Check the discussion section in which you would like your exam returned. If you do not choose your correct section, you will not get your exam returned to you as promptly.

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<th>Section</th>
<th>Time</th>
<th>Location</th>
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</table>

THERE ARE 10 ESSAY-STYLE QUESTIONS and a total of 155 points possible.

Please look through the entire exam before starting to ensure that the entire exam is included. Finish the problems that you know you can answer easily, and then proceed to the problems on which you need to spend more time. RELAX!

1. 15 points
2. 16 points
3. 15 points
4. 19 points
5. 13 points
6. 16 points
7. 12 points
8. 18 points
9. 17 points
10. 14 points

Total /150 (although 155 point possible)

Regrades: Any requests for regrades must be submitted in writing within 1 week following the return of the exam in discussion. You must explicitly state what has been misgraded and provide an argument as why it should be regraded. Be aware that the entire exam will be regraded when it is submitted for a regrade. Regrades late in the semester on earlier work will not be considered just because you never went to pick up your assignments in discussion.
1. **Drawing Organic Molecules.**

a. Convert the following molecule into a line drawing. Fill in all lone pairs clearly.  

\[(\text{CH}_3)_2\text{CHCH}_2\text{CO}_2\text{CH}_2\text{CH}_3\]

b. Fill in the lone pairs on all heteroatoms in each compound and assign correct formal charges.  

![Heteroatoms with lone pairs and formal charges]

c. Determine the hybridization and shape around the indicated atoms in the following molecules.  

- sp
- sp\(^2\)
- sp\(^3\)

linear
trigonal planar
bent

d. Answer the following questions about the molecule below. (Circle one answer for each below) (2 points)

- Which is the shortest C—C single bond?  
- Which is the longest C—C single bond?  
- Considering ALL the bonds, which is the shortest C—C bond?  
- Considering ALL the bonds, which is the weakest C—C bond?
2. **Resonance.** Using correct arrows, provide valid resonance structures for the molecules or ions for the species below that demonstrate resonance. If a species does not have additional resonance structures, then write NAS. 

(16 points)

Follow the arrows provided and draw the ion that results.
3. **Functional Groups & Isomers.** Provide a line drawing that exemplifies each of the following functional groups. Draw a real molecule, not just the generic formula using the letter “R”, and your molecule must contain 5 carbons. (9 points)

- **Ester**
- **3° Amine**
- **Amide**
- **Ether**
- **Carboxylic acid**
- **2° Alcohol**
- **1° Alkyl bromide**
- **Ketone**
- **Aldehyde**

b. Draw THREE constitutional isomers with the formula C₆H₁₀O. (6 points)
4. **Molecular Polarity & Intermolecular Forces.**

a. Provide a line drawing of the following solvents and indicate if the following molecules are polar (P) or non-polar (NP). (12 points)

- THF
- Acetonitrile
- DMF
- Toluene
- DMSO
- Diethyl ether
- Acetone
- Acetic acid

b. Answer the following questions about Vitamin B-2, riboflavin: (4 points)

- How many sites of unsaturation does riboflavin contain? 10 (3 rings and 7 pi bonds)
- Do you expect riboflavin to be water soluble? YES
- Based on the table below, which would be the best solvent to dissolve riboflavin? Ethanol

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Dielectric Constant</th>
<th>Identify each as either Polar (P) or Non-polar (NP)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl acetate</td>
<td>6</td>
<td>NP</td>
</tr>
<tr>
<td>1-Butanol</td>
<td>17</td>
<td>P</td>
</tr>
<tr>
<td>Ethanol</td>
<td>24</td>
<td>P</td>
</tr>
</tbody>
</table>

c. Draw in the δ+ and δ- on the appropriate atoms in each indicated bonds below. (3 points)

\[
\begin{align*}
\text{H}_3\text{C} & \quad \delta^+ \quad \delta^- \\
\text{H}_2\text{B} & \quad \delta^+ \quad \delta^- \\
\text{H}_2\text{O} & \quad \delta^- \quad \delta^+ \\
\text{H}_2\text{N} & \quad \delta^- \quad \delta^+ \\
\text{H}_2\text{C} & \quad \delta^+ \quad \delta^+ \\
\end{align*}
\]
5. **Reactive sites.** a. Indicate if the following atoms or bonds are either nucleophiles (Nu), electrophiles (E) or neither (Ne) in the boxes provided.

