CHEM 222 - ORGANIC CHEMISTRY II
MIDTERM EXAMINATION

INSTRUCTIONS:  PLEASE READ THIS PAGE WHILE WAITING TO START YOUR EXAM.

This test paper includes 4 pages (both sides) including a periodic table with electronegativities and a page of potentially useful information. Check that your paper is complete. You can remove the last page if you wish. Model kits and calculators are permitted; cell phones and electronic dictionaries are not allowed. You have 70 minutes to complete the test. Read through the whole test quickly before starting. GOOD LUCK.

LAST NAME: _____________________  FIRST NAME: _____________________
STUDENT NUMBER: ________________

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Mark breakdown:

Page 2.          / 13
Page 3.          / 12
Page 4.          /  6
Page 5.          / 10

TOTAL:             / 40  (maximum grade $\frac{41}{40}$)

PERCENT:          %

EARNED toward
FINAL GRADE:      / 15
# 1. (6 marks) TRUE or FALSE? Circle T or F to describe the following statements.

T / F If a substance appears green, it likely absorbs in the orange region of the spectrum.

T / F If a carbonyl absorption band appears in a substance’s IR spectrum at <1700 cm⁻¹, it suggests that the C=O bond in the substance is somewhat stronger than the C=O in a typical ketone.

T / F Thiols are more acidic than alcohols because sulfur atoms are larger than oxygen atoms.

T / F Mass spectrometry allows us to determine the molecular weight and the mass of some fragments of a compound.

T / F The stronger the NMR spectrometer’s magnet, the lower the energy of radio waves needed to cause protons to “flip” their spins.

T / F Grignard reagents are best prepared using a protic solvent such as ethanol.

# 2. (2 marks) Which of the following reagents would be best to convert ethanol to chloroethane in one step?

a) PCC  
b) NaCl  
c) TsCl  
d) SOCl₂  
e) Cl₂ / hν

# 3. (2 marks) What is the product of the following reaction?

\[
\begin{array}{c}
\text{CH₃OCH₂CH₂CH₂CH₂OH} \\
\text{CH₃OH}
\end{array}
\]

a) I  
b) II  
c) III  
d) IV  
e) V

# 4. (3 marks) What is (are) the major product(s) from the following reaction sequence?

\[
\begin{array}{c}
\text{H₃CCH₂CH₂C} \\
\text{OH}
\end{array}
\xrightarrow{1.) \text{PBr₃, pyridine}}
\xrightarrow{2.) \text{NaCN}}
\]

a) I  
b) II  
c) III  
d) IV  
e) I and II  
f) III and IV
# 5. (2 marks) Which of the following is/are true about the mass spectrum of 1-bromobutane?
   a) Peaks of approximately equal intensity are observed at m/z 136 and 138.
   b) The major fragmentation occurs by cleavage of the C-Br bond.
   c) The most intense peak occurs at m/z 43.
   d) both a and b
   e) both a and c
   f) all of the above (a, b and c)

# 6. (2 marks) What compound results when cyclopentanol undergoes oxidation with chromic acid?
   a) cyclopentanone
   b) cyclopentanal
   c) cyclopentanoic acid
   d) cyclopentene
   e) 1,2-cyclopentanediol

# 7. (2 marks) Which of the following methyl groups would be most deshielded in a $^1$H NMR experiment?
   a) I
   b) II
   c) III
   d) IV
   e) V

# 8. (2 marks) Which of the following compounds absorbs the longest wavelengths in the UV/Vis region?
   a) I
   b) II
   c) III
   d) IV
   f) V

# 9. (4 marks) Which of the following sequences of reactions would work best to convert cyclohexene oxide (shown at right) into propylcyclohexane?
   a) (1) CH₃C≡CNa (2) H₃O⁺
   b) (1) CH₃CH₂CH₂MgBr (2) H₂SO₄, Δ (3) H₂, Pt
   c) (1) H₂O⁺ (2) CH₃C≡CNa
   d) (1) CH₃CH₂CH₂Li (2) HBr
   e) (1) H₃PO₄, Δ (2) CH₃CH₂CH₂MgBr (3) H₃O⁺
# 10. (6 Marks) Provide a step-by-step mechanism to explain how THF undergoes the following reaction in the presence of excess hydrogen bromide:

