Good luck ("I believe in you, you can do it", etc.) and please read the questions!

1) Identify the class of compounds each of the following molecules belongs to (22.5pts).

2) Circle the molecule which is most acidic (1.5pts)

3) Double circle the molecule which is most basic (1.5pts)

4) Underline the molecule, which has the most ring strain (1.5pts)

5) Put a cross through the molecule that contains the shortest carbon-nitrogen bond (1.5pts)
6) (2+2+2+2+2+4+2=16pts) The following compound was produced in a Diels-Alder reaction.

\[ \text{CF}_3 \quad \text{CF}_3 \]

a) How many sp\(^3\) hybridized carbons are in this molecule?

b) How many chiral centers are in this molecule?

c) How many \(\pi\) bonds?

d) Are trifluoromethyl substituents *electron donating* or *electron withdrawing*?

e) Briefly explain your answer to (d).

f) Draw the *diene* and *dienophile* which react together to give this product.

g) Is this reaction *entropically* favorable or unfavorable?
7) The following reactions are named after their inventors - give the names of the following reactions (9pts).

(a) \[ \mathrm{C}_{6} \mathrm{H}_{5} \rightarrow \mathrm{C}_{6} \mathrm{H}_{4} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{3} \]

(b) \[ \mathrm{C}_{6} \mathrm{H}_{5} \rightarrow \mathrm{C}_{6} \mathrm{H}_{6} \]

(c) \[ \mathrm{O} \rightarrow \mathrm{C}_{5} \mathrm{H}_{9} \]

(d) \[ \mathrm{N}_{2}^{+} \rightarrow \mathrm{C}_{6} \mathrm{H}_{5} \mathrm{Cl} \]

(e) \[ \mathrm{R} - \mathrm{C} = \mathrm{O} + \mathrm{NH}_{2} \rightarrow \mathrm{R} - \mathrm{C} = \mathrm{NH} \rightarrow \mathrm{R} - \mathrm{NH}_{2} \]

(f) \[ \mathrm{O} \rightarrow \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{C} = \mathrm{C} \mathrm{R} \rightarrow \mathrm{R} - \mathrm{C} = \mathrm{C} - \mathrm{R} \]

8) Write the mechanism for the reaction of a PRIMARY AMINE with an ACID FLUORIDE to generate an AMIDE and H-F. (7pts).
9) Give one advantage and one disadvantage of Molecular orbital theory (4pts).

10) State whether each of the following Molecular orbitals are overall bonding, antibonding or non-bonding (4.5pts).

(a) 

(b) 

(c) 

11) Draw two Lewis resonance structures for an allylic cation, and show the electron movement which interconverts the two forms (5pts).

12) Indicate which one has the lower energy (1pt).
13) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the molecules are planar). (12pts)

14) Pick one of the above antiaromatic molecules, and use the polygon rule to demonstrate its antiaromaticity. (8pts)
15) Give the products in **six** of the following reactions, paying attention to **regio/stereochemistry** where applicable. (18pts)

1) Zn, HCl
2) NaNO₂, HCl
3) CuCl, HCl

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaOH</td>
<td><strong>Br</strong></td>
</tr>
<tr>
<td>CH₃CH₂I</td>
<td><strong>NO₂</strong></td>
</tr>
<tr>
<td>mcpba</td>
<td><strong>CH₃</strong></td>
</tr>
<tr>
<td>A</td>
<td><strong>Br</strong></td>
</tr>
<tr>
<td>Excess HI</td>
<td><strong>NO₂</strong></td>
</tr>
<tr>
<td>CO, HCl</td>
<td><strong>CH₃</strong></td>
</tr>
<tr>
<td>CuCl, AlCl₃</td>
<td><strong>NO₂</strong></td>
</tr>
</tbody>
</table>

*Sp09org2Final*
16) The below heterocycle is $6\pi$ Hückel aromatic.

\[
\begin{array}{c}
\text{N} \\
\text{N} \\
\text{N}
\end{array}
\]

What is a heterocycle? (1pt)

Explain why there are $6 \pi$ electrons (3pts).