![Diagram of Viracept molecule](image)

Viracept is an antiretroviral drug used in the treatment of the human immunodeficiency virus (HIV).

b. **Intermolecular forces.** Indicate if the following molecules are soluble in HEXANES (write Y or N for yes or no), and indicate with an X in the boxes if these molecules exhibit London forces (LF), dipole-dipole (DD), or contain a hydrogen bond acceptor (HBA) or a hydrogen bond donor (HBD). (7 points)

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Soluble in hexanes?</th>
<th>LF</th>
<th>DD</th>
<th>HBA</th>
<th>HBD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absinthe</td>
<td>YES</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Benzopyrene</td>
<td>YES</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemlock</td>
<td>NO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Absinthe = a high proof, 19th century herbal liqueur, is available again in Britain after an 85-year absence.

Benzopyrene = a suspected carcinogen found in automobile exhaust fumes, tobacco, incense, marijuana, wood smoke, and in charbroiled food.

Hemlock = poisonous plant that achieved a certain notoriety for it being responsible for the execution of Socrates (399 BC).
6. **Nomenclature.** a. Provide line drawings based on the following IUPAC names. (8 points)

- 3-ethyl-2,2-dimethylheptane
- 1-tert-butyl-3-ethylcyclohexane
- 4-iodo-3-isopropyl-2-methyl-5-ethyloctane
- bicyclo[3.2.0]heptane

b. Provide IUPAC names for the following line drawings. (8 points)

- 3-chloro-4,4,5-trimethylheptane
- 4-bromo-1-ethyl-2-isopropylcyclopentane
- bicyclo[4.3.1]decane
- 3-bromo-3-ethylhexane
7. Acids & Bases. Complete the following reactions using the appropriate curved arrows to show the flow of electrons pairs in each reaction. Determine the direction of the equilibrium and calculate the $K_{eq}$. Write the pKa values under the acids, so we can evaluate your progress better and give partial credit. Finally, label the acid (A), base (B), conjugate acid (CA) and base (CB) correctly. Blank answers will not be counted for credit. (12 points)

\[
\begin{align*}
\text{pKa 20} & \quad A \\
\text{pKa 25} & \quad CA \\
\text{pKa 16} & \quad CA \\
\text{pKa 5} & \quad B
\end{align*}
\]
8. **Acids & Bases.** You were never asked to learn the pKa of toluene, but you can make a very good estimate based on knowing the pKa values on the pKa table from the lecture notes. Draw the conjugate base (CB) for toluene, and then circle the best estimate below. (4 points)

![Diagram of toluene and its conjugate base](image)

The pKa of an sp³ C—H bond is 51. Due to the large amount of resonance in the conjugate base, you should have estimated that the pKa of toluene was 41. A pKa of 48 would have been too low of a difference with how much resonance has played a role in what we have seen for the last two weeks. Anything lower in pKa would have been too extreme.

b. **Pyrrole has a pKa of 23.** Predict if imidazole is a stronger or weaker acid (e.g. pKa of 18 of 28?), and provide a *brief* argument. Start answering the questions by drawing the conjugate base for imidazole and ALL its resonance structures; structures must be provided to answer the question well enough for full credit. (6 points)

![Diagram of pyrrole and imidazole](image)

Imidazole and pyrrole have identical numbers of resonance structures in their conjugate bases. Resonance will **NOT** be the determining factor in this answer. When imidazole is deprotonated, you will have 2 resonance structures with a negative charge on N and 3 RS with a negative on C. When pyrrole is deprotonated, you will have only one RS with a negative N and 4 RS with a negative C. The difference is electronegativity. Imidazole will have a lower pKa because its CB is more stable due to the extra nitrogen in the ring.

