))\(_2\)C=C(CH\(_3\))\(_2\)

- **Second Reaction:**
  - **Reagents:** H\(_2\), Pd/C
  - **Products:** C\(_5\)H\(_10\)

- **Third Reaction:**
  - **Reagents:** BH\(_3\), H\(_2\)O\(_2\), NaOH, H\(_2\)O
  - **Products:** CH\(_3\)CH(CH\(_3\))\(_2\)

- **Fourth Reaction:**
  - **Reagents:** H\(_2\)O\(_2\), NaBH\(_4\), H\(_2\)O
  - **Products:** CH\(_3\)CHCH\(_2\)CH\(_3\)

- **Fifth Reaction:**
  - **Reagents:** Hg(OAc)\(_2\), H\(_2\)O, THF
  - **Products:** CH\(_3\)CHCH\(_2\)CH\(_3\)
19. (2) What is the sole and sufficient requirement for an object to be chiral?

20. (2) Indicate for each chirality center whether $R$ or $S$.

21. (2) For the following pairs of compounds, indicate whether they are identical, enantiomers, or diastereomers.

22. (4) Draw the major product for each of the following reactions, being sure to indicate any relevant stereochemistry where important:
23. (6) Draw the major product for each of the following reactions, being sure to indicate any relevant stereochemistry where appropriate:

\[
\begin{align*}
\text{Br}_2 & \quad \text{H}_3\text{C} - \text{CH}_3 \\
\text{CH}_2\text{Cl}_2 & \quad \text{Br}_2 \\
(\text{electrophilic} & \quad \text{addition!})
\end{align*}
\]

24. (4) Draw the major product or best starting material for each of the following reactions. Indicate any stereochemistry where appropriate.

\[
\begin{align*}
1 \text{ H}_3\text{C} - \text{C} & \equiv \text{C} - \text{CH}_3 \\
& \quad \text{CH}_2\text{Cl}_2 \\
1 \text{ Br}_2 & \quad \text{H}_2\text{O}_2, \text{H}_2\text{O}
\end{align*}
\]
25. (6) Starting with ethyne, how could you make 1-bromobutane? You can use any organic or inorganic reagents. Note: it can be accomplished in three steps.

\[
\text{HC≡CH} \quad \xrightarrow{?} \quad \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}
\]

26. (2) Which of the following compounds have delocalized electrons? You must show your work/reasoning!

\[
\text{CH}_3\text{OCH}≡\text{CH}_2
\]

27. (2) Predict the site(s) on the following compound where the reaction can occur.

\[
\text{CH}_3 + \text{Br}^-
\]
28. (3) Draw the dipolar resonance form for aniline where the N is formally positively charged and the ring carbon explicitly indicated is formally negatively charged.

\[
\begin{align*}
\text{NH}_2 & \\
\text{C} & \\
\text{H} & \\
\end{align*}
\]

29. (2) Draw and name the configurational isomers for 2-methyl-2,4-hexadiene.

30. (5) Draw the major product for each of the following reactions. Indicate any relevant stereochemistry where important.

\[
\begin{align*}
\text{CH}_3 & \\
\end{align*}
\]

1 HCl

\[
\begin{align*}
\text{H}_3\text{C} & \\
\end{align*}
\]

1 HCl, high temp. conditions
31. (4) (a) What is the product from the reaction of 1,3-butadiene with cis-1,2-dichloroethene?

(b) The product in part (a) contains chirality centers, yet it is not optically active. Explain.

32. (2) How many different monochloro products can be obtained from the free-radical chlorination of 2,2,3-trimethylpentane? Ignore stereoisomers.

33. (4) Draw the major product(s) for the following reaction, indicating any stereochemistry in the product(s) where appropriate.
34. (4) Draw the major product(s) for the following reactions.

\[
\text{BrCH}_2\text{–} \xrightarrow{\text{CH}_3\text{O}^-} \text{CH}_3\text{O} \quad \text{(S}_2\text{ conditions)}
\]

\[
(\text{CH}_3)_3\text{CBr} \xrightarrow{\text{H}_2\text{O}} \quad \text{(S}_1\text{ conditions)}
\]

35. (3) Rank the following alkyl halides in decreasing order of reactivity in an 
\(\text{S}_2\) reaction. Use 1 for the most reactive and 4 for the least reactive.

1-chlorobutane

2-chloro-2-methylpropane

2-chlorobutane

1-bromobutane

36. (3) All other variables being equal, a \(\text{S}_2\) reaction between an alkyl halide and 
an anionic nucleophile proceeds faster in a polar aprotic solvent versus a polar 
protic one. Briefly explain why this is so.
37. (4) Give the major elimination product from an E1 reaction of the following alkyl halides:

\[ \text{Br} \]

\[ \text{CH}_3\text{CH}_2\text{CHCHCH}_3 \]

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

38. (3) Use a Newman projection to show a suitable conformation that 2-bromobutane can eliminate HBr from in an E2 reaction to give \textit{trans}-2-butene as the major product.

39. (3) Why does the following alkyl halide \textbf{not} undergo an E2 reaction?