Chem 240 Practice Problems
Exam 1

Nomenclature
Isomers
Rotational Energy Diagrams
Free Radical Halogenation
Hybridization
Sigma and Pi bonds
Boat Chair Configurations
Intermolecular Forces
Polarity and Dipoles
Resonance Structures
## Analysis of Dimethylcyclohexane Using Chem3D Pro

All Values in kJoules

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Chair</th>
<th>Twist Boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cis 1, 2</td>
<td>10.0625 ae (ea)</td>
<td>15.5686 ae</td>
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<tr>
<td>Trans 1, 2</td>
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<td>10.8828 aa</td>
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<td>13.7837 ee</td>
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<td>17.0596 aa</td>
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<td>Trans 1, 4</td>
<td>10.7757 aa</td>
<td>7.2161 ee</td>
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<tr>
<td></td>
<td>13.6442 ae (ea)</td>
<td></td>
</tr>
</tbody>
</table>
**Mechanism of Free Radical Halogenation using Bromine**

**Chain Initiation**

\[ \text{Br}_2 \xrightarrow{\text{light}} 2 \text{Br}^* \]

**Chain Propagation**

\[ \text{Br}^* + \text{CH}_2 = \text{CH}_2 \rightarrow \text{HBr} + \text{CH}_3 = \text{CH} = \text{CH}_2^* \]

\[ \text{Br}_2 + \text{CH}_2 = \text{CH}_2 \rightarrow \text{HBr} + \text{Br}^* \]

**Chain Termination**

\[ \text{Br}^* + \text{Br}^* \rightarrow \text{Br}_2 \]

\[ \text{Br}^* + \text{CH}_2 = \text{CH}_2 \rightarrow \text{HBr} + \text{CH}_3 = \text{CH} = \text{CH}_2 \]

\[ \text{Br}^* + \text{CH}_2 = \text{CH}_2 \rightarrow \text{HBr} + \text{CH}_3 = \text{CH} = \text{CH}_2 \]

**Relative Reactivity**

<table>
<thead>
<tr>
<th></th>
<th>1°</th>
<th>2°</th>
<th>3°</th>
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</thead>
<tbody>
<tr>
<td>Chlorination</td>
<td>1</td>
<td>3.5</td>
<td>5</td>
</tr>
<tr>
<td>Bromination</td>
<td>1</td>
<td>97</td>
<td>∞</td>
</tr>
</tbody>
</table>
1) Please draw the rotational energy diagram for the rotation of 2,3-dimethyl butane around the C2-C3 bond.

Draw the molecule below, convert it to a Newman projection and then rotate it about the C2-C3 bond. Based on your rotations, draw the energy diagram above.

2) Please draw the rotational energy diagram for the rotation of 3-methyl pentane around the C2-C3 bond.

Draw the molecule below, convert it to a Newman projection and then rotate it about the C2-C3 bond. Based on your rotations, draw the energy diagram above.
3) Please draw all of the isomers of C₄H₇Cl. There are more than a dozen.

4) Please draw all of the isomers of C₃H₅Cl.

5) Please draw all of the isomers of C₃H₄Cl₂.

6) Please draw all of the isomers of C₃H₈O

7) Please answer the following questions concerning the molecule given below.
   a) How many pi and sigma bonds are in this compound?

   ![Molecule](image)

   b) What is the hybridization on the following atoms;

   1 5 7 8 9

8) Please answer the following questions concerning the molecule given below.
   a) How many pi and sigma bonds are in this compound?

   ![Molecule](image)

   b) What is the hybridization on the following atoms;

   2 3 4 5 7 8

9) Please answer the following questions concerning the molecule given below.
   a) How many pi and sigma bonds are in this compound?

   ![Molecule](image)

   b) What is the hybridization on the following atoms;

   1 2 5 7
10) Please draw the most stable form of trans 1,2 dimethyl cyclohexane.

11) Please draw the most stable form of cis 1,3 dihydroxy cyclohexane.

12) Please draw the most stable form of cis 1,3 dimethyl cyclohexane.

13) Please draw the most stable form of cis 1,3 cyclopentadiol.

