1-15) are True or False (15pts)

1) Aqueous carboxylic acids have pH values above 7.

2) Penicillins contain a lactam functionality.

3) Esters undergo nucleophilic acyl substitution reactions.

4) Tertiary amides have an sp hybridized Nitrogen atom.

5) Nitriles must have at least one sp\(^2\) hybridized Nitrogen atom.

6) Esters are more reactive than anhydrides in nucleophilic acyl substitution reactions.

7) Amides are more reactive than acid fluorides in nucleophilic acyl substitution reactions.

8) Carboxylic acids can be reduced to primary alcohols by KMnO\(_4\).

9) Esters have more resonance stability than amides.

10) Nucleophilic acyl substitution reactions proceed through a linear intermediate.

11) The nucleophilic acyl substitution mechanism is an example of an addition-elimination mechanism.

12) Nitriles are less basic than secondary amines.

13) Esters are used in the flavoring and perfume industries.

14) Grignard reagents are good carbon centered nucleophiles.
15) This molecule is chiral:

\[
\begin{align*}
\text{CO}_2\text{H} & \\
\text{C} & \\
\text{CF}_3 & \\
\text{CH}_3 & \\
\text{CH}_2\text{CH}_2\text{CH}_3 & \\
\end{align*}
\]

16) (10pts) Name the general class of organic compound that each of these molecules belong to.
17) Name the following compounds in IUPAC acceptable terms. (18pts)

18) Fill in all the reagents. (12pts)
19) Fill in all the missing products. (12pts)

![Chemical reaction diagram]

20) (2+6pts) i) Why is an *anhydride* named as such?

ii) When trifluoroethanoic acid and trichloroethanoic acid are heated in the presence of sulphuric acid, 3 different anhydrides are produced. Indicate which 2 of the 3 have the *largest* molecular weights.
21) (7+2pts) i) Write the mechanism for the reaction of a SECONDARY AMINE with an ANHYDRIDE to generate an AMIDE and a CARBOXYLIC ACID.

ii) What is the NAME of this mechanism?

22) Give the product for the following transformation. (3pts)
23) What two products are formed when an acid chloride is hydrolyzed by water?

Write the mechanism for this reaction. (2+5pts)

24) Circle the strongest acid in each of the following threesomes. (6pts)

(a) \[
\begin{array}{c}
\text{O} \\
\text{CO}_2\text{H}
\end{array} \\
\begin{array}{c}
\text{F} \\
\text{CO}_2\text{H}
\end{array} \\
\begin{array}{c}
\text{Cl} \\
\text{Cl}
\end{array}
\]

(b) \[
\begin{array}{c}
\text{CH}_3\text{CH}_2\text{-O-O-H}
\end{array} \\
\begin{array}{c}
\text{CH}_3\text{-CO}_2\text{H}
\end{array} \\
\begin{array}{c}
\text{CH}_3\text{CH}_2\text{-O-H}
\end{array}
\]

(c) \[
\begin{array}{c}
\text{CH}_3\text{CO}_2\text{H}
\end{array} \\
\begin{array}{c}
\text{H}_2\text{O}
\end{array} \\
\begin{array}{c}
\text{H}_2\text{SO}_4
\end{array}
\]
*Bonus question* (up to 4pts)

Draw the mechanism for an acid catalyzed Fisher esterification.
1-15) are True or False (15pts)

1) Aqueous carboxylic acids have pH values above 7.  F

2) Penicillins contain a lactam functionality.  True

3) Esters undergo nucleophilic acyl substitution reactions.  True

4) Tertiary amides have an sp hybridized Nitrogen atom.  F

5) Nitriles must have at least one sp² hybridized Nitrogen atom.  F

6) Esters are more reactive than anhydrides in nucleophilic acyl substitution reactions.  F

7) Amides are more reactive than acid fluorides in nucleophilic acyl substitution reactions.  F

8) Carboxylic acids can be reduced to primary alcohols by KMnO₄.  F

9) Esters have more resonance stability than amides.  F

10) Nucleophilic acyl substitution reactions proceed through a linear intermediate.  F

11) The nucleophilic acyl substitution mechanism is an example of an addition-elimination mechanism.  True

12) Nitriles are less basic than secondary amines.  True

13) Esters are used in the flavoring and perfume industries.  True

14) Grignard reagents are good carbon centered nucleophiles.  True
15) This molecule is chiral:

\[ \text{CO}_2\text{H} \]
\[ \text{CH}_3\text{C} - \text{CF}_3 \]
\[ \text{CH}_2\text{CH}_2\text{CH}_3 \]

