1) Identify the class of compounds that the following molecules belong to (12pts).

\[
\begin{align*}
R\text{-}C\equiv\text{NH}_2 & \quad R\text{-}O\text{-}H & \quad R\text{-}O\text{-}O\text{-}R \\
\text{O} & \quad \text{O} & \quad \text{O} \\
R\text{-}C\equiv\text{H} & \quad R\text{-}C\text{-}R & \quad R\text{-}C\text{-Cl} & \quad R\text{-}C\text{-O}\text{-}R
\end{align*}
\]

2) Draw a Lewis structure including lone pairs for the following similar but different species: (12pts)

\[
\text{Nitronium Ion } NO_2^+ \quad \text{Nitrosonium Ion } NO^+ \\
\text{Nitric Acid } HONO_2 \quad \text{Nitrous Acid } HONO
\]

3) Circle a molecule in (2) with an sp\textsuperscript{2} hybridized Nitrogen atom. (1.5pts)

4) Put a cross through a compound in (1) which has ring strain (1.5pts).
5) Identify the general class of each of the below reactions (e.g. oxidation, electrophilic addition, etc) (16pts)

(a) \[ \text{H}_2\text{SO}_4 \]

(b) \[ R\text{Cl} + \text{\textsuperscript{\textbullet}OH} \rightarrow R\text{OH} \]

(c) \[ R\text{CH}_{2}\text{OH} + \text{CH}_3\text{NH}_2, H^+ \rightarrow R\text{CH}_{2}\text{NH}_2^+ \]

(d) \[ \text{CH}_3\text{O}^- \]

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

(f) \[ \text{NaBH}_4 \]

(g) \[ \text{HNO}_3 \]

(h) \[ \text{HCN} \]
6) Define the following terms (10.5pts).

**CONCERTED REACTION**

**PERICYCLIC REACTION**

**THERMODYNAMIC PRODUCT**

7) Give one use of Molecular Orbital theory, and also state a disadvantage of MO theory. (4pts).

8) State whether each of the following Molecular orbitals are overall bonding, antibonding or nonbonding (4.5pts).

(a) ![Molecular Orbital](image)
(b) ![Molecular Orbital](image)
(c) ![Molecular Orbital](image)

9) Draw two Lewis resonance structures for a carboxylate anion RCO₂⁻ (4pts).

10) Which one is more stable (2pts)?
11) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the molecules are planar). (15pts)

12) Circle the more stable species in these pairs. (8pts)
13) Give the products in **six** of the following reactions, paying attention to regio/stereochemistry where applicable. (18pts)

- **Reaction 1:**
  - $\text{Ph-O-CH}_2\text{-O-CH}_2\text{Ph}$
  - Reaction: Excess HI
  - Product: $\text{Ph-O-CH}_2\text{-O-CH}_2\text{Ph}$

- **Reaction 2:**
  - $\text{Ph}$
  - Reaction: $\text{CH}_3\text{Cl, AlCl}_3$
  - Product: $\text{Ph}$

- **Reaction 3:**
  - $\text{Ph}$
  - Reaction: 1) Zn, HCl
  - Product: $\text{Ph}$
  - Reaction: 2) NaNO$_2$, HCl
  - Product: $\text{Ph}$
  - Reaction: 3) CuCl, HCl
  - Product: $\text{Ph}$

- **Reaction 4:**
  - $\text{CH}_3\text{CH}_2\text{CH}_2\text{-Br}$
  - Reaction: Br$_2$, uv light
  - Product: $\text{CH}_3\text{CH}_2\text{CH}_2\text{-Br}$

- **Reaction 5:**
  - $\text{H-C≡CF}_3$
  - Reaction: heat
  - Product: $\text{H-C≡CF}_3$

- **Reaction 6:**
  - $\text{Br-Ph-OH}$
  - Reaction: 1) NaOH
  - Product: $\text{Br-Ph-OH}$
  - Reaction: 2) CH$_3$CH$_2$CH$_2$-Br
  - Product: $\text{Br-Ph-OH}$

- **Reactions A and B:**
  - $\text{PhC=CH}_2$
  - Reaction: Cl$_2$, H$_2$O
  - Product: A
  - Reaction: KOH
  - Product: B
14) The below heterocycle is pyridine, and it is $6\pi$ Hückel aromatic.