14) Please describe what happens to the melting point of a large alkene (C20 or larger) if the double bond changes from cis to trans. Also explain why it does this.

15) Please explain what happens to the melting point of an alkane as it becomes more branched.

16) What kinds of compounds can hydrogen bond? What is hydrogen bonding?

17) What is the major intermolecular bonding type for each of the following compounds?

<table>
<thead>
<tr>
<th>Compound</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃CH₂NH₂</td>
<td>CH₂Cl₂</td>
<td>CH₃COOH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18) Which compound in each pair has the highest boiling point?

<table>
<thead>
<tr>
<th>Compound 1</th>
<th>Compound 2</th>
<th>Type 1</th>
<th>Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃OCH₂CH₃</td>
<td>CH₃CH(OH)CH₃</td>
<td>H-bond</td>
<td>Dipole-Dipole</td>
</tr>
<tr>
<td>CH₃CH₂CH₂CH₂CH₃</td>
<td>CH₃CH₂CH₂CH₃</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
</tr>
<tr>
<td>(CH₃)₂CHCH₃</td>
<td>CH₃CH₂CH₂CH₃</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
</tr>
</tbody>
</table>

19) Please predict the primary type of bonding that will occur in each of the following liquids.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCl₄</td>
<td>H-bond</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
<td></td>
</tr>
<tr>
<td>C₁₆H₃₄</td>
<td>H-bond</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
<td></td>
</tr>
<tr>
<td>Propanone</td>
<td>H-bond</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
<td></td>
</tr>
</tbody>
</table>
1) Please draw the rotational energy diagram for the rotation of 2,3-dimethyl butane around the C2-C3 bond.

Draw the molecule below, convert it to a Newman projection and then rotate it about the C2-C3 bond. Based on your rotations, draw the energy diagram above.
2) Please draw the rotational energy diagram for the rotation of 3-methyl pentane around the C2-C3 bond.

Draw the molecule below, convert it to a Newman projection and then rotate it about the C2-C3 bond. Based on your rotations, draw the energy diagram above.
3) Please draw all of the isomers of C₄H₇Cl. There are more than a dozen.

4) Please draw all of the isomers of C₃H₅Cl.

5) Please draw all of the isomers of C₃H₄Cl₂.

6) Please draw all of the isomers of C₃H₈O.
7) Please answer the following questions concerning the molecule given below.

a) How many pi and sigma bonds are in this compound? 5 pi and 16 sigma

b) What is the hybridization on the following atoms:

1 sp2  5 sp  7 sp2  8 sp2  9 sp3

8) Please answer the following questions concerning the molecule given below.

a) How many pi and sigma bonds are in this compound? 4 pi and 16 sigma

b) What is the hybridization on the following atoms:

2 sp2  3 sp3  4 sp2  5 sp  7 sp3  8 sp3

9) Please answer the following questions concerning the molecule given below.

a) How many pi and sigma bonds are in this compound? 3 pi and 21 sigma

b) What is the hybridization on the following atoms:

1 sp2  2 sp2  5 sp3  7 sp2  8 sp3

10) Please draw the most stable form of trans 1,2 dimethyl cyclohexane.

```
H3C

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>H3C</td>
<td></td>
</tr>
</tbody>
</table>
```

11) Please draw the most stable form of cis 1,3 dihydroxy cyclohexane.

```
HO

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HO</td>
<td></td>
</tr>
</tbody>
</table>
```

12) Please draw the most stable form of cis 1,3 dimethyl cyclohexane.

\[ \text{H}_3\text{C} - \text{H}_3\text{C} \]

13) Please draw the most stable form of cis 1,3 cyclopentadiol.

\[ \text{HO} - \text{OH} \]

14) Please describe what happens to the melting point of a large alkene (C20 or larger) if the double bond changes from cis to trans. Also explain why it does this.

_The melting point increases. A cis bond puts a kink in the chain that makes it hard to stack. By changing the cis to a trans the chain straightens out and makes it easier to stack. This allows for more dispersion forces and increases the melting point._

15) Please explain what happens to the melting point of an alkane as it becomes more branched.

