Summary of the Reactions of Chapter 9:

1) Reactions of Carboxylic Acids

- a) Reaction of a Carboxylic acid and water.
 - When placed in water, a carboxylic acid molecule acts as an acid and water acts as a base. An H⁺ from the hydroxyl group (OH) of the carboxylic acid is donated to H₂O.

O O
$$||$$
 $R-C-OH + H_2O \rightleftharpoons R-C-O^- + H_3O^+$
carboxylic acid (acid form) (base form)

- b) Neutralization: Reaction of a Carboxylic Acid and a Hydroxide Ion
 - In a **neutralization reaction**, a carboxylic acid will react with a *hydroxide-containing base* compound to produce H₂O and *a carboxylic acid salt*.

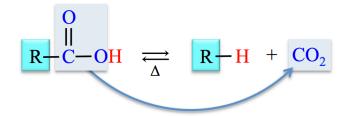
O
$$R - C - OH + NaOH \rightleftharpoons R - C - O^{-}Na^{+} + H_{2}O$$
carboxylic acid

carboxylic acid

carboxylic acid salt
(an ionic compound)

- c) Esterification: The Reaction of a Carboxylic Acid and an Alcohol
 - In an *esterification reaction*, a carboxylic acid reacts with an alcohol to produce an *ester* and water.

- d) Decarboxylation of Carboxylic Acids
 - In decarboxylation reactions, *carboxyl group* (COOH) is removed and *replaced by a hydrogen atom*.



2) Chemical Reactions of Amines

- a) Reactions of Amines with Water
 - An amine acts as a *base* when it reacts with *water* to produce a *quaternary ammonium ion* and a *hydroxide ion*.

- b) Reaction of Amines with Acids
 - An amine will react with an *acid* to produce *a quaternary ammonium compound* in a *neutralization* reaction.

$$\begin{array}{c|ccccc}
R'' \text{ or } H & + & HA & \rightleftharpoons & \begin{pmatrix} H & \\ R'' \text{ or } H & \\ R' \text{ or } H & \end{pmatrix} & A^{-} \\
\hline
R' \text{ or } H
\end{array}$$

3) Formation of Amides: The Reaction of Carboxylic Acids with Amines

• An amide is produced when a *carboxylic acid* reacts with an *amine* or *ammonia* (NH₃).

4) Hydrolysis of Amides

- The reverse of the *amide formation* reaction is the **hydrolysis of amides**.
- With heat and an acid catalyst, an amide can be hydrolyzed to produce a **carboxylic acid** and an **amine** (or ammonia).

1)	Write the chemical equation for the reaction of propanoic acid with 1-butanol (an alcohol). The formula of 1-butanol is CH ₃ -CH ₂ -CH ₂ -CH ₂ -OH.
2)	Write the chemical equation for the reaction of ethanoic acid with N-methylethanamine.
3)	Write the chemical equation for a pentanoate ion <i>acting as base</i> when it reacts with hydrochloric acid (HCl).
4)	Write the chemical equation for the <i>decarboxylation</i> of 2-methyl-propanoic acid.
5)	Write the chemical equation for the reaction of propanoic acid with water.

6) Write the chemical equation for the reaction of *N*,*N*-diethyl-1-propanamine with water. (Hint: the amine is a base):

7) Complete the following reactions:

a)

O
$$\parallel CH_3CH_2CH_2CH_2 - C - OH (aq) + H_2O (l)$$

b)

$$CH_3 - N - H (aq) + H_2O (l)$$

$$CH_2CH_3$$

c)

O
$$\parallel$$
 $CH_3CH_2 - C - OH (aq) + NaOH (aq)$

d)

$$\begin{array}{c} O \\ \parallel \\ CH_3-C-O-H + CH_3CH_2 CHCH_2OH \\ \mid \\ CH_2CH_3 \end{array}$$

e) decarboxylation

$$\begin{array}{c}
O \\
\parallel \\
CH_3CH_2-C-O-H
\end{array}$$
+ CO₂

f)

$$\begin{array}{c} O \\ \parallel \\ CH_3CH_2-C-O-H + NH_3 \end{array} \;\; \rightleftharpoons \;\;$$

g)

h)

i)

8) Fill in the missing reactant(s):

a)

CH₃ CH₂CH₂CH₃ + CO₂ (decarboxylation reaction)

b)

c)

d)

O
$$\parallel$$
 + H₂O (l) \rightleftharpoons CH₃CH₂CH₂CH₂-C - O⁻ (aq) + H₃O⁺ (aq)

e)

f)

 CH_2CH_3

Key

1) Write the chemical equation for the reaction of propanoic acid with 1-butanol (an alcohol). The formula of 1-butanol is CH₃-CH₂-CH₂-CH₂-OH.