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

Explain why there are $6\pi$ electrons (2pts)

What is the hybridization of the 5 carbons in the ring (1.5pts)

What is the hybridization of the Nitrogen atom (1.5pts)

15) Write the mechanism for the electrophilic aromatic substitution reaction below. (8pts)

\[
\text{C}_6\text{H}_5^+ + \text{HSO}_4^- \rightarrow \text{C}_6\text{H}_4^+\text{NO}_2^- \\
\begin{array}{c}
\text{NO}_2^- \\
\end{array}
\]
16) Give reagents and conditions to accomplish **five** of the following transformations. (15pts)

- Benzene $\rightarrow$ Benzoic acid $\rightarrow$ Benzoic acid
- Nitrobenzene $\rightarrow$ Nitrobenzene
- Maleic acid $\rightarrow$ Pyrrole
- Phenylacetic acid $\rightarrow$ Phenylacetaldehyde
- Propenal $\rightarrow$ Propenal
17) Circle the stronger base in the following threesomes. (10pts)

(a) 

(b) 

(c) 

(d) 

(e) 

18) Circle the stronger acid in the following pairs. (8pts)

(a) 

(b) 

(c) 

(d)
19) Name the following compounds in IUPAC form (14pts).

\[
\begin{align*}
&\text{H}_3\text{C} \quad \text{Br} \\
&\text{(CH}_3\text{CH}_2)\text{N}^+ \quad \text{F}^- \\
&\text{CH}_3 \\
&\text{CH}_3 \\
&\text{CH}_3 \\
&\text{CH}_3 \\
&\text{Ketone} \\
&\text{NH}_2 \\
&\text{HO} \\
&\text{CH}_3 \quad \text{NH}_2
\end{align*}
\]

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

(a) \[
\text{CH}_3\text{CH}_2\text{NH}_2 \quad \text{HCl}
\]

(b) \[
\text{H}_3\text{C} \quad \text{C} \quad \text{CH}_3 \quad \text{Ag}_2\text{O}
\]

(c) \[
\begin{align*}
1) &\text{excess CH}_3\text{-Br} \\
2) &\text{Ag}_2\text{O}, \text{H}_2\text{O}, \text{heat}
\end{align*}
\]
21) Give reagents for the following transformations. (9pts)

\[
\begin{align*}
\text{H} & \quad \xrightarrow{\text{Ph}} \quad \text{N} \\
\text{OH} & \quad \xrightarrow{\text{CF}_2\text{H}} \quad \text{N}
\end{align*}
\]
22) Give the mechanism for two of the below conversions. (16pts)

(a) $\text{NH}_2$  
$\text{CH}_3\text{Br}$  
$\text{Ag}_2\text{O}, \text{H}_2\text{O}, \text{heat}$

(b) $\text{N}^+\text{Cl}^-$

(c) $\text{H}_3\text{C}-\text{Ph}$  
$\text{HOCH}_2\text{CH}_2\text{OH}$  
$\text{H}_2\text{SO}_4$
*Bonus question* (up to 4 points)

Give four different ways that knowledge of organic chemistry could help you make money.
1) Identify the class of compounds that the following molecules belong to (12pts).