b. **Provide pKa values for the most acidic proton on each molecule below.** Do not round. (8 points)

<table>
<thead>
<tr>
<th>Molecule</th>
<th>pKa</th>
</tr>
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<tbody>
<tr>
<td>H2O</td>
<td>15.7</td>
</tr>
<tr>
<td>OH2</td>
<td>5</td>
</tr>
<tr>
<td>OH</td>
<td>-2</td>
</tr>
<tr>
<td>HX</td>
<td>50-51</td>
</tr>
<tr>
<td>H2</td>
<td>35</td>
</tr>
<tr>
<td>NH</td>
<td>38</td>
</tr>
<tr>
<td>OH</td>
<td>44</td>
</tr>
<tr>
<td>OH</td>
<td>50-51</td>
</tr>
<tr>
<td>OH</td>
<td>16</td>
</tr>
<tr>
<td>O</td>
<td>20</td>
</tr>
<tr>
<td>HX</td>
<td>-7 to -9</td>
</tr>
<tr>
<td>NH</td>
<td>9.2</td>
</tr>
</tbody>
</table>
9. **Acids & Bases.**

   a. There are two separate problems below; due to space constraints two problems are next to each other separated by the bold line. In the boxes provided under each molecule, enter a number (1 to 4) indicating the order of **acid strength** (1 is strongest & 4 is weakest). (4 points)

   ![Molecule Diagram for Acids & Bases]

   b. There are two separate problems below; due to space constraints two problems are next to each other separated by the bold line. In the boxes provided under each molecule, enter a number (1 to 4) indicating the order of **base strength** (1 is strongest & 4 is weakest). (4 points)

   ![Molecule Diagram for Acids & Bases]

   c. Rank the following protons in order of acidity. (7 points)

   ![Proton Diagram]

   \[\text{H}_c \ > \ \text{H}_d \ > \ \text{H}_b \ > \ \text{H}_a\]

   \[\text{H}_e \ > \ \text{H}_f \ > \ \text{H}_g\]

   d. Provide the structures two reagents that are strong enough to deprotonate tert-butanol. (2 points)

   ![OH Molecule]

   Any strong enough base is one whose pKa of its CA is higher than 16. Common reagents: NaH, NaNH₂, CH₃Li (a deprotonated alkene is ok but not very often used in reality).
10. a. Consider the structure of 1-iodo-2-methylbutane below. Draw its **MOST** stable conformation and its **LEAST** stable conformation in Newman projections while looking down the C1—C2 bond. Put your final answers in the boxes provided. (4 points)

\[ 
\begin{align*}
\text{I} & \quad \text{CH}_3 \\
\text{H} & \quad \text{H} \\
\text{CH}_2\text{CH}_3 & \\
\end{align*}
\]

**MOST STABLE**

\[ 
\begin{align*}
\text{Et} & \quad \text{I} \\
\text{H} & \quad \text{H} \\
\text{CH}_3 & \\
\end{align*}
\]

**LEAST STABLE**

b. Convert this Newman projection to a well-drawn line drawing (i.e. you probably have to draw a cruddy answer first and then convert this to a nice line drawing.) Finally, name it using IUPAC rules. (6 points)

\[ 
\begin{align*}
\text{Cl} & \quad \text{CH}_3 \\
\text{Br} & \quad \text{CH}_2\text{CH}_3 \\
\text{CH}_2\text{CH}_2\text{CH}_3 & \\
\end{align*}
\]

4-bromo-3-chloro-4-methylheptane

c. Regarding the conformations below for 1-bromopropane, provide the order of stability from **LEAST** to **MOST STABLE** AND **LOWEST** to **HIGHEST** energy? (4 points)

\[ 
\begin{align*}
\text{A} & \quad \text{B} \\
\text{C} & \quad \text{D} \\
\end{align*}
\]

**LOWEST ENERGY** \( \text{C} < \text{B} < \text{D} < \text{A} \)

**HIGHEST ENERGY**

**LEAST STABLE** \( \text{A} < \text{D} < \text{B} < \text{C} \)

**MOST STABLE**