2) Write the chemical equation for the reaction of ethanoic acid with N-methylethanamine.

$$\begin{array}{c} \mathbf{O} \\ \parallel \\ \mathbf{CH_3 - C - O - H} \\ + \mathbf{H - N CH_2CH_3} \\ \parallel \\ \mathbf{CH_3 - C - N CH_2CH_3} \\ + \mathbf{H_2O} \\ \parallel \\ \mathbf{CH_3} \\ \end{array}$$

3) Write the chemical equation for a pentanoate ion *acting as base* when it reacts with hydrochloric acid (HCl).

O
$$\parallel$$
 CH₃ CH₂ CH₂CH₂C $-$ O $^-$ + HCl \rightleftharpoons CH₃ CH₂ CH₂CH₂C $-$ OH $+$ Cl $^-$

4) Write the chemical equation for the *decarboxylation* of 2-methyl-propanoic acid.

$$\begin{array}{c|cccc}
\mathbf{O} \\
& \parallel \\
& \text{CH}_3\text{CH} - \mathbf{C} - \mathbf{O} - \mathbf{H} \\
& \parallel \\
& \text{CH}_3
\end{array}$$

$$\begin{array}{c|ccccc}
& \text{CH}_3\text{CH}_2\text{ CH}_3 + \mathbf{CO}_2 \\
& \parallel \\
& \text{CH}_3
\end{array}$$

5) Write the chemical equation for the reaction of propanoic acid with water.

O O
$$\parallel$$
 CH₃CH₂ - C - OH (aq) + H₂O (l) \rightleftharpoons CH₃CH₂ - C - O (aq) + H₃O (aq)

6) Write the chemical equation for the reaction of *N*,*N*-diethyl-1-propanamine with water. (Hint: the amine is a base):

7) Complete the following reactions:

a) O O O
$$\parallel$$
 CH₃CH₂CH₂CH₂-C - OH (aq) + H₂O (l) \rightleftharpoons CH₃CH₂CH₂CH₂-C - O⁻ (aq) + H₃O⁺ (aq)

b)

c)

O O
$$\parallel$$
 CH₃CH₂ - C - OH (aq) + NaOH (aq) \rightleftharpoons CH₃CH₂ - C - O⁻ Na⁺ (aq) + H₂O (1)

d)

O
$$CH_3 - C - O - H + CH_3CH_2 CHCH_2OH$$

$$CH_3 - C - O - CH_2CH CH_2CH_3 + H_2O$$

$$CH_3 - C - O - CH_2CH CH_2CH_3 + CH_2CH_3$$
e)

$$\begin{array}{c|cccc}
O & & & & \\
\parallel & & & & \\
CH_3CH_2 - C - O - H & & \rightleftharpoons & CH_3CH_3 + CO
\end{array}$$

$$\begin{array}{c} O \\ \parallel \\ CH_3CH_2-C-O-H+NH_3 \end{array} \qquad \begin{array}{c} CH_3CH_2-C-NH_2 + H-O-H \end{array}$$

g)

$$CH_{3}CH_{2} CHCH_{2}-C-OH+CH_{3}OH$$

$$CH_{3}CH_{2} CHCH_{2}-C-O-CH_{3}+H_{2}O$$

$$CH_{3}$$

$$CH_{3}$$

h)

CH₃ CH₂-C-OH + HNCH₂CH₃
$$\rightleftharpoons$$
 CH₃CH₂-C-NCH₂CH₃ + H₂O $\stackrel{|}{\underset{CH_2CH_3}{|}}$ CH₂CH₃

i)

8. Fill in the missing reactant(s):

a)

$$\begin{array}{c|ccccc}
\mathbf{O} & & & & \\
& & & & \\
\text{CH}_3 \text{ CH}_2\text{CH}_2 \text{ CH}_2 - \mathbf{C} - \mathbf{O} - \mathbf{H} & & & & \\
\end{array}$$

$$\begin{array}{c|ccccccccc}
\mathbf{CH}_3 \text{ CH}_2\text{CH}_2\text{CH}_3 & + & \mathbf{CO}_2
\end{array}$$

b)

O
$$\parallel$$
 $CH_3CH_2 CH_2 - C - OH + CH_3NH_2$
 \rightleftharpoons
 $CH_3CH_2 CH_2 - C - NCH_3 + H-O-H$
 \parallel
 \parallel