- $R-C-NH_2$: Amide
- $R-O-H$: Alcohol
- $R-O-O-R$: Peroxide
- $R-C-H$: Aldehyde
- $R-C-R$: Ester
- $R-C-Cl$: Chloride
- $R-C-O-R$: Esters

2) Draw a Lewis structure including lone pairs for the following similar but different species: (12pts)

- Nitronium Ion $NO_2^+$
- Nitrosonium Ion $NO^+$
- Nitric Acid $HONO_2$
- Nitrous Acid $HONO$

3) Circle a molecule in (2) with an $sp^3$ hybridized Nitrogen atom. (1.5pts)

4) Put a cross through a compound in (1) which has ring strain (1.5pts).
5) Identify the general class of each of the below reactions (e.g. oxidation, electrophilic addition, etc) (16pts)

(a) \( \text{H}_2\text{SO}_4 \) 

(b) \( \text{Nucleophilic Acyl Substitution} \)

(c) \( \text{Condensation} \)

(d) \( \text{Nuc. Aromatic Substitution} \)

(e) \( \text{Oxidation Elimination} \)

(f) \( \text{Reduction Addition} \)

(g) \( \text{Electrophilic Aromatic Substitution} \)

(h) \( \text{Addition} \)
6) Define the following terms (10.5 pts).

**CONCERTED REACTION**
A reaction that occurs in one step (bond breaking & formation at the same time).

**PERICYCLIC REACTION**
Electron movement within a closed loop of interacting orbitals.

**THERMODYNAMIC PRODUCT**
The most stable product.

7) Give one use of Molecular Orbital theory, and also state a disadvantage of MO theory. (4 pts).

Explain - delocalized bonds / aromaticity / cycloaddition reactions.
It can be complicated or confusing.

8) State whether each of the following Molecular orbitals are overall bonding, antibonding or nonbonding (4.5 pts).

(a) ![Non-Bonding MO](image)

(b) ![Antibonding MO](image)

(c) ![Bonding MO](image)

9) Draw two Lewis resonance structures for a carboxylate anion RCO₂⁻ (4 pts).

\[ R^+ \overset{\cdot}{\overset{\cdot}{\overset{\cdot}{\overset{\cdot}{\overset{\cdot}{O}}}}} \rightleftharpoons \overset{\cdot}{\overset{\cdot}{\overset{\cdot}{\overset{\cdot}{\overset{\cdot}{O}}}}} \]

10) Which one is more stable (2 pts)?

*Both the same energy.*
11) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the molecules are planar). (15pts)

- Aromatic
- Anti-Aromatic
- Non-Aromatic

12) Circle the more stable species in these pairs. (8pts)

a) 

b) 

c) 

d)
13) Give the products in **six** of the following reactions, paying attention to regio/stereochemistry where applicable. (18pts)

\[
\begin{align*}
\text{Ph} - \text{O} - \text{O} - \text{Ph} & \xrightarrow{\text{Excess HI}} \text{Ph} \quad \text{I} \quad \text{I} \quad \text{I} \\
\text{F} & \xrightarrow{\text{CH}_3\text{Cl}, \text{AlCl}_3} \text{F} \\
\text{NO}_2 & \xrightarrow{1) \text{Zn, HCl}} \text{Cl} \\
& \xrightarrow{2) \text{NaNO}_2, \text{HCl}} \text{Cl} \\
& \xrightarrow{3) \text{CuCl, HCl}} \text{Cl} \\
\text{CH}_3 & \xrightarrow{\text{Br}_2, \text{uv light}} \\
\text{H} - \equiv - \text{CF}_3 & \xrightarrow{\text{heat}} \\
\text{Br} - \text{OH} & \xrightarrow{1) \text{NaOH}} \\
& \xrightarrow{2) \text{CH}_3\text{CH}_2\text{CH}_2\text{-Br}} \\
\text{Ph} - \text{C} = \text{CH}_2 & \xrightarrow{\text{Cl}_2, \text{H}_2\text{O}} \text{A} \\
& \xrightarrow{\text{KOH}} \text{B}
\end{align*}
\]
14) The below heterocycle is pyridine, and it is 6π Hückel aromatic.

\[
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N}
\]

Explain why there are 6π electrons (2pts)

There are 3 Ti bonds = 6 electrons.