Would you expect this compound to undergo substitution or addition reactions? (1pt)

Suppose the nitrogen is deprotonated, draw the product, and state whether it is still aromatic or not (4pts).
17) Give reagents and conditions to accomplish **five** of the following transformations. (15pts)

\[ \text{A} \quad \text{A} \quad \text{A} \quad \text{A} \quad \text{A} \]

1. \[
\text{CH}_3\text{CH}_2\text{CN} \quad \xrightarrow{\text{Conditions}} \quad \text{Ph} \quad \text{Ph} \quad \text{CHO}
\]
2. \[
\text{CH}_3\text{CH}=\text{CH} \quad \xrightarrow{\text{Conditions}} \quad \text{CH}_2\text{CHO}
\]
3. \[
\text{CH}_3\text{Ph} \quad \xrightarrow{\text{Conditions}} \quad \text{Ph} \quad \text{CH}_2\text{CN}
\]
4. \[
\text{H}_3\text{C} \quad \xrightarrow{\text{Conditions}} \quad \text{Ph} \quad \text{Ph} \quad \text{H}
\]
5. \[
\text{O}_2\text{N} \quad \xrightarrow{\text{Conditions}} \quad \text{O}_2\text{N} \quad \text{Ph}
\]
18) Circle the stronger base in the following threesomes. (9pts)

(a) \( \text{NH}_3 \) \( \text{H}_2\text{O} \) \( \text{HNO}_3 \)

(b) 

(c) 

19) i) Circle the stronger acid in the following threesomes. (6pts)

(a) \( \text{H}_3\text{C}-\text{C}-\text{O}-\text{H} \) \( \text{CH}_3\text{CH}_2-\text{OH} \) \( \text{H}_3\text{C}-\text{C}-\text{O}-\text{O}-\text{H} \)

(b) 

ii) Draw the most acidic isomer of chlorobutanoic acid. (3pts)
20) Name **five** of the following compounds in IUPAC form (14pts).

\[
\begin{align*}
\text{HC} & \text{-} \text{CH} & \text{F} \\
\text{O} & \text{O} & \text{Br} \\
\text{O} & \text{O} & \text{H} \\
\text{F} & \text{O} & \text{N} \\
\text{O} & \text{O} & \text{N} \\
\end{align*}
\]

21) Fill in the blanks for **two** of the following reactions. (6pts)

\[
\begin{align*}
\text{(a)} & \quad \text{NH}_2 \\
& \quad \text{excess CH}_3\text{-Br} \\
& \quad \text{Ag}_2\text{O}, \text{H}_2\text{O}, \text{heat} \\
\text{(b)} & \quad \text{CH}_3\text{CH}_2\text{-NH}_2 \\
& \quad \text{excess H}_3\text{C}\text{-C}\text{=Cl} \\
\text{(c)} & \quad \text{H}_3\text{C}\text{-C}\text{-CH}_3 \\
& \quad \text{1) PhMgBr} \\
& \quad \text{2) H}_3\text{O}^+ \\
\end{align*}
\]
22) Fill in the blanks for three of the following reactions. (9pts)

(a) \[
\ce{\text{phenyl}} \xrightarrow{1) \text{HNO}_3, \text{H}_2\text{SO}_4} \quad \text{?} \quad \xrightarrow{1) \text{NaNO}_2, \text{HCl}} \quad \text{?} \\
\ce{\text{2) Zn, HCl}} \\
\ce{\text{2) H}_2\text{O, Steam}}
\]

(b) \[
\ce{\text{phenyl}} \xrightarrow{\text{SOCl}_2} \quad \text{?} \quad \xrightarrow{\text{?}} \quad \ce{\text{phenyl}}
\]

(c) \[
\ce{\text{phenyl}} \xrightarrow{\text{?}} \quad \ce{\text{phenyl}} \quad \xrightarrow{\text{?}} \quad \ce{\text{phenylCl}}
\]

(d) \[
\ce{\text{phenyl}} \xrightarrow{\text{?}} \quad \ce{\text{phenyl}} \quad \xrightarrow{\text{?}} \quad \ce{\text{phenyl}}
\]
23) Give the mechanism for **two** of the below conversions (16pts)

(a) \[ \text{NH}_2 \quad 1) \text{excess CH}_3\text{Br} \quad 2) \text{Ag}_2\text{O}, \text{H}_2\text{O}, \text{heat} \]

(b) \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl} \quad \text{AlCl}_3 \]

(c) \[ \text{Ph} \text{O} \quad \text{HO-NH}_2 \quad \text{H}_2\text{SO}_4 \]
*Bonus question* (up to 4 points)

Provide the common names for 4 of these compounds which we talked about this semester.
If you do not want your graded exam placed in the box outside my office, then please tick here.

Good luck ("I believe in you, you can do it", etc.) and please read the questions!

1) Identify the class of compounds each of the following molecules belongs to (22.5pts).