_The more branched an alkane becomes the lower the melting point. Branching makes it more difficult to stack the molecules and this reduces the molecules ability to use dispersion forces for bonding._

16) What kinds of compounds can hydrogen bond? What is hydrogen bonding?

_Hydrogen bonds are formed between molecules that have OH or NH bonds (also HF but HF is not an organic compound)._ 

_A hydrogen bond is a sharing of protons between the oxygen or nitrogen molecules. The hydrogen atoms freely move between the oxygens or nitrogens by sharing grabbing onto the lone pair electrons found on these atoms. Each atom of oxygen or nitrogen can have up to 4 atoms of hydrogen surrounding them, each of them sharing their electrons._

17) What is the major intermolecular bonding type for each of the following compounds?

\[ \text{CH}_3\text{CH}_2\text{NH}_2 = \text{H bond} \quad \text{CH}_2\text{Cl}_2 = \text{Dipole-dipole} \quad \text{CH}_3\text{COOH} = \text{H bond} \]
18) Which compound in each pair has the highest boiling point?

- CH₃OCH₂CH₃ or CH₃CH(OH)CH₃ \textit{(because of H bonds)}
- CH₃CH₂CH₂CH₂CH₃ \textit{(because it is bigger)} or CH₃CH₂CH₂CH₃
- (CH₃)₃CHCH₃ or CH₃CH₂CH₂CH₃ \textit{(because it is less branched)}

19) Please predict the primary type of bonding that will occur in each of the following liquids.

<table>
<thead>
<tr>
<th>Compound</th>
<th>H-bond</th>
<th>Dipole-Dipole</th>
<th>Dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCl₄</td>
<td></td>
<td></td>
<td>Dispersion</td>
</tr>
<tr>
<td>C₁₆H₃₄</td>
<td></td>
<td></td>
<td>Dispersion</td>
</tr>
<tr>
<td>Propanone</td>
<td></td>
<td>\textit{Dipole-Dipole}</td>
<td>Dispersion</td>
</tr>
</tbody>
</table>
CLOSED BOOK EXAM - No books or notes allowed. All work must be shown for full credit. You may use a calculator.

<table>
<thead>
<tr>
<th>Question</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(18)</td>
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<tr>
<td>2(21)</td>
<td></td>
</tr>
<tr>
<td>3(9)</td>
<td></td>
</tr>
<tr>
<td>4(12)</td>
<td></td>
</tr>
<tr>
<td>5(6)</td>
<td></td>
</tr>
<tr>
<td>6(18)</td>
<td></td>
</tr>
<tr>
<td>7(16)</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

1) Please name or draw the structure of the following compounds.

![Structure 1](image1)

![Structure 2](image2)

![Structure 3](image3)

![Structure 4](image4)

![Structure 5](image5)
2) Please draw the rotational energy diagram for the rotation of 2,3-dichlorobutane around the C2-C3 bond.

![Energy Diagram](image)

Draw the molecule below, convert it to a Newman projection and then rotate it about the C2-C3 bond. Based on your rotations, draw the energy diagram above.

3) Please draw all of the isomers of C₃H₃Cl

4) Please answer the following questions concerning the molecule given below.
a) How many pi and sigma bonds are in this compound?

b) What is the hybridization on the following atoms:

5) Please draw the LEAST stable form of trans 1,2 dichlorocyclohexane. You have the freedom to draw the molecule in whatever form you believe is the LEAST stable.

6a) Please write down all the steps in the mechanism of the free radical chlorination of 2-methylbutane.
6b) What is the ratio of products formed in the free radical chlorination of bicyclo [3,2,0] heptane?

7a) What are the advantages of using bromine instead of chlorine in a free radical halogenation?

a) 

b) 

7b) What happens to the boiling point of an alkane when it becomes branched?

7c) How do the intermolecular bonding forces change when acids become larger?

7d) What is the primary intermolecular bonding force in each of the following compounds?