What is the hybridization of the 5 carbons in the ring (1.5pts)

\[\text{sp}^2\]

What is the hybridization of the Nitrogen atom (1.5pts)

\[\text{sp}^2\]

15) Write the mechanism for the electrophilic aromatic substitution reaction below. (8pts)

\[
\text{NO}_2^+ + \text{HSO}_4^- \rightarrow \text{NO}_2
\]
16) Give reagents and conditions to accomplish five of the following transformations. (15pts)

- Benzene $\xrightarrow{\text{Br, FeCN}}$ 1- bromocyclopentene $\xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4}$ 1-nitrobenzene
- Benzenediazonium $\xrightarrow{\text{Na}_2, \text{NH}_3, \text{C}_2\text{H}_5\text{OH}}$ 1-aminobenzene
- Acetone $\xrightarrow{\text{H}_2\text{N}-\text{NH}_3\text{H}^+}$ 1-pyrrolidine
- Benzoic acid $\xrightarrow{\text{SOCl}_2}$ 1-carboxy-1-cyclopentene $\xrightarrow{\text{LiAlH(OEt)}_3}$ 1-(methoxycarbonyl)benzene
- Allyl aldehyde $\xrightarrow{\text{NaBH}_4}$ 1-hydroxy-2-pentene $\xrightarrow{\text{H}_2\text{O}^+}$
- Benzene $\xrightarrow{\text{HNO}_3, \text{H}_2\text{SO}_4}$ 1-nitrocyclopentene $\xrightarrow{\text{Cl}_2, \text{AlCl}_3}$ 1-chlorobenzene
17) Circle the stronger base in the following threesomes. (10pts)

(a) [Compounds with different base structures]

(b) [Compounds with different base structures]

(c) [Compounds with different base structures]

(d) [Compounds with different base structures]

(e) [Compounds with different base structures]

18) Circle the stronger acid in the following pairs. (8pts)

(a) [Compounds with different acid structures]

(b) [Compounds with different acid structures]

(c) [Compounds with different acid structures]

(d) [Compounds with different acid structures]
19) Name the following compounds in IUPAC form (14pts).

5-Bromo-2-pentanone

\[ \text{CH}_3\text{C-O-CH}_3 \]

Tetraethyl Ammonium Fluoride

\[ (\text{CH}_3\text{CH}_2\text{)}_4\text{N}^+ \text{ F}^- \]

Cis-2,3-dimethyl Cyclohexanone

\[ \text{HO-C-CH}_3\text{NH}_2 \]

5-Aminopentanoic Acid

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

(a) \[ \text{CH}_3\text{CH}_2\text{-NH}_2 \] \[ \rightarrow \text{HCl} \rightarrow \text{CH}_3\text{CH}_2\text{-NH}_2\text{Cl} \]

(b) \[ \text{H}_3\text{C-C-CH}_3 \] \[ \rightarrow \text{Ag}_2\text{O} \rightarrow \text{No Reaction} \]

(c) \[ \text{NH}_2 \] \[ 1) \text{excess CH}_3\text{-Br} \]

\[ \rightarrow \text{2) Ag}_2\text{O, H}_2\text{O, heat} \]
21) Give reagents for the following transformations. (9pts)

\[
\begin{align*}
\text{O} & \quad \text{H}^+ \\
\text{O} & \quad \text{Zn, H}_2\text{O}^+ \\
\text{O} & \quad \text{PhCH}_2\text{NH}_2, \text{H}^+ \\
\text{H}_2\text{O}^+ & \quad \text{H}_2\text{O}^+ \\
\end{align*}
\]
22) Give the mechanism for **two** of the below conversions. (16pts)

(a) 
\[
\begin{align*}
&\text{CH}_2\text{Br} \\
&1) \text{excess CH}_3\text{Br} \\
&2) \text{Ag}_2\text{O, H}_2\text{O, heat}
\end{align*}
\]

(b) 
\[
\begin{align*}
&\text{NaNO}_2, \text{HCl} \\
&\text{Ph-N} = \text{N}
\end{align*}
\]

(c) 
\[
\begin{align*}
&\text{H}_2\text{SO}_4 \\
&\text{H}_3\text{C} - \text{Ph} \\
&\text{HOCH}_2\text{CH}_2\text{OH}
\end{align*}
\]

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