- \( \text{Lactam} \)
- \( \text{Cyclic Acetal} \)
- \( \text{Amine} \)
- \( \text{Carboxylic Acid} \)
- \( \text{Ester} \)
- \( \text{Isocyanate} \)
- \( \text{Nitrile} \)
- \( \text{Acenaphthene} \)
- \( \text{Ketone} \)
- \( \text{Acid Chloride} \)
- \( \text{Anhydride} \)
- \( \text{Alcohol} \)
- \( \text{Ether} \)
- \( \text{Peroxide} \)

2) Circle the molecule which is most acidic (1.5pts)

3) Double circle the molecule which is most basic (1.5pts)

4) Underline the molecule, which has the most ring strain (1.5pts)

5) Put a cross through the molecule that contains the shortest carbon-nitrogen bond (1.5pts)
6) (2+2+2+2+2+4+2=16pts) The following compound was produced in a Diels-Alder reaction.

![Diels-Alder reaction product]

a) How many sp\(^3\) hybridized carbons are in this molecule? 6

b) How many chiral centers are in this molecule? 2

c) How many π bonds? 1

d) Are trifluoromethyl substituents *electron donating* or *electron withdrawing*? *Electron withdrawing*

e) Briefly explain your answer to (d).

F\(^-\)

\[\text{The F's are more electronegative than the C, so they cause the C to take on the charge.}\]

F\(^-\)

\[\text{This tue charge attracts the e}^+\text{s = e}^-\text{withdrawing}\]

f) Draw the *diene* and *dienophile* which react together to give this product.

![Diene and Dienophile]

g) Is this reaction *entropically* favorable or unfavorable?
7) The following reactions are named after their inventors - give the names of the following reactions (9pts).

(a) \[ \text{Friedel-Crafts} \]

(b) \[ \text{Birch Reduction} \]

(c) \[ \text{Kemmerer (or Wolff-Kishner)} \]

(d) \[ \text{Sadtler} \]

(e) \[ \text{Hoffman} \]

(f) \[ \text{Wittig} \]

8) Write the mechanism for the reaction of a PRIMARY AMINE with an ACID FLUORIDE to generate an AMIDE and H-F. (7pts).

\[
\begin{align*}
\text{R-NH}_2 + \text{R}^\prime \text{C}^\equiv \text{R} & \rightarrow \text{R}^\prime \text{C}^\equiv \text{R} + \text{H-F} \\
\text{R-N}^\equiv \text{R}^{\text{II}} & \rightarrow \text{R-N=c-R} \\
\rightarrow \text{H} & \rightarrow \text{H}^\circ \text{O} \\
\end{align*}
\]
9) Give one advantage and one disadvantage of Molecular orbital theory (4pts).

Adv: Accurate; explains resonance/aromaticity/Woodward-Hoffman Rules

Dis: Complicated; time consuming.

10) State whether each of the following Molecular orbitals are overall bonding, antibonding or non-bonding (4.5pts).

(a) Bonding

(b) Anti Bonding

(c) Non Bonding

11) Draw two Lewis resonance structures for an allylic cation, and show the electron movement which interconverts the two forms (5pts).

12) Indicate which one has the lower energy (1pt).
13) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the molecules are planar). (12pts)

14) Pick one of the above antiaromatic molecules, and use the polygon rule to demonstrate its antiaromaticity. (8pts)
15) Give the products in **six** of the following reactions, paying attention to regio/stereochemistry where applicable. (18pts)
16) The below heterocycle is $6\pi$ Hückel aromatic.

What is a *heterocycle*? (1pt)

A ring with atoms other than Carbon.

Explain why there are $6\pi$ electrons (3pts).

Each T bond contributes two $e^-$s.

Also the N of the N-H uses its lone pair to conjugate with the T system. $4 + 2 = 6$

Would you expect this compound to undergo *substitution* or *addition* reactions? (1pt)

*Substitution*

Suppose the nitrogen is deprotonated, draw the product, and state whether it is still aromatic or not (4pts).
17) Give reagents and conditions to accomplish five of the following transformations. (15pts)

\[
\begin{align*}
\text{Ph} & \quad \text{SOCl}_2 \quad \text{A} \quad \text{LiAlH}_4 \quad \text{PhCHO} \\
\text{CH}_2=\text{CHCH}_2\text{CHO} & \quad \text{H}_2, \text{Ni} \quad \text{CH}_2\text{CHCH}_2\text{CHO} \\
\text{PhCH}_3 & \quad \text{Br}_2, \text{u.v.} \quad \text{A} \quad \text{NaCN} \quad \text{PhCH}_2\text{CN} \\
\text{Ph} & \quad \text{PhMgBr} \quad \text{H}_3\text{C}\text{CPh}_2\text{HO} \\
\text{O}_2\text{N} & \quad \text{PhMgBr} \quad \text{H}_3\text{C}\text{CPh}_2\text{O}_2\text{N} \\
\text{C}_2\text{H}_4\text{CO}_2\text{CH}_3 & \quad \text{CH}_3\text{CH}_2\text{OH} \quad \text{H}_2\text{O}^+ \quad \text{PhCO}_2\text{CH}_2\text{CH}_3
\end{align*}
\]

