ACS Review Spectroscopy

1. Which of the following has only a single peak in its proton NMR spectrum?
   
   I. (CH₃)₃CCl   II. (CH₃)₂C=C(CH₃)₂   III. C=C
   
   A. only I
   B. only II
   C. I and II
   D. I, II, and III

2. A compound is either cyclononane or cyclodecane. Which of the following is the most useful technique in identifying the compound?
   
   A. IR spectroscopy
   B. mass spectrometry
   C. proton NMR
   D. C-13 NMR

3. Which of the following gives the furthest downfield shift from TMS in its proton NMR spectrum?
   
   A. (CH₃)₄C
   B. (CH₃)₃N
   C. (CH₃)₂O
   D. CH₃F

4. Which of the following gives the furthest downfield shift from TMS in its proton NMR spectrum?
   
   A. CCl₄
   B. CHCl₃
   C. CH₂Cl₂
   D. CH₂Cl

5. How many different sets of equivalent protons are there for para-xylene (1,4-dimethylbenzene)?
   
   A. only 1
   B. two
   C. three
   D. four

6. How many different sets of equivalent protons are there in the following compound?
   
   A. three
   B. four
   C. five
   D. six

7. What is the multiplicity of the methylene hydrogens indicated in the proton NMR of the following compound?
8. What is the multiplicity of the methylene hydrogens indicated in the proton NMR of the following compound?

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

A. singlet  
B. doublet  
C. triplet  
D. quartet

9. What are the approximate intensities of the four lines in the quartet from the proton NMR of diethyl ether, \((\text{CH}_3\text{CH}_2)_2\text{O}\)? (Assume distortion of the quartet is minimal.)

A. 1:1:1:1  
B. 1:2:2:1  
C. 2:3:3:2  
D. 1:4:4:1

10. Which compound below fits the following proton NMR data?

- triplet \(\delta 1.22 \text{ (3H)}\)
- singlet \(\delta 1.98 \text{ (3H)}\)
- quartet \(\delta 4.07 \text{ (2H)}\)

A) \(\text{CH}_3\text{CH}_2\text{COCH}_3\)  
B) \(\text{CH}_3\text{COCH}_2\text{CH}_3\)  
C) \(\text{H}_2\text{C}==\text{C} \begin{array}{c} \text{OCH}_3 \\ \text{CH}_3 \end{array}\)  
D) \(\text{CH}_3\text{CCH}_2\text{OCH}_3\)
11. The proton NMR of 1,1-dibromoethane would appear as a:
   A. downfield doublet and upfield quartet
   B. downfield quartet and upfield doublet
   C. downfield doublet and upfield triplet
   D. downfield triplet and upfield doublet

12. The proton NMR spectrum of a compound gives a singlet at δ 2.10 and δ 2.56 in a ratio of 3:2, respectively. Which compound below is the best match for the spectrum?
   A) CH₃OCH₂CH₂OCH₃
   B) CH₃OCCH₂CH₂COCH₃
   C) CH₃CCH₂CH₂CCH₃
   D) CH₃CH₂C—CCH₂CH₃

13. The proton NMR of a compound, C₈H₉ClO, has the following peaks. Which compound below best fits the data?

<table>
<thead>
<tr>
<th>Peak Type</th>
<th>δ  Value</th>
<th>Multiplicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>broad singlet</td>
<td>2.41</td>
<td>1H</td>
</tr>
<tr>
<td>triplet</td>
<td>2.75</td>
<td>2H</td>
</tr>
<tr>
<td>triplet</td>
<td>3.69</td>
<td>2H</td>
</tr>
<tr>
<td>doublet</td>
<td>7.02</td>
<td>2H</td>
</tr>
<tr>
<td>doublet</td>
<td>7.50</td>
<td>2H</td>
</tr>
</tbody>
</table>

   A. I
   B. II
   C. III
   D. IV
14. The proton NMR spectrum of a compound, C\textsubscript{3}H\textsubscript{6}Cl\textsubscript{2}, has a pentet at $\delta$ 2.19 and a triplet at $\delta$ 3.72 in a 1:2 ratio, respectively. Which compound below best matches the data?

