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

\[ \text{R-C-NH}_2 \quad \text{R-O-H} \quad \text{R-O-O-R} \]

2) Draw Lewis structures (lone pairs not required) for the following classes of compound. (12pts)

- **Ether**
- **Carboxylic Acid**
- **Peroxy Acid**

- **Cyclopropane**
- **Isocyanate**

- **Xanthate**
- **Alkyl Azide**
- **Aryl Diazonium Ion**

3) Circle the molecule in question (2) with the lowest pH (3pts)
4) The following reactions are named after their inventors - give the names of the following reactions (16pts)

(a) 

(b) 

(c) 

(d) 

(e) 

(f) 

(g) 

(h)
5) Define the following terms (15pts).

**PROTECTING GROUP**

**AROMATICITY**

**PERICYCLIC REACTION**

**KINETIC PRODUCT**

**CONJUGATED DOUBLE BONDS**

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

7) Draw all the resonance structures for the below species (don’t need curly arrows) (6pts).

\[
\begin{array}{c}
\text{N}\text{=\text{C}}\text{=O} \\
\text{H} \\
\end{array}
\]
8) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the molecules are planar). (15pts)

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

1) HOCH$_2$CH$_2$CH$_2$OH; H$_3$O$^+$
2) NaBH$_4$
3) H$_3$O$^+$

4) Excess HI

5) CH$_3$Cl, AlCl$_3$

6) Br$_2$, uv light

7) NaOH
   1) NaOH
   2) CH$_3$OCH$_2$CH$_2$-Br

8) Zn, HCl
9) NaNO$_2$, HCl
10) CuCl, HCl

Sp06org2final Page 5
11) Design a synthetic scheme for the below transformation (5pts)

\[
\begin{align*}
\text{benzene} & \xrightarrow{\text{(in exactly a 1:1 ratio)}} \text{phenol} \\
\text{phenol} & \xrightarrow{\text{(in exactly a 1:1 ratio)}} \text{diphenol}
\end{align*}
\]

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

\[
\begin{align*}
\text{benzene} & \xrightarrow{\text{NO}_2^+ \text{ HSO}_4^-} \text{nitrobenzene}
\end{align*}
\]
13) Provide reagents to accomplish **five** of the following transformations. (15pts)

- Benzene $\rightarrow$ Phenol with nitration
- Benzene $\rightarrow$ Phenol with sulfonation
- Phenol $\rightarrow$ Phenol with chlorination
- Propiolic acid $\rightarrow$ Propionic acid
- Propiolic acid $\rightarrow$ Phenylpropionic acid
14) Circle the most basic nitrogen in each molecule. (9pts)

\[ \text{N} \quad \text{N} \quad \text{NH}_2 \quad \text{CN} \quad \text{NH} \quad \text{NH}_2 \]

15) Circle the stronger acid in the following threesomes. (9pts)

(a) \( \text{CH}_3-\text{CO}_2\text{H} \quad \text{CH}_3\text{CH}_2-\text{O}-\text{H} \quad \text{CH}_3\text{CH}_2-\text{O}-\text{O}-\text{H} \)

(b) \( \text{CH}_3\text{OH} \quad \text{NH}_3 \quad \text{CH}_4 \)

(c) \[ \text{F}_2\text{CO}_2\text{H} \quad \text{CO}_2\text{H} \quad \text{CO}_2\text{H} \]

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

\[ \text{H}_3\text{C} - \text{Br} \quad \text{F}_3\text{C} - \text{O} - \text{CO}_2 \text{C}_8 \text{H}_{17} \]

\[ \text{CH}_3 \quad \text{CH}_3 \quad \text{HO} - \text{C}_8 \text{H}_{17} - \text{NH}_2 \]

Sp06org2final  Page 8
17) Fill in the blanks for two of the following reactions. (6pts)

(a) \[
\begin{array}{c}
\text{H} \\
\text{Ph}
\end{array}
\xrightarrow{\text{H}_2\text{SO}_4, \text{CH}_3\text{OH}}
\begin{array}{c}
\text{H} \\
\text{Ph}
\end{array}
\]

(b) \[
\begin{array}{c}
\text{NH}_2 \\
\text{Ph}
\end{array}
\xrightarrow{1) \text{excess CH}_3\text{-Br}}
\begin{array}{c}
\text{H} \\
\text{Ph}
\end{array}
\xrightarrow{2) \text{Ag}_2\text{O, H}_2\text{O, heat}}
\begin{array}{c}
\text{H} \\
\text{Ph}
\end{array}
\]

