**YOU ARE NOT ALLOWED TO TAKE SPARE COPIES OF THIS EXAM FROM THE TESTING ROOM**

- PRINT YOUR NAME ON EACH PAGE!
- READ THE DIRECTIONS CAREFULLY!
- USE BLANK PAGES AS SCRATCH PAPER
- work on blank pages will not be graded...
- WRITE CLEARLY!
- MOLECULAR MODELS ARE ALLOWED
- DO NOT USE RED INK
- DON'T CHEAT, USE COMMON SENSE!

<table>
<thead>
<tr>
<th>H</th>
<th>He</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li Be B N O F Ne</td>
<td></td>
</tr>
<tr>
<td>Na Mg Al Si P S Cl Ar</td>
<td></td>
</tr>
<tr>
<td>K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr</td>
<td></td>
</tr>
<tr>
<td>Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe</td>
<td></td>
</tr>
<tr>
<td>Cs Ba Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn</td>
<td></td>
</tr>
</tbody>
</table>

Interaction Energies, kcal/mol

<table>
<thead>
<tr>
<th>Eclipsing</th>
<th>Gauche</th>
</tr>
</thead>
<tbody>
<tr>
<td>H/H ~1.0</td>
<td>Me/Me ~0.9</td>
</tr>
<tr>
<td>H/Me ~1.4</td>
<td>Et/Me ~0.95</td>
</tr>
<tr>
<td>Me/Me ~2.6</td>
<td>i-Pr/Me ~1.1</td>
</tr>
<tr>
<td>Me/Et ~2.7</td>
<td>t-Bu/Me ~2.7</td>
</tr>
</tbody>
</table>

Infrared Correlation Chart

- O-H 3200–3300 broad
- C=O 1700–1730
- C–H 3000–3100
- N-H 3300

NMR Correlation Charts

- O–CH₃ 122-130
- C–H 6–8.5
Question 1 (13 pts). Give the IUPAC name for the following compound. Be sure to use cis/trans, E/Z or R/S where appropriate.

![Chemical Structure]

Extra credit question (5 pts). β-carotene is synthesized using which reaction?
- Clemmenson
- Grignard
- Wittig
- Aldol

Question 2 (22 pts). Rank in order of increasing rate of electrophilic aromatic substitution at the carbons indicated by the arrows. Give a BRIEF explanation.

![Chemical Structure with Arrows]

slowest <  < fastest
Question 3 (32 pts.) Provide the missing major organic products or reagents/conditions as appropriate, you can IGNORE stereochemistry in these problems

a) \[
\begin{align*}
&\text{NO}_2
\end{align*}
\] \\
\[ \xrightarrow{1. \text{H}_2/\text{Pd/C}} \]
\[ \xrightarrow{2. \text{SO}_3/\text{H}_2\text{SO}_4} \]

b) \[
\begin{align*}
&\text{H}_2\text{N-CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CO}^\ddagger \\
\end{align*}
\] \\
\[ \xrightarrow{\text{HCl (cat.)}} \] (cyclization reaction)

c) \[
\begin{align*}
&\text{\text{C}_6\text{H}_5-\text{C}=\text{O} \\
\end{align*}
\] \\
\[ \rightarrow \]

d) \[
\begin{align*}
&\text{O-CH}_2-\text{O-CH}_2-\text{C}=\text{O} \\
\end{align*}
\] \\
\[ \xrightarrow{1. \text{PhMgBr}} \]
\[ \xrightarrow{2. \text{Zn(Hg)/HCl/H}_2\text{O}} \]

Question 4 (16 pts.) IN THE BOXES, give the missing reagents/conditions or structures, as required, to complete the following Stork (enamine) alkylation of cyclopentanone

\[
\begin{align*}
&\text{give reagents} \\
&\text{give reagents} \\
&\text{give structure} \\
&\text{give reagents} \\
\end{align*}
\]
Question 5 (20 pts.) Synthesize the (target) molecules on the right from the starting molecules on the left. This cannot be done in one reaction. Give reagents and conditions and the intermediate molecules at each step. Do not show any mechanisms or transient intermediates.
Question 6 (20 pts.) Synthesize the (target) molecule on the right from the starting molecule the left. This can not be done in one reaction. Give reagents and conditions and the intermediate molecules at each step. Do not show any mechanisms or transient intermediates.
Question 7 (32 pts.) For the following TWO reactions a) and b):

1) Give complete curved arrow-pushing mechanisms
2) Indicate the lewis acid/base for each INTERmolecular step (LB or LA) and whether they are also Bronsted bases/acids (LB/BB or LA/BA)
3) Show where every proton comes from and goes to (i.e., no +H⁺ or -H⁺)
4) DRAW ALL RELEVANT RESONANCE CONTRIBUTORS FOR THE INTERMEDIATES

(a) 
\[
\text{N}^+ \quad \xrightarrow{\text{H}_3\text{O}^+} \quad \text{O}^+ 
\]

(b) 
\[
\text{O} \quad \xrightarrow{\Theta \text{OH/H}_2\text{O}} \quad \text{OH}
\]

Give the number of transition states in your mechanism for reaction a) ________

Give the number of steps in your mechanism for reaction b) ________
Question 8 (20 pts.) Give a complete arrow-pushing mechanisms for the following reaction. 
*Show exactly where each proton comes from and goes to (no abbreviated +H\(^+\) or -H\(^-\)). Indicate the lewis acid/base for each INTERmolecular step (LB or LA) and whether they are also Brønsted bases/acids (LB/BB or LA/BA)
*DO NOT ATTEMPT TO DRAW RESONANCE CONTRIBUTORS FOR THE INTERMEDIATES*