<table>
<thead>
<tr>
<th>Compound</th>
<th>H-Bond</th>
<th>Dipole-Dipole</th>
<th>Dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isopropyl Alcohol</td>
<td>H-Bond</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
</tr>
<tr>
<td>1,3-dichloropropane</td>
<td>H-Bond</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
</tr>
<tr>
<td>$\text{C}<em>{12}\text{H}</em>{25}\text{NH}_2$</td>
<td>H-Bond</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
</tr>
<tr>
<td>methylcyclohexane</td>
<td>H-Bond</td>
<td>Dipole-Dipole</td>
<td>Dispersion</td>
</tr>
</tbody>
</table>
1) Please name or draw the structure of the following compounds.

- Bicyclo[4, 2, 1] nonane
- S-3-chloro-2-methylbutane
- cis-1,4-dimethylcyclohexane
- 2,2,4-trimethylpentane
- Z-bromo-1,2-dichlorocyclobutane
- 2-bromo-2-methylpropane
2) Please draw the rotational energy diagram for the rotation of 2,3-dichlorobutane around the C2-C3 bond.

Draw the molecule below, convert it to a Newman projection and then rotate it about the C2-C3 bond. Based on your rotations, draw the energy diagram above.

3) Please draw all of the isomers of C3H3Cl
4) Please answer the following questions concerning the molecule given below.

a) How many pi and sigma bonds are in this compound?
   20 sigma and 6 pi

b) What is the hybridization on the following atoms:
   1  2  3  4
   sp  sp3 sp3 sp3

5) Please draw the LEAST stable form of trans 1,2 dichlorocyclohexane. You have the freedom to draw the molecule in whatever form you believe is the LEAST stable.

6a) Please write down all the steps in the mechanism of the free radical chlorination of 2-methylbutane.

**Chain Initiation**

\[
\text{Cl}_2 \xrightarrow{\text{light}} 2 \text{Cl}^* 
\]

**Chain Propagation**

\[
\begin{align*}
\text{Cl}^* + \text{H}_3\text{C} \equiv \text{C} \equiv \text{C}_2\text{H}_5 & \rightarrow \text{HCl} + \text{H}_3\text{C} \equiv \text{C} \equiv \text{C}_2\text{H}_5 \\
\text{H}_3\text{C} \equiv \text{C} \equiv \text{C}_2\text{H}_5 + \text{Cl}_2 & \rightarrow \text{H}_3\text{C} \equiv \text{C} \equiv \text{C}_2\text{H}_5 + \text{Cl}^* 
\end{align*}
\]

**Chain Termination**

\[
\begin{align*}
\text{Cl}^* + \text{Cl}^* & \rightarrow \text{Cl}_2 \\
\text{Cl}^* + \text{H}_3\text{C} \equiv \text{C} \equiv \text{C}_2\text{H}_5 & \rightarrow \text{H}_3\text{C} \equiv \text{C} \equiv \text{C}_2\text{H}_5 \\
\text{H}_3\text{C} \equiv \text{C} \equiv \text{C}_2\text{H}_5 + \text{Cl}^* & \rightarrow \text{Cl}_2
\end{align*}
\]
6b) What is the ratio of products formed in the free radical chlorination of bicyclo [3,2,0] heptane?

\[
\frac{\text{secondary}}{\text{tertiary}} \times \frac{10}{2} \times \frac{3.5}{5} = \frac{X}{100-X} = X = 77.78\% \text{ secondary} \\
X = 77.78\% \text{ secondary} \quad 22.22\% \text{ tertiary}
\]

7a) What are the advantages of using bromine instead of chlorine in a free radical halogenation?

a) fewer by-products

b) higher yield

7b) What happens to the boiling point of an alkane when it becomes branched?

The boiling point goes down

7c) How do the intermolecular bonding forces change when acids become larger?

As acids get larger they get less soluble in water so the intermolecular bonding force changes from being mostly H-bond to mostly dispersion forces

7d) What is the primary intermolecular bonding force in each of the following compounds?