A) CH\textsubscript{3}CH\textsubscript{2}CHCl\textsubscript{2}  
B) ClCH\textsubscript{2}CH\textsubscript{2}CH\textsubscript{2}Cl  
C) CH\textsubscript{3}CHCH\textsubscript{2}Cl  
D) CH\textsubscript{3}CCH\textsubscript{3}  

15. A large doublet and a small septet pattern in $^1$H NMR is usually indicative of a(an):

A. ethyl group  
B. propyl group  
C. isopropyl group  
D. phenyl group  

16. A triplet and quartet pattern in $^1$H NMR often indicates the presence of a(an):

A. ethyl group  
B. propyl group  
C. isopropyl group  
D. phenyl group  

17. Which of the following describes the spin-spin splitting of the indicated H in the $^1$H NMR of the compound shown below?

A. singlet  
B. doublet of doublets  
C. triplet  
D. doublet of triplets  

18. Identify the C\textsubscript{4}H\textsubscript{6}Cl isomer given the following proton NMR data:

doublet $\delta$ 1.04 (6H)
multiplet $\delta$ 1.95 (1H)
doublet $\delta$ 3.35 (2H)

A) $(\text{CH}_3)_3\text{CCl}$

B) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$

C) $\text{CH}_3\text{CH}_2\text{CHCH}_3$

D) $(\text{CH}_3)_2\text{CHCH}_2\text{Cl}$

A. A
B. B
C. C
D. D

19. What region of the electromagnetic spectrum is used in nuclear magnetic resonance spectroscopy?
   A. radio wave
   B. X-ray
   C. ultraviolet
   D. microwave

20. Which of the compounds below fit the following C-13 NMR?

   A. para-dichlorobenzene
   B. meta-dichlorobenzene
   C. ortho-dichlorobenzene
   D. chlorobenzene

21. Identify which one of the following isomers of C$_6$H$_{14}$ has the C-13 NMR below.
22. Which one of the following isomers of C₈H₁₈ has only two peaks in its \(^{13}\)C NMR?

A) CH₃(CH₂)₆CH₃
B) CH₃CHCH₂CH₂CHCH₃
C) CH₃CHCHCHCH₃
D) (CH₃)₃CC(CH₃)₃

A. A  
B. B  
C. C  
D. D

23. In infrared spectroscopy, absorption of electromagnetic radiation results in transitions between _________ energy levels.

A. vibrational  
B. electronic  
C. rotational  
D. nuclear

24. In proton NMR, \(^1\)H-\(^1\)H spin-spin splitting is common. Why is there no comparable \(^{13}\)C-\(^{13}\)C spin-spin splitting in C-13 NMR?

A. C-13 has a nuclear spin of zero.  
B. The probability of two C-13 nuclei being next to each other in a compound is very low.  
C. The coupling constant is very small-too small to be observed.  
D. There is \(^{13}\)C-\(^{13}\)C spin-spin splitting but because of the complex splitting patterns decoupling techniques are used to suppress it.

25. What is the multiplicity of the indicated carbon in an off-resonance decoupled C-13 NMR spectrum? (In off-resonance decoupled spectra, direct \(^{13}\)C-\(^1\)H coupling is observed.)
26. Which one of the following compounds fits the C-13 NMR spectrum shown below?

\[
\text{H}_3\text{C} - \text{CH} - \text{CH}_2 - \text{CH}_2\text{OH}
\]

A. singlet  
B. doublet  
C. quartet  
D. multiplet

27. A C-13 NMR spectrum of a compound, C\textsubscript{10}H\textsubscript{14}, has five peaks. Two peaks are in the 10-30 ppm region and the other three are in the 120-140 ppm area. Which of the following compounds fits the data?