\[
\text{\begin{tikzpicture}
  \node [molecule, draw=black, fill=white] (a) at (0,0) {O};
  \node [molecule, draw=black, fill=white] (b) at (1,1) {HBr};
  \node [molecule, draw=black, fill=white] (c) at (2,2) {CH}_2\text{CH}_2\text{CH}_2\text{CH}_2 \text{Br}
  \end{tikzpicture}} \quad \text{heat} \quad \text{\begin{tikzpicture}
  \node [molecule, draw=black, fill=white] (d) at (0,0) {O};
  \node [molecule, draw=black, fill=white] (e) at (1,1) {HBr};
  \node [molecule, draw=black, fill=white] (f) at (2,2) {CH}_2\text{CH}_2\text{CH}_2\text{CH}_2 \text{Br}
  \end{tikzpicture}}
\]
# 11. (10 marks) Deduce the identity of the compound from the following experimental data. In the tables below, provide a point-form summary of the information you learned from each type of experimental data.

The compound has molecular formula C8H13Br, and it is one of the following five compounds:

- a) CH3CHBrCCC(CH3)3
- b) HCCCH2C(CH3)2CH2CH2Br
- c) 3-bromo-1,2-dimethylcyclohexene
- d) 4-bromo-1,2,4-trimethylcyclopentene
- e) BrCH2CH2CCC(CH3)3

Data:

- IR (selected peak positions in cm⁻¹): 2950, 2150
- ¹H NMR (δ, multiplicity, integral): 3.5 (t, 2H), 1.8 (t, 2H), 0.9 (s, 9H)
- ¹³C NMR: 6 signals

<table>
<thead>
<tr>
<th>Formula</th>
<th>IR data</th>
<th>¹³C NMR data</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

¹H NMR data
EXTRA SPACE FOR ROUGH WORK
# POTENTIALLY USEFUL INFORMATION

## TABLE OF $pK_a$ VALUES

<table>
<thead>
<tr>
<th>Compound</th>
<th>$pK_a$</th>
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<tbody>
<tr>
<td>CH$_3$CH$_2$CH$_2$CH$_3$</td>
<td>&gt;51</td>
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<tr>
<td>CH$_4$</td>
<td>51</td>
</tr>
<tr>
<td>H$_2$C=CH$_2$</td>
<td>44</td>
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<tr>
<td>CH$_3$NH$_2$</td>
<td>40</td>
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<tr>
<td>NH$_3$</td>
<td>38</td>
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<tr>
<td>HCC=CH</td>
<td>25</td>
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<tr>
<td>(CH$_3$)$_3$COH</td>
<td>19</td>
</tr>
<tr>
<td>CH$_3$CH$_2$OH</td>
<td>17</td>
</tr>
<tr>
<td>CH$_3$OH</td>
<td>15.5</td>
</tr>
<tr>
<td>H$_2$O</td>
<td>15.7</td>
</tr>
<tr>
<td>RNH$_3^+$</td>
<td>9</td>
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<tr>
<td>H$_2$CO$_3$</td>
<td>6.4</td>
</tr>
<tr>
<td>CH$_3$C$^{18}$OH</td>
<td>4.7</td>
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<tr>
<td>HF</td>
<td>3.2</td>
</tr>
<tr>
<td>CH$_3$CH$_2$OH$_2^+$</td>
<td>-2.4</td>
</tr>
<tr>
<td>H$_2$SO$_4$</td>
<td>-5.2</td>
</tr>
<tr>
<td>HCl</td>
<td>-7</td>
</tr>
<tr>
<td>HI</td>
<td>-9</td>
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</table>

## SELECTED SPECTROSCOPIC DATA

<table>
<thead>
<tr>
<th>Type of bond</th>
<th>Wavenumber (cm$^{-1}$)</th>
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<tbody>
<tr>
<td>C≡N</td>
<td>2260–2220</td>
</tr>
<tr>
<td>C≡C</td>
<td>2260–2100</td>
</tr>
<tr>
<td>C=C</td>
<td>1680–1600</td>
</tr>
<tr>
<td>C=N</td>
<td>1650–1550</td>
</tr>
<tr>
<td>C=O</td>
<td>~1600 and ~1500–1430</td>
</tr>
<tr>
<td>C—O</td>
<td>1780–1650</td>
</tr>
<tr>
<td>C—O</td>
<td>1250–1050</td>
</tr>
<tr>
<td>C—N</td>
<td>1230–1020</td>
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<tr>
<td>O—H (alcohol)</td>
<td>3650–3200</td>
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<tr>
<td>O—H (carboxylic acid)</td>
<td>3300–2500</td>
</tr>
<tr>
<td>N—H</td>
<td>3500–3300</td>
</tr>
<tr>
<td>C—H</td>
<td>3300–2700</td>
</tr>
</tbody>
</table>