3055 BA SANGAM COLLEGE

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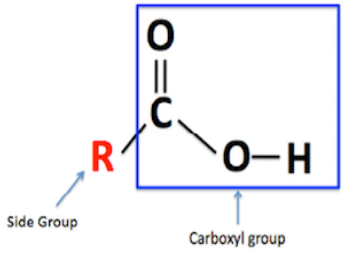
WORKSHEET 19

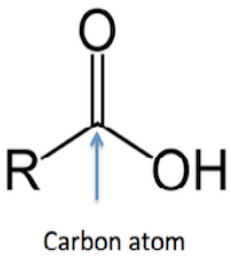
School: Ba Sangam College **Year:** 13
Subject: Chemistry **Name:**

Strand	**4 - Materials**
Sub strand	**4.2- Organic Chemistry**
Content Learning Outcome	**-State the general formula of carboxylic acids.** **-Describe the physical properties of carboxylic acids.** **-Describe methods of carboxylic acid preparation and write reaction equations for these reactions.**

Carboxylic Acids

-General formula RCOOH.





Many food and food items used daily contain carboxylic acids. For instance, vinegar contains ethanoic acid. Human breast milk and cow's milk contain a substituted carboxylic acid, commonly known as lactic acid.

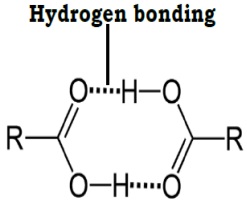
Physical Properties of Carboxylic Acids

The physical properties (such as, boiling point and solubility) of the carboxylic acids are governed by their ability to form hydrogen bonds.

1. Boiling Points

Carboxylic acids have high boiling points due to the intra molecular hydrogen bonding. The higher boiling point of the carboxylic acids is still caused by hydrogen bonding, but operating in a different way.

-Dimer is a molecule or molecular complex consisting of two identical molecules linked together.



This immediately doubles the size of the molecule and so increases the van der Waals dispersion forces between one of these dimers and its neighbors, resulting in a high boiling point.

2. Solubility in water

-In the presence of water, the carboxylic acids do not dimerise. Instead, hydrogen bonds are formed between water molecules and individual molecules of acid.

The solubility of the bigger acids decreases very rapidly with size. This is because the longer hydrocarbon "tails" of the molecules get between water molecules and break the hydrogen bonds. In this case, these broken hydrogen bonds are only replaced by much weaker van der Waals dispersion forces. Also the longer carbon chains make the acid slightly non-polar, thus less soluble in water.

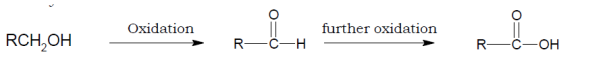
Preparation of carboxylic acids

-Primary alcohols and aldehydes are normally oxidised to carboxylic acids using potassium dichromate solution in the presence of dilute sulphuric acid. During the reaction, the potassium dichromate solution turns from orange to green.

Note: The potassium dichromate can be replaced with sodium dichromate.
This is because what matters is the dichromate ion, all the equations and
colour changes would be the same. Also potassium permanganate can be
used as the oxidising agent with change in colour from purple to colourless.

a. Oxidation of Primary Alcohols

Primary alcohols are oxidised to carboxylic acids in two stages - first to an aldehyde and then to the acid.



(Primary alcohol) (Aldehyde) (Carboxylic acid)

The complete equation for the conversion of a primary alcohol to a carboxylic acid is:

$$3RCH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3RCOOH + 4Cr^{3+} + 11H_2O$$

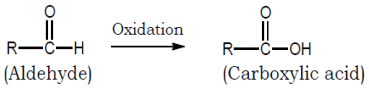
Example

$$3CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$$

(Ethanol) (Ethanoic acid)

b. Oxidation of Aldehydes

If you are starting with an aldehyde, then the aldehyde would directly be oxidised to carboxylic acid.



The complete equation for the conversion of an aldehyde to a carboxylic acid is:

$$3RCHO + Cr_2O_7^{2-} + 8H^+ \rightarrow 3RCOOH + 2Cr^{3+} + 4H_2O$$

Example

$$\underset{\text{(Ethanal)}}{3CH_3CHO} + Cr_2O_7^{2-} + 8H^+ \rightarrow \underset{\text{(Ethanoic acid)}}{3CH_3COOH} + 2Cr^{3+} + 4H_2O$$

The alcohol is heated under reflux with an excess of a mixture of potassium dichromate solution and dilute sulphuric acid.

When oxidation is complete, the mixture can be distilled, leaving behind an aqueous solution of the acid.

Note:

1. Heating under reflux (heating in a flask with a condenser placed vertically in it) prevents any aldehyde formed from escaping before it has time to be oxidised to the carboxylic acid.
2. Using an excess of oxidising agent ensures there is enough oxidising agent present for the oxidation of all the alcohol to the carboxylic acid.

Why are carboxylic acids acidic?

From the definition of an acid as a "**substance which donates protons (hydrogen ions) to other substances**", the carboxylic acids are acidic because of the hydrogen in the (-COO**H**) group.

In water solution, a hydrogen ion is transferred from the -COOH group to a water molecule.

Example

With an ethanoic acid, you get an ethanoate ion formed together with a hydronium ion, H_3O^+.

This reaction is reversible. This means that at one point in time, only a very little percentage of ethanoic acid would dissociate to give ethanoate ion.

Ethanoic acid is therefore a weak acid.

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

Reactions of carboxylic acids

1. with metals

Carboxylic acids react with the more reactive metals to produce a salt and hydrogen gas. The reactions are the same as with strong acids like Hydrochloric acid, except they are slower.

Examples

a. **Reaction of dilute ethanoic acid with sodium**
Sodium reacts to produce a colourless solution of sodium ethanoate, and hydrogen gas is given off.

$$\underset{\text{(Ethanoic acid)}}{2CH_3COOH} + 2Na \rightarrow \underset{\text{(Sodium ethanoate)}}{2CH_3COONa} + H_2$$

a) **Reaction of dilute ethanoic acid with magnesium**
Magnesium reacts to produce a colourless solution of magnesium ethanoate, and hydrogen gas is given off.

$$\underset{\text{(Ethanoic acid)}}{2CH_3COOH} + Mg \rightarrow \underset{\text{(Magnesium ethanoate)}}{(CH_3COO)_2Mg} + H_2$$

2. with metal hydroxides

These are simple neutralisation reactions and are the same as any other reaction in which hydrogen ions from an acid react with hydroxide ions.

Example

When dilute ethanoic acid is mixed with sodium hydroxide solution, a colourless solution containing sodium ethanoate is produced.

Note: The rise in temperature indicates that a change has happened.

Reaction equation

$$\underset{\text{(Ethanoic acid)}}{CH_3COOH} + NaOH \rightarrow \underset{\text{(Sodium ethanoate)}}{CH_3COONa} + H_2O$$

3. With carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-)

When carboxylic acids react with carbonates and bicarbonates, a salt is formed together with carbon dioxide and water. Both are most easily represented by ionic equations.

a) **With carbonates:**

Example

If some dilute ethanoic acid is poured onto some white sodium carbonate crystals, there is an immediate fizzing as carbon dioxide gas is produced. A colourless solution of sodium ethanoate is formed.

$$\underset{\text{(Ethanoic acid)}}