A. A  
B. B  
C. C  
D. D

27. A C-13 NMR spectrum of a compound, C\textsubscript{10}H\textsubscript{14}, has five peaks. Two peaks are in the 10-30 ppm region and the other three are in the 120-140 ppm area. Which of the following compounds fits the data?
28. Which one of the following isomeric \( \text{C}_8\text{H}_{18} \) compounds has five peaks in its \( ^{13}\text{C} \) NMR spectrum?
A. octane
B. 2-methylheptane
C. 3-methylheptane
D. 4-methylheptane

29. Which one of the following has a \( \lambda_{\text{max}} \) in its UV-visible spectrum with the longest wavelength?

\[ \text{A)} \hspace{1cm} \text{B)} \hspace{1cm} \text{C)} \hspace{1cm} \text{D)} \]

A. A
B. B
C. C
D. D

30. The reaction shown below gave two products in a ratio of approximately 1:2. The mass spectrum of the major product has a base peak at \( m/z \) 119. The minor product gave a base peak at \( m/z \) 133. Based on the reaction given and the information on the mass spectra, which of the following is the major product?

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{Cl/AlCl}_3 \]

\[ \text{A)} \hspace{1cm} \text{B)} \hspace{1cm} \text{C)} \hspace{1cm} \text{D)} \]

A. A
B. B
C. C
D. D
31. Which of the methods below would be most useful in distinguishing between the following two compounds?

\[
\begin{align*}
&\text{H} \quad \text{CH}_3 \\
&\text{C} &= \text{C} \quad \text{and} \quad \text{C} &= \text{C} \\
&\text{H} \quad \text{CH}_3 \\
&\text{H} \quad \text{H}
\end{align*}
\]

A. UV spectroscopy  
B. C-13 NMR  
C. IR spectroscopy  
D. mass spectrometry

32. Match each steroid below with its \( \lambda_{\text{max}} \) in its UV-visible spectrum.

\[
\begin{align*}
\text{I} & \quad \text{II} & \quad \text{III} \\
& \quad \text{C}_6\text{H}_7 \\
& \quad \text{C}_6\text{H}_7 \\
& \quad \text{H} \\
\end{align*}
\]

\[
\begin{align*}
\text{I} & \quad \text{II} & \quad \text{III} \\
\text{A}) & \quad 209 \text{ nm} & \quad 241 \text{ nm} & \quad 284 \text{ nm} \\
\text{B}) & \quad 241 \text{ nm} & \quad 284 \text{ nm} & \quad 206 \text{ nm} \\
\text{C}) & \quad 284 \text{ nm} & \quad 241 \text{ nm} & \quad 206 \text{ nm} \\
\text{D}) & \quad 284 \text{ nm} & \quad 206 \text{ nm} & \quad 241 \text{ nm}
\end{align*}
\]

A. A  
B. B  
C. C  
D. D

33. Which C-C bond would most likely break and give fragments in the mass spectrum of butyl benzene?

\[
\begin{align*}
\text{CH}_2 & - \text{CH}_2 & - \text{CH}_2 & - \text{CH}_3 \\
& & & \\
1 & 2 & 3 & 4
\end{align*}
\]

A. 1  
B. 2  
C. 3  
D. 4

34. Which of the following compounds fits the proton NMR shown below?
A) $\text{CH}_3\text{CH}_2\text{CH}_2\text{COCH}_3$

B) $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$

C) $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$

D) $\text{CH}_3\text{CCH}_2\text{CH}_2\text{OCH}_3$

A. A  
B. B  
C. C  
D. D
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1. c
2. b
3. d
4. b
5. b
6. a
7. d
8. a
9. d
10. b
11. b
12. c
13. c
14. b
15. c
16. a
17. b
18. d
19. a
20. c
21. d
22. d
23. a
24. b
25. b
26. d
27. d
28. d
29. a
30. d
31. b
32. c
33. b
34. c