16) (10pts) Name the general class of organic compound that each of these molecules belong to.

\[ \text{R-C-O-C-R} \] \text{ANHYDRIDE}
\[ \text{R-C-NR}_2 \] \text{AMIDE}
\[ \text{LACTONE} \]
\[ \text{R-C-NH}_2 \] \text{AMIDE}
\[ \text{R-COH} \] \text{CARBOXYLIC ACID}
\[ \text{LACTAM} \]
\[ \text{R-CN} \] \text{NITRILE}
\[ \text{R-C-Br} \] \text{ACID}
\[ \text{R-C-O-R} \] \text{ESTER}
\[ \text{R-C-R} \] \text{IMINE}
17) Name the following compounds in IUPAC acceptable terms. (18pts)

\[
\begin{align*}
\text{6-N-EthylaminoHexanoic Acid} & \quad \text{Ethanamide} \\
\text{Propanoyl Fluoride} & \quad \text{2-BromoButyl Pentanoate} \\
\text{10-AminoDecanoic Acid Lactam} & \quad \text{3-HydroxyPropionic Acid Lactone}
\end{align*}
\]

18) Fill in all the reagents. (12pts)

\[
\begin{align*}
\text{Ph-C-NHCH₃} & \quad \text{CH₃NH₃⁺, H⁺} \\
\text{Ph-C-OCH₂CF₃} & \quad \text{CF₃CH₂OH, H⁺} \\
\text{Ph-C-OCH₃} & \quad \text{H₂O, H⁺} \\
\text{Ph-COH} & \quad \text{Ph-H₂SO₄, H₂O} \\
\text{Ph-C-OH} & \quad \text{Ph-H₂SO₄, H₂O}
\end{align*}
\]
19) Fill in all the missing products. (12pts)

\[
\begin{align*}
\text{CH}_3\text{C}^\text{O}\text{OCH}_3 \\
\text{NaOCH}_3 \\
\text{CH}_3\text{CH}_2\text{OH} & \rightarrow \text{LiAl(OBu)}_3\text{H} \\
\text{H}_3\text{C}\text{C}^\text{O}\text{Cl} & \rightarrow \text{CH}_3\text{C}^\text{H} \\
\text{Benzene, AlCl}_3
\end{align*}
\]

20) (2+6pts) i) Why is an anhydride named as such?

An anhydride is formally produced from two carboxylic acids by the removal of water \((-\text{H}_2\text{O})\)

ii) When trifluoroethanoic acid and trichloroethanoic acid are heated in the presence of sulphuric acid, 3 different anhydrides are produced. Indicate which 2 of the 3 have the largest molecular weights.

\[
\begin{align*}
\text{CF}_3\text{CO}_2\text{H} & \rightarrow \text{CF}_3\text{C}^\text{O} \equiv \text{C}^\text{O} \equiv \text{CF}_3 \\
\text{CCl}_3\text{CO}_2\text{H} & \rightarrow \text{CCl}_3\text{C}^\text{O} \equiv \text{C}^\text{O} \equiv \text{CCl}_3
\end{align*}
\]

Two largest M.W.
21) (7+2pts) i) Write the mechanism for the reaction of a SECONDARY AMINE with an ANHYDRIDE to generate an AMIDE and a CARBOXYLIC ACID.

ii) What is the NAME of this mechanism?

22) Give the product for the following transformation. (3pts)
23) What two products are formed when an *acid chloride* is hydrolyzed by water?

\[
R-\overset{\text{Cl}}{C} - Cl + H_2O \rightarrow R-\overset{\text{OH}}{C} - O-H + HCl
\]

Carboxylic acid
Hydrogen chloride

Write the mechanism for this reaction. (2+5pts)

- initial structure
- water addition
- proton transfer
- product formation

24) Circle the strongest acid in each of the following threesomes. (6pts)

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

(b)  
\[
\text{CH}_3-\overset{\text{CO}_2}\text{H}
\]

(c)  
\[
\text{CH}_3\overset{\text{CO}_2}\text{H}
\]

H$_2$O

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

Draw the mechanism for an acid catalyzed Fisher esterification.

\[ R-C=O-H + ROH \xrightleftharpoons{H^+} R-C-O-R + H_2O. \]