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- WRITE CLEARLY!
- MOLECULAR MODELS ARE ALLOWED
- DO NOT USE RED INK
- DON'T CHEAT, USE COMMON SENSE!

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**Infrared Correlation Chart**

<table>
<thead>
<tr>
<th>Interaction Energies, kcal/mol</th>
<th>Eclipsing</th>
<th>Gauche</th>
</tr>
</thead>
<tbody>
<tr>
<td>H/H</td>
<td>-1.0</td>
<td>Me/Me</td>
</tr>
<tr>
<td>H/Me</td>
<td>-1.4</td>
<td>Et/Me</td>
</tr>
<tr>
<td>Me/Me</td>
<td>-2.6</td>
<td>i-Pr/Me</td>
</tr>
<tr>
<td>Et/Me</td>
<td>-3.1</td>
<td>t-Bu/Me</td>
</tr>
</tbody>
</table>

**NMR Correlation Charts**

- R—NH₂ variable and condition dependent, R—OH ca. 2·6 δ
- Aromatic Ar—H mainly 8·6.5
- Alkyl 3’>2’>1’
- Aromatic 3’>2’>1’

---

**Chemical Elements**

- H, He
- Li, Be
- Na, Mg, Al, Si, P, S, Cl, Ar
- K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr
- Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Ag, Cd, In, Sn, Sb, Te, I, Xe
- Cs, Ba, Lu, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn

---

**Chemical Structures**

- C—H
- C—N
- C=O
- N—H
- O—H
- C—C
- C—O
- C=O
- O—C
- R—OH
- R—CO₂
- R—C=O
- R—C="

---

**Printing Instructions**

- PRINT YOUR NAME ON EACH PAGE!
- PRINTED FIRST NAME ____________________
- PRINTED LAST NAME ____________________

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**Directions**

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(EVEN THOUGH YOU ALREADY DID THIS ON THE COVER PAGE)
AND ALSO GIVE YOUR ASU OR POSTING ID NUMBER
WE NEED THIS NUMBER BECAUSE YOU WOULDN'T BELIEVE THE NUMBER OF
STUDENTS WHOSE NAMES WE CAN'T READ!

Points by question

1_____________/18

2_____________/16

3_____________/12

4a_____________/2

4b_____________/36

4c_____________/10

5_____________/10

6_____________/12

7_____________/27

8_____________/16

9_____________/16

Points Removed for cover errors ____/2

Extra Credit_____/5

Total (incl Extra)_____/175+5

**YOU ARE NOT ALLOWED TO TAKE SPARE COPIES OF THIS EXAM FROM THE TESTING ROOM**
Question 1 (18 pts.) Here is a pictorial representation of the $\Psi$ of a 3p atomic orbital.

a) Give a plot of the magnitude of the wavefunction ($\Psi$) versus distance from the nucleus, $r$, on the axes provided, **AND IDENTIFY ANY NODES ON THIS PLOT**

b) Give a plot of the magnitude of the wavefunction squared ($\Psi^2$) versus distance from the nucleus, $r$, on the axes provided.

---

Question 2 (16 pts.) For the N-Ha and N-Hb bonds in the 2 structures below, explain which would have the LARGER bond dissociation energy (BDE) and give a BRIEF explanation that must include the term "energy of the electrons".

---

Question 3 (12 pts.) For homolytic dissociation of the N-H bond indicated below by the arrow, draw the curved arrow-pushing that describe bond breaking and give the product of bond breaking. Include all non-bonding electrons.
Question 4 For the molecular formula $C_5H_8$

a) (2 pts.) Give the degrees of unsaturation

b) (36 pts.) Draw **SIX** structural isomers that obey the normal rules of valence for each atom. You can draw Lewis structures or line-angle structures (your choice).

c) (10 pts.) Draw **ONE PAIR** of stereoisomers that obey the normal rules of valence for each atom for $C_5H_8$. You do NOT have to identify cis- or trans-isomers. **DO NOT INCLUDE ANY STRUCTURES in part c) THAT WERE DRAWN AS PART OF YOUR ANSWER TO PART b) OF THIS QUESTION**

Question 5 (10 pts.) Convert the provided condensed formula into a line-angle structure (include all non-bonding electrons).

$$(\text{CH}_3\text{CH}_2)_2\text{CH}\text{CH}_2\text{CH(OH)}\text{CH(CH}_3)\text{CHO}$$

Extra Credit (5 pts.) In the "Organic Chemistry in Real Life" pages, anti-bonding molecular orbitals were described as playing an important role in which of the following

- color
- burning hydrocarbons
- ATP energy conversion
Question 6. (12 pts). Indicate the direction of the MOLECULAR dipole moments in the following.

![Molecular structures]

Question 7 (27 pts.) Shown below is the simplest amino acid, glycine, in its neutral form. For the orbitals indicated, draw directly ON TOP of the molecule either $\Psi$ or $\Psi^2$ as requested (read the question carefully!) and indicate the appropriate atomic orbitals that are involved. For drawings of $\Psi$, indicate ALL NODES. For drawings of $\Psi^2$, indicate all places where the probability of finding the electrons is zero.

- $\Psi^2$ for the carbon-oxygen $\pi$ bonding orbital

- $\Psi$ for the carbon-oxygen $\sigma^*$ ANTI-bonding orbital

- $\Psi$ for the non-bonding electrons on oxygen
Question 8 (16 pts.) Rank the indicated pairs of electrons A - C in the essential amino acid tryptophan (shown in its neutral form) in order of increasing energy. Give a BRIEF explanation for your choice (all of the points are for the explanation, not the order).

\[
\begin{align*}
A & \text{(C=C } \pi\text{-bond)} \\
B & \text{(non-bonding on N)} \\
C & \text{(N-H } \sigma\text{-bond)}
\end{align*}
\]

\[
\begin{array}{ccc}
\text{lowest energy} & < & \text{highest energy}
\end{array}
\]

Question 9 (16 pts.) Circle and identify all functional groups in the following structure, ignore alkyl groups. Indicate any amines, amides or alcohols as primary, secondary or tertiary, as appropriate. Non-bonding electrons are omitted in this structure for clarity.

\[
\text{structure based on that of Relenza - a flu drug}
\]