1. (16) For each of the following compounds indicate how many signals would appear in both its carbon and proton NMR spectra?

- H: 4 signals  
  C: 4 signals
- H: 3 signals  
  C: 3 signals
- H: 1 signal
  C: 3 signal
- H: 2 signals
  C: 2 signals

2. (19) Show reasonable products from the following reactions. Draw the stereochemistry of the product(s) as appropriate.

- a) 

- b) 

- c) 

3. (5) Which of the following compounds has two signals in its carbon NMR spectrum?

   a) CH₃CH(OH)CH₃  
   b) CH₃CH₂CH(Br)CH₃  
   c) HOCH₂CH₂OH  
   d) (CH₃)₂CHCH₂OH

4. (3.5) True or False. The molecule shown would have only 4 signals in its proton NMR spectrum.

5. (3.5) True or False. A position further to the right in an NMR spectrum is called downfield.
6. (5) Give 2 important requirements for an internal NMR standard like TMS.
- unreactive
- volatile
- large number of identical hydrogens

7. (5) The two general types of molecule required for a Diels-Alder reaction are called?
- conjugated diene and a dienophile

8. (3) A sharp, medium strength peak at ~1640 and no peak at 1500 cm⁻¹ in an IR spectrum would indicate?
   A. A carboxylic acid
   B. An alkene
   C. An aromatic ring
   D. An amine
   E. A ketone

9. (4) Circle the one molecule that does not have conjugated double bonds.

   ![Molecules](image)

   (A) ![Molecule A](image)
   (B) ![Molecule B](image)
   (C) ![Molecule C](image)
   (D) ![Molecule D](image)

10. (4) A sharp, medium strength peak at ~3300 cm⁻¹ in an IR spectrum would indicate?
    A. A carboxylic acid
    B. An amine
    C. An aromatic ring
    D. A cyclohexene
    E. An alcohol

11. (6) Which of the following gives two products upon E2 reaction with KOH?

   ![Compounds](image)

   a) ![Compound A](image)
   b) ![Compound B](image)
   c) ![Compound C](image)
   d) ![Compound D](image)

   this one

12. (10) For each of the following compounds, indicate by yes or no whether or not they contain a conjugated system.

   ![Compounds](image)

   a) yes
   b) yes
   c) yes
   d) no

13. (6) State, in each of the following, whether or not the dienes shown would undergo the Diels-Alder reaction.

   ![Dienes](image)

   a) yes
   b) no
14. (4.5) What splitting pattern (singlet, doublet, etc.) is observed in the $^1\text{H}$-NMR spectrum for a hydrogen on the indicated carbon?

triplet

15. (7.5) At what locations (give numbers) would you expect to see peaks in the IR spectrum of the following molecule?

- CH str. alkyl at 2900 cm$^{-1}$
- CH str. aromatic at 3100 cm$^{-1}$
- CH bend aromatic at 800 cm$^{-1}$
- C=O str. at 1700 cm$^{-1}$
- C=C str. aromatic at 1500 & 1600 cm$^{-1}$

16. (6) Considering only the absorptions in the IR spectrum that we have discussed in class, it would be easy to tell the two molecules in each pair apart - except for one pair. Which pair would not be so easy to distinguish? Briefly, but clearly, explain why not?

<table>
<thead>
<tr>
<th></th>
<th>(A)</th>
<th>(B)</th>
<th>(C)</th>
<th>(D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H$_2$N +</td>
<td>OH +</td>
<td>O +</td>
<td>COOH +</td>
</tr>
</tbody>
</table>

In A, each molecule would exhibit 2 sharp peaks at ~3300 cm$^{-1}$ and alkyl CH str. At 2900 cm$^{-1}$. In all of the other cases there would be at least 1 peak in one molecule which would allow clear distinction.

17. (6) An unknown compound having the molecular formula C$_{10}$H$_{12}$O and an IR peak at 1710 cm$^{-1}$ gave the following $^1\text{H}$ NMR spectrum. Choose the correct structure from below.

$\delta$ 1.6, singlet, 3H
$\delta$ 2.3, singlet, 2H
$\delta$ 1.8, singlet, 3H
$\delta$ 7.2 & 7.6, 2 doublets, 4H

this one

18. (5) The molecule shown may be prepared by a Diels-Alder reaction. Write the structures of the diene and dienophile necessary to do so.

CO$_2$Et

this one

EtOOC
19. (6) Which of the following molecules displays 3 signals in its $^{13}$C NMR spectrum?

![Molecules](image)

20. (5) Which of the protons in the compound shown appears as a doublet in the $^1$H NMR spectrum?

$$\text{H}_3\text{C}-\text{CH}_2-\text{C}==\text{CH}_3$$

- a) F
- b) H
- c) C
- d) d

21. (5) Which of the answers below describes the products of the elimination reaction shown?

![Reaction](image)

- a) I only
- b) II only
- c) I (major), II (minor)
- d) II (major), I (minor)

22. (4) A base such as is shown below (molecule Y) [as opposed to e.g. MeO$^-$] is often useful for E2 reactions because:

- A. The methyl groups in Y stabilize the carbocation intermediate
- B. MeO$^-$ is too small to cause elimination
- C. The molecule Y is usually too bulky to undergo $S_{N2}$
- D. The bulk of Y makes it a better nucleophile

23. (4) There are two key **general** areas in an infrared spectrum - name them.

**The functional group region and the fingerprint region**

24. (4) True or False. The compound shown would have 2 larger peaks and 3 smaller peaks in its C-13 NMR spectrum.

![Compounds](image)

25. (3) A strong peak at ~2900 cm$^{-1}$ in an IR spectrum would indicate?

- A. A carboxylic acid
- B. An alkane
- C. An aromatic ring
- D. An alkene
- E. A ketone