14. The following compound, with the formula $\text{C}_4\text{H}_8\text{O}_2$, is an ester. Give its structure and assign the chemical shift values.

![NMR Spectrogram](image)

15. The following compound is a monosubstituted aromatic hydrocarbon with the formula $\text{C}_9\text{H}_{12}$. Give its structure and assign the chemical shift values.

![NMR Spectrogram](image)
16. The following compound is a carboxylic acid which contains a bromine atom: \( \text{C}_4\text{H}_7\text{O}_2\text{Br} \). The peak at 10.97 ppm was moved onto the chart (which runs only from 0 to 8 ppm) for clarity. What is the structure of the compound?

![NMR Spectrum of C_4H_7O_2Br]

17. The following compounds are isomeric esters derived from acetic acid, each with formula \( \text{C}_3\text{H}_10\text{O}_2 \). The peaks of the spectrum have been labeled to indicate the degrees of splitting. With the first spectrum as an example, use the integral curve traced on the spectrum to calculate the number of hydrogens represented in each multiplet (pp. 113–114). The multiplets appear both on the spectrum and in the first column of the following table. The second column is obtained by dividing through by the lowest number (1.7 div). The third column is obtained by multiplying by 2 and rounding off the values. Notice that the sum of the numbers in the third column equals the number of hydrogen atoms (10) present in the formula. Often one can inspect the spectrum and visually approximate the relative numbers of hydrogen atoms, thus avoiding the more mathematical approach demonstrated in the following table. Using either method, the second spectrum yields a ratio of 1:3:6. What are the structures of the two esters?

<table>
<thead>
<tr>
<th>div</th>
<th>integral</th>
<th>ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7</td>
<td>1.0</td>
<td>2 H</td>
</tr>
<tr>
<td>2.5</td>
<td>1.47</td>
<td>3 H</td>
</tr>
<tr>
<td>1.7</td>
<td>1.0</td>
<td>2 H</td>
</tr>
<tr>
<td>2.5</td>
<td>1.47</td>
<td>3 H</td>
</tr>
</tbody>
</table>
18. The compound which gives the following NMR spectrum has the formula $\text{C}_3\text{H}_6\text{Br}_2$. Draw the structure.
19. Draw the structure of an ether with formula $\text{C}_5\text{H}_{12}\text{O}_2$ that fits the following NMR spectrum.

![NMR Spectrum of $\text{C}_5\text{H}_{12}\text{O}_2$]

20. Following are the NMR spectra of three isomeric esters with the formula $\text{C}_7\text{H}_{14}\text{O}_2$, all derived from propanoic acid. Provide a structure for each.

(a)

![NMR Spectrum of $\text{C}_7\text{H}_{14}\text{O}_2$ (a)]

(b)

![NMR Spectrum of $\text{C}_7\text{H}_{14}\text{O}_2$ (b)]
21. The two isomeric carboxylic acids which give the following NMR spectra both have the formula C$_3$H$_5$ClO$_2$. Draw their structures.
22. The following NMR spectra are of monosubstituted aromatic hydrocarbon compounds with the formula C$_{10}$H$_{14}$. Make no attempt to interpret the aromatic proton area between 7.1 and 7.3 ppm except to determine the relative number of hydrogen atoms. Draw structures for these compounds.

(a)
23. The following compound, with formula C₈H₁₁N, shows a doublet at about 3350 cm⁻¹ and bands in the range from 1600 to 1450 cm⁻¹ in the infrared spectrum. Draw its structure.

![NMR Spectrum of C₈H₁₁N](image)

24. The following compounds are isomers with formula C₁₀H₁₂O. Their infrared spectra show strong bands near 1715 cm⁻¹ and in the range from 1600 to 1450 cm⁻¹. Draw their structures.

(a)

![NMR Spectrum of C₁₀H₁₂O](image)
25. The following four NMR spectra are of isomeric monosubstituted aromatic esters with formula $C_{10}H_{12}O_2$. Make no attempt to interpret the aromatic proton areas between 7.1 and 7.4 ppm. Draw the structures of the compounds.
26. Along with the following NMR spectrum, this compound, with formula C$_5$H$_{10}$O$_2$, shows bands at 3450 cm$^{-1}$ (broad) and 1713 cm$^{-1}$ (strong) in the infrared spectrum. Draw its structure.

27. The following ester, with formula C$_5$H$_6$O$_2$, shows medium bands in the infrared spectrum at 3270 and 2118 cm$^{-1}$. Draw the structure of the compound.
28. The following compound, with formula $\text{C}_7\text{H}_{12}\text{O}_4$, shows strong absorption at 1734 cm$^{-1}$ and has several strong bands centering at about 1200 cm$^{-1}$ in the infrared spectrum. Draw its structure.