(c) \[
\begin{array}{c}
\text{H} \\
\text{Ph}
\end{array}
\xrightarrow{\text{NaOCH}_3, \text{CH}_3\text{OH}}
\begin{array}{c}
\text{H} \\
\text{Ph}
\end{array}
\]

18) When one equivalent of hydrogen chloride is added to the following conjugated diene, a mixture of two products is formed.

\[\text{C=C=C} \xrightarrow{\text{H-Cl}}\]

i) Draw the two products.
ii) Provide the step-by-step mechanism which explains the generation of both products.
iii) One of the products contains a chiral center. Asterix (*) that chiral carbon. (9pts)
19) Give the mechanism for two of the below conversions. (16pts)

(a)  \[
\begin{align*}
\text{CH}_3\text{OH, NaOH} & \quad \rightarrow \\
\text{HO-} & \quad \text{O-CH}_3
\end{align*}
\]

(b)  \[
\begin{align*}
\text{NaNO}_2, \text{HCl} & \quad \rightarrow \\
\text{N} & \quad \text{N}^+ \text{Cl}^{-}
\end{align*}
\]

(c)  \[
\begin{align*}
\text{H}_3\text{C}- & \quad \text{Ph} \\
\text{H}_2\text{SO}_4 & \quad \rightarrow \\
\text{HOCH}_2\text{CH}_2\text{OH} & \quad \rightarrow \\
\text{H}_3\text{C} & \quad \text{Ph}
\end{align*}
\]
*Bonus question* (up to 4 points)

During the last week of class, Dr. Roche showed photographs of his two most influential mentors. One was from England, and the other from the US.

Name those two mentors, and name the universities at which Dr. Roche was fortunate enough to learn from these world experts.
1) Identify the class of compounds that the following molecules belong to (12pts).

- **Amide**: R-C-NH₂
- **Alcohol**: R-O-H
- **Peroxide**: O
- **Epoxy**: \( \bigtriangleup \)
- **Aldehyde**: R-C-H
- **Ketone**: R-C-R
- **Acid Chloride**: R-C-Cl
- **Ester**: R-C-O-R

2) Draw Lewis structures (lone pairs not required) for the following classes of compound. (12pts)

- **Ether**: R-O-R
- **Carboxylic Acid**: R-C=O-H
- **Peroxy Acid**: R-C-O-O-H
- **Cyclopropane**: \( \bigtriangleup \)
- **Isocyanate**: R-N=C=O
- **Xanthate**: R-O-C-S-R
- **Alkyl Azide**: R-N=N=N
- **Aryl Diazonium Ion**: Ar-N=\( \oplus \)N

3) Circle the molecule in question (2) with the *lowest* pH (3pts)
4) The following reactions are named after their inventors - give the names of the following reactions (16pts)

(a) $\text{Hoffman Eun}$

(b) $\text{Fisher Esterification}$

(c) $\text{Wittig Rin}$

(d) $\text{Friedel Crafts Acylation}$

(e) $\text{Grignard Reaction}$

(f) $\text{Sondreye Reaction}$

(g) $\text{Hoffman Rearrangement}$

(h) $\text{Diels-Alder Cycladd}$
5) Define the following terms (15pts).

**PROTECTING GROUP**
A group introduced to prevent a more reactive site of the molecule from taking part in a chemical reaction. Ideally, it should be easy to introduce & remove.

**AROMATICITY**
A cyclic species that exhibits a large resonance energy (ie. is especially stable/unreactive). Must have continuous overlapping p orbitals, & (4n+2) p electrons.

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

**KINETIC PRODUCT**
The product which is formed the fastest.

**CONJUGATED DOUBLE BONDS**
Alternating double-single-double bonds. These are especially stable as the overlapping p orbitals allow for delocalization.

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

Use: accurate description of delocalized bonding, aromaticity, pericyclic behavior...

Disadvantage: completely takes a long time to write Lewis structure type mechanisms.

7) Draw all the resonance structures for the below species (don’t need curly arrows) (6pts).

![Resonance Structures](image)
8) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the molecules are planar). (15pts)

- [Images of molecules with labels: Aromatic, Anti, Non, Aromatic]

9) Pick one of the above aromatic molecules, and use the polygon rule to demonstrate its aromaticity. (8pts)

- [Images of molecules with labels: Aromatic, Non, Aromatic]

6π electrons give a closed bonding shell = v.stable

- [Images of molecules with labels: Aromatic, Non]
10) Give the products in **six** of the following reactions, paying attention to regio/stereochemistry where applicable. (18pts)