<table>
<thead>
<tr>
<th>Compound</th>
<th>H-Bond</th>
<th>Dipole-Dipole</th>
<th>Dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isopropyl Alcohol</td>
<td>[H-Bond]</td>
<td>[Dipole-Dipole]</td>
<td>Dispersion</td>
</tr>
<tr>
<td>1,3-dichloropropane</td>
<td>H-Bond</td>
<td>[Dipole-Dipole]</td>
<td>Dispersion</td>
</tr>
<tr>
<td>C\textsubscript{12}H\textsubscript{25}NH\textsubscript{2}</td>
<td>H-Bond</td>
<td>Dipole-Dipole</td>
<td>[Dispersion]</td>
</tr>
<tr>
<td>methylcyclohexane</td>
<td>H-Bond</td>
<td>Dipole-Dipole</td>
<td>[Dispersion]</td>
</tr>
</tbody>
</table>
1) Please name or draw the structure of the following compounds.

![Structure 1](image1)

![Structure 2](image2)

![Structure 3](image3)

![Structure 4](image4)
2) Please draw the rotational energy diagram for the rotation of 2,2 dichloropentane around the C2-C3 bond.

![Energy Diagram](energy_diagram.png)

Draw the molecule below, convert it to a Newman projection and then rotate it about the C2-C3 bond. Based on your rotations, draw the energy diagram above.

3) Please draw all of the isomers of $\text{C}_3\text{H}_4\text{Cl}_2$
4) Please answer the following questions concerning the molecule given below.

a) How many pi and sigma bonds are in this compound?

b) What is the hybridization on the following atoms:

1 2 3 4 5

5) Please draw the LEAST stable form of trans 1,2 dichlorocyclohexane.

6) Please predict the percentage of products made by the free radical chlorination of bicycle [4,2,0] octane.

7a) Hexane and cyclohexane both have six carbons but one has a higher boiling point than the other. Which one has the higher boiling point and why?

7b) Rank the following compounds from highest to lowest boiling point (highest = 4, lowest = 1)

7d) What is the primary intermolecular bonding force in each of the following compounds (H-bond, Dipole, Dispersion)?

\[ \text{C}_2\text{H}_5\text{NH}_2 \quad \text{C}_{12}\text{H}_{25}\text{COH} \]

\[ \text{cis 2,3-dichlorobutene} \quad \text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{Br} \]
1) Please name or draw the structure of the following compounds.

Cis-1,2-dichlorocyclopentane

Bicyclo [4,1,0] heptane

4-ethyl-5-methyloctane

2R,3R-2,3-dichloropentane
2) Please draw the rotational energy diagram for the rotation of 2,2 dichloropentane around the C2-C3 bond.

3) Please draw all of the isomers of C\textsubscript{3}H\textsubscript{4}Cl\textsubscript{2}
4) Please answer the following questions concerning the molecule given below.

![Molecule Image]

a) How many pi and sigma bonds are in this compound?

18 sigma and 4 pi

b) What is the hybridization on the following atoms:

1 sp2  
2 sp3  
3 sp3  
4 sp2  
5 sp

5) Please draw the LEAST stable form of trans 1,2 dichlorocyclohexane.

6) Please predict the percentage of products made by the free radical chlorination of bicycle [4,2,0] octane.

![Octane Image]

\[
X = \frac{12 \times 3.5}{2} = 80.77\% \text{ secondary}
\]

6.7) Hexane and cyclohexane both have six carbons but one has a higher boiling point than the other. Which one has the higher boiling point and why?

Hexane has the higher boiling point because it is longer and less compact than cyclohexane so it has more opportunity to exert dispersion forces on its neighbors.

7b) Rank the following compounds from highest to lowest boiling point (highest = 4, lowest = 1)

![Compounds Image]

7d) What is the primary intermolecular bonding force in each of the following compounds (H-bond, Dipole, Dispersion)?

<table>
<thead>
<tr>
<th>Compound</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{C}_2\text{H}_5\text{NH}_2 )</td>
<td>H-bond</td>
</tr>
<tr>
<td>cis 2,3-dichlorobutene</td>
<td>Dispersion</td>
</tr>
<tr>
<td>( \text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{Br} )</td>
<td>Dipole-Dipole (borderline)</td>
</tr>
<tr>
<td>( \text{C}<em>{12}\text{H}</em>{25}\text{COH} )</td>
<td>Dispersion (too big)</td>
</tr>
</tbody>
</table>