NAME:

There are 7 questions on this exam. You are allowed to use molecular models and a calculator, but no other material may be used. A periodic table is provided at the end of the exam. The exam is over at 11:15 AM.
<table>
<thead>
<tr>
<th>Question</th>
<th>Points</th>
<th>Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>49</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>250</td>
</tr>
</tbody>
</table>
1. Rank the following compounds in the trend requested. (15 points each)
   a. Rank by downfield shift in a $^1$H NMR spectrum. Consider the hydrogen that has the furthest downfield shift in each compound. The compound that has the farthest downfield shift is 1, while the compound with the least downfield shift is 5.

   ![Compound Images]

   b. Rank by number of signals in a spin decoupled $^{13}$C NMR spectrum. The compound with the least number of signals is 1, while the compound with the most number of signals is 5.

   ![Compound Images]

   c. Rank by energy of multiple bond stretch in an infrared spectrum. Consider only the multiple bonded part of each compound that shows the highest energy stretch for each compound in the IR spectrum. The compound with the highest energy stretch is 1, while the compound with the lowest energy stretch is 5.

   ![Compound Images]
2. (32) Each IR spectrum shown below corresponds to one of the ten compounds listed. Write the letter corresponding to the appropriate structure next to each IR. (The major scale bars on each spectrum correspond to 500, 1000, 1500, 2000, 3000 and 4000 cm\(^{-1}\).)

- ________
- ________
- ________
- ________
3. The MS for three alcohols with molecular formula C₄H₁₀O₁ are shown. They are either 1-butanol, 2-butanol or 2-methyl-2-propanol (all with parent m/z = 74). Draw the structure corresponding to each MS next to the appropriate MS. (4 points each)

b. Draw the structure representing the most intense peak in each MS. For the first MS this corresponds to m/z = 59, the second m/z = 56 and m/z = 45 in the third.
4. The IR and spin-decoupled $^{13}$C NMR are shown for four different compounds. The molecular formula is also given for each compound. Indicate what structure corresponds to each compound. (8 points each)

(a) $\text{C}_4\text{H}_8\text{O}_2$

(b) $\text{C}_4\text{H}_8\text{O}_1$
c. \( \text{C}_3\text{H}_6\text{O}_2 \)

d. \( \text{C}_4\text{H}_8\text{O}_4 \)
5. Indicate the preferred product for the following reactions. Assume proper work-up for each step. (7 points each)

a. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{HBr} \\
\end{align*}
\]

b. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{1) \text{TsCl, pyridine}} \\
& \quad \xrightarrow{2) \text{pyridine}} 
\end{align*}
\]

c. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{\text{H}_2\text{Cr}_2\text{O}_7, \text{pyridine}} 
\end{align*}
\]

d. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{\text{PhC}l} 
\end{align*}
\]

e. 
\[
\begin{align*}
\text{Ph-OH} & \quad \xrightarrow{1) \text{CrO}_3} \\
& \quad \xrightarrow{2) \text{CH}_3\text{OH (excess) H}^{+}} 
\end{align*}
\]

f. 
\[
\begin{align*}
\text{OH} & \quad \xrightarrow{\text{PBr}_3} 
\end{align*}
\]

g. 
\[
\begin{align*}
\text{HOH} & \quad \xrightarrow{\text{NaIO}_4} 
\end{align*}
\]
6. The $^1$H NMR of five isomers with molecular formula $C_6H_{12}O_2$ are shown. Indicate the structure that corresponds to each $^1$H NMR. The integration for each spectrum is indicated. (8 points each)

a.

b. There are two overlapping peaks. There is a doublet at ~1.2 ppm (integrates to 6) and a triplet at ~1.1 ppm (integrates to 3).
e. The peak at 3.8 ppm disappears when sample is mixed with D$_2$O.
A combustion analysis was performed on an unknown compound A and it was determined that it contained nine carbons and eleven hydrogens in its molecular formula. Any other elements, however, were not tested so it is unknown what else it might contain. The mass spectrum for compound A determined the parent molecular ion peak to have m/z of 154. The MS and 1H NMR for A are shown on the following page. (In the 1H NMR for A the peak at 7.11 ppm integrates to 1 and is a triplet, while the peak at 7.04 ppm integrates to 2 and is a doublet. The peak at 1.5 ppm is due to a water impurity in the sample – not part of the compound). Compound A was then reacted with NaOH to generate compound B. Compound B was then reacted to generate compound C. The parent molecular ion peak for compound C was determined to be m/z = 145. The IR for compound C is shown. Indicate the structures for compounds A, B and C and list the reagents required to synthesize compound C from B.

\[
\text{Compound A} \xrightarrow{\text{NaOH}} \text{Compound B} \xrightarrow{?} \text{Compound C}
\]