1) HOCH₂CH₂CH₂OH; H₃O⁺
2) NaBH₄
3) H₃O⁺

Excess HI

heat

CH₃Cl, AlCl₃

1) Zn, HCl
2) NaNO₂, HCl
3) CuCl, HCl

Br₂, uv light

1) NaOH
2) CH₃OCH₂CH₂-Br
11) Design a synthetic scheme for the below transformation (5pts)

\[
\text{[Diagram of reaction pathway]}\]

(in exactly a 1:1 ratio)

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

\[
\text{[Mechanism diagram]}\]
13) Provide reagents to accomplish five of the following transformations. (15pts)

- **Cyclohexane**
  1. $\text{Br}_2, \text{FeBr}_3$
  2. $\text{HNO}_3, \text{H}_2\text{SO}_4$

- **Cyclohexene**
  1. $\text{CH}_3\text{Cl}, \text{AlCl}_3$
  2. $\text{HNO}_3, \text{H}_2\text{SO}_4$
  3. $\text{KBrO}_4, \text{heat}$

- **Benzene**
  1. $\text{SOCl}_2$
  2. $\text{LiAIH}_2\text{R}_3\text{H}$

- **2-Methylpropanal**
  $\text{A}_2\text{O}$

- **Cyclohexene**
  1. $\text{HNO}_3, \text{H}_2\text{SO}_4$
  2. $\text{Cl}_2, \text{AlCl}_3$

- **2-Phenylpropanoic acid**
  1. $\text{H}_2\text{O}_2, \text{H}_2\text{O}_2^+$
  2. $\text{Ph-NH}_2, \text{H}^+$
  3. $\text{H}_3\text{O}^+$

- **2-Methylpropanal**
  $\text{A}_2\text{O}$
14) Circle the most basic nitrogen in each molecule. (9pts)

15) Circle the stronger acid in the following threesomes. (9pts)

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

(b)  \( \text{CH}_3\text{OH} \)  \( \text{NH}_3 \)  \( \text{CH}_4 \)

(c)  \( \text{F} \)  \( \text{CO}_2\text{H} \)

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

- 5-Bromo-2-pentanone
- Trifluoro octanoic anhydride
- CIS-2,3-dimethyl cyclohexanone
- 5-Aminopentanoic acid
17) Fill in the blanks for two of the following reactions. (6pts)

(a) \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{O} \\
\text{Ph} \\
\hline
\text{Ph}
\end{array}
\quad \xrightarrow{\text{H}_2\text{SO}_4, \text{CH}_3\text{OH}}
\quad \begin{array}{c}
\text{H} \\
\text{H} \\
\end{array}
\quad \xrightarrow{	ext{1) excess CH}_3\text{-Br}}
\quad \begin{array}{c}
\text{Ph} \\
\text{CH}_3
\end{array}
\quad \xrightarrow{	ext{2) Ag}_2\text{O, H}_2\text{O, heat}}
\quad \begin{array}{c}
\text{Ph}
\end{array}
\]

(b) \[
\begin{array}{c}
\text{NH}_2 \\
\text{Ph}
\end{array}
\quad \xrightarrow{\text{1) excess CH}_3\text{-Br}}
\quad \begin{array}{c}
\text{Ph}
\end{array}
\quad \xrightarrow{\text{2) Ag}_2\text{O, H}_2\text{O, heat}}
\quad \begin{array}{c}
\text{Ph}
\end{array}
\]

(c) \[
\begin{array}{c}
\text{H} \\
\text{Ph}
\end{array}
\quad \xrightarrow{\text{NaOCH}_3, \text{CH}_3\text{OH}}
\quad \begin{array}{c}
\text{O} \\
\text{Ph}
\end{array}
\]

18) When one equivalent of hydrogen chloride is added to the following conjugated diene, a mixture of two products is formed.

\[
\begin{array}{c}
\text{CH}_3
\end{array}
\quad \xrightarrow{\text{H-Cl}}
\quad \begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{Cl}
\end{array}
\quad \xrightarrow{\text{H}}
\quad \begin{array}{c}
\text{Cl}
\end{array}
\]

i) Draw the two products. ✓
ii) Provide the step-by-step mechanism which explains the generation of both products.
iii) One of the products contains a chiral center. Asterix (*) that chiral carbon. (9pts) ✓
19) Give the mechanism for **two** of the below conversions. (16pts)

(a) CH$_3$OH, NaOH

(b)  

(c) H$_2$SO$_4$
*Bonus question* (up to 4 points)

During the last week of class, Dr. Roche showed photographs of his two most influential mentors. One was from England, and the other from the US.

Name those two mentors, and name the universities at which Dr. Roche was fortunate enough to learn from these world experts.

Prof. R.D. Chambers, University of Durham, U.K.

Prof. W.R. Dolber, Jr., University of Florida, U.S.A.