\(\text{Sp09org2Final}\)
18) Circle the stronger base in the following threesomes. (9pts)

(a) \( \text{NH}_3 \) \( \text{H}_2\text{O} \) \( \text{HNO}_3 \)
(b) \( \text{H}_3\text{C} - \text{C} - \text{OH} \) \( \text{CH}_3\text{CH}_2 - \text{OH} \) \( \text{H}_3\text{C} - \text{C} - \text{OH} \)
(c) \( \text{O} \) \( \text{O} \) 

19) i) Circle the stronger acid in the following threesomes. (6pts)

(a) \( \text{H}_3\text{C} - \text{C} - \text{OH} \) \( \text{CH}_3\text{CH}_2 - \text{OH} \) \( \text{H}_3\text{C} - \text{C} - \text{OH} \)
(b) \( \text{CO}_2\text{H} \) \( \text{CO}_2\text{H} \) \( \text{CO}_2\text{H} \)

ii) Draw the most acidic isomer of chlorobutanoic acid. (3pts)
20) Name **five** of the following compounds in IUPAC form (14pts).

\[
\begin{align*}
&(Z) - 4\text{-fluoro-3-butenal} \\
\text{Propanoic acid anhydride} \\
\text{Butanoyl bromide} \\
5\text{-hydroxypentanoic acid lactone} \\
(E) - 5\text{-amino-2-hexenoic acid} \\
\text{N-ethyl-N-methyl propanamide}
\end{align*}
\]

21) Fill in the blanks for **two** of the following reactions. (6pts)

\[
\begin{align*}
\text{(a)} & \quad \text{NH}_2 \quad 1) \text{excess CH}_3\text{-Br} \\
& \quad 2) \text{Ag}_2\text{O, H}_2\text{O, heat} \\
\text{(b)} & \quad \text{CH}_3\text{CH}_2\text{-NH}_2 \quad \text{excess } \text{H}_3\text{C} = \text{C}-\text{Cl} \\
\text{(c)} & \quad \text{H}_3\text{C} = \text{C}-\text{CH}_3 \quad 1) \text{PhMgBr} \\
& \quad 2) \text{H}_3\text{O}^+
\end{align*}
\]
22) Fill in the blanks for three of the following reactions. (9pts)

(a) \[
\begin{align*}
\text{benzene} & \quad \xrightarrow{1) \text{HNO}_3, \text{H}_2\text{SO}_4} \quad \text{cyclopentanone} \quad 1) \text{NaNO}_2, \text{HCl} \\
& \quad \xrightarrow{2) \text{Zn}, \text{HCl}} \quad \xrightarrow{2) \text{H}_2\text{O, Steam}} \quad \text{benzene}
\end{align*}
\]

(b) \[
\begin{align*}
\text{benzene} & \quad \xrightarrow{\text{SOCl}_2} \quad \text{Cl-cyclopentane} \quad \xrightarrow{?} \quad \text{benzene}
\end{align*}
\]

(c) \[
\begin{align*}
\text{phenylamine} & \quad \xrightarrow{?} \quad \text{benzamide} \quad \xrightarrow{?} \quad \text{phenyl chloride}
\end{align*}
\]

(d) \[
\begin{align*}
\text{acetophenone} & \quad \xrightarrow{\text{CH}_3\text{NH}_2\text{H}_3\text{O}^+} \quad \text{acetamide} \quad \xrightarrow{?} \quad \text{acetophenone}
\end{align*}
\]
23) Give the mechanism for two of the below conversions (16 pts)

(a) \[
\text{NH}_2
\]
\[
\text{CH}_3\text{Br}
\]
1) excess \( \text{CH}_3\text{Br} \)
2) \( \text{Ag}_2\text{O}, \text{H}_2\text{O}, \text{heat} \)

(b) \[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}
\]
\[
\text{AlCl}_3
\]

(c) \[
\text{Ph} \quad \text{HO-NH}_2
\]
\[
\text{H}_2\text{SO}_4
\]

\[
\text{Ph} \quad \text{N-OH}
\]

\[
\text{Ph} \quad \text{Ph}
\]
*Bonus question* (up to 4 points)

Provide the common names for 4 of these compounds which we talked about this semester.

- VX
- Methamphetamine
- Ecstasy
- Penicillin V
- Cocaine
- Nicotine
- Ritalin