1. (10 pts) An unknown organic compound has the empirical formula C₄H₈O. Given the following spectral data, provide a structure for the unknown that agrees with the data.

**¹H NMR (ppm)**
1.09 (d, 6H, J = 7.2 Hz); 1.47 (s, 9H); 2.47 (septet, 1H, J = 7.2 Hz)

**¹³C NMR (ppm)**
19.0, 28.7, 34.9, 60.0, 177.2

Mass spectrum (m/z) 144.01 (M+)

Infra Red (cm⁻¹) 1740
2. (10 pts) A chemist produces a new pharmaceutical with the spectral characteristics given below and thinks that the new compound is one of the possibilities shown. Which structure is correct and why? Include a complete assignment of all of the given $^1$H NMR data in your answer.

$^1$H NMR (ppm) 1.66 (s, 3H); 2.16 (s, 3H); 2.30 (s, 3H); 3.00 (d, 2H); 5.70 (t, 1H); 7.05 (m, 4H)

$^{13}$C NMR (ppm) 18.37, 21.35, 25.99, 37.30, 127.69, 129.12, 134.17, 136.11, 139.57, 140.94, 197.46

IR (cm$^{-1}$) 1720, 790

![Chemical Structures]

3. (10 pts) Draw the approximate $^{13}$C NMR spectrum (including the scale) for the molecule below. Include approximate chemical shifts and indicate which signal corresponds to which carbon(s) in the molecule.

![Chemical Structure]
4. (10 pts) An unknown organic compound has the molecular formula C_{11}H_{16}O and, in the mass spectrum, M⁺ = 164.00. Given the following ¹H and ¹³C data, give the structure of the unknown and assign all of the ¹H and ¹³C signals to your structure.

¹H NMR (ppm) 1.12 (d, 6H, J = 7.1 Hz); 1.34 (t, 3H, J = 7.0 Hz); 2.80 (septet, 1H, J = 7.1 Hz); 3.87 (q, 2H, J = 7.0 Hz); 6.88 (m, 4H)

¹³C NMR (ppm) 15.20, 24.08, 33.58, 64.10, 115.41, 125.10, 143.62, 159.82

Answer:
5. (10 pts) You are given two unlabelled bottles each containing a colorless solid. One bottle contains 2-acetoxy-benzoic acid (aspirin), the other contains 4-acetoxy-benzoic acid (poisonous). Explain how you would use any of the spectroscopic techniques discussed in 3720 to tell the two apart.

\[
\text{2-Acetoxy-benzoic acid} \quad \text{4-Acetoxy-benzoic acid}
\]

6. (6 pts) Sodium borohydride reduction of acetophenone (methylphenylketone, PhCOCH₃) in methanol gives a product with the molecular formula C₈H₁₀O and the following NMR data. Give the structure of the product and match the \( ^1H \text{NMR} \) data to that structure.

\[
\begin{align*}
\text{\(^1H \text{NMR} \) (ppm)} & \quad 1.41 \text{ (d, 3H, } J = 7.0 \text{ Hz); 4.75 \text{ (q, 1H, } J = 7.0 \text{ Hz); 7.17 \text{ (m, 5H)}} \\
\text{\(^{13}C \text{NMR} \) (ppm)} & \quad 25.0, 69.9, 125.4, 127.0, 128.2, 146.0
\end{align*}
\]
7. (10 pts) Give the products $A$ and $B$ from the following sequence and then give a complete mechanism (using arrows to show bonds forming and breaking) for the formation of $A$. 

\[
\text{MgBr} \quad \text{OCH}_3 \quad \text{THF} \quad \overset{2}{\text{\longrightarrow}} \quad \overset{\text{H}_2\text{O}^+}{\text{\longrightarrow}}
\]

\begin{align*}
A & \quad & B
\end{align*}
8. (15 pts) Give the major organic products from each of the following reactions. When there is more than one step, a product from each is expected.

a. 

\[
\begin{align*}
\text{1. } & m\text{-CPBA} \\
\text{2. } & \text{CH}_3\text{MgBr} \\
\text{3. } & \text{H}_3\text{O}^+ 
\end{align*}
\]

b. 

\[
\begin{align*}
\text{1. } & 2\text{ CH}_3\text{Li, THF} \\
\text{2. } & \text{H}_3\text{O}^+ 
\end{align*}
\]

c. 

\[
\begin{align*}
\text{1. } & \text{LiAlH}_4, \text{ether} \\
\text{2. } & \text{H}_3\text{O}^+ 
\end{align*}
\]

d. 

\[
\begin{align*}
\text{Zn, CH}_2\text{I}_2 \\
\text{ether} 
\end{align*}
\]

e. 

\[
\begin{align*}
\text{1. } & \text{CH}_3\text{CH}_2\text{MgBr, THF} \\
\text{2. } & \text{H}_3\text{O}^+ 
\end{align*}
\]
9. (10 pts) Show a reasonable retrosynthesis for the following alcohol that would take you back to a simple starting alcohol and a suitable ketone or ester precursor. Then show the synthesis of this molecule in the forward direction.

\[ \text{OH} \]

10. (9 pts) Give the final organic products from each of the following reactions. The spectroscopic information may be useful as clues.

1. \( \text{LiAlH}_4, \text{THF} \)
2. \( \text{H}_3\text{O}^+ \)

IR spectrum: 3200 cm\(^{-1}\)

2. \( \text{OsO}_4, \text{t-BuOOH} \)
3. \( \text{NaOH} \)

IR spectrum: 3200 cm\(^{-1}\)

4. \( \text{H}^+ \text{catalytic} \)
5. \( \text{heat} \)

\( ^{13}\text{C} \) spectrum: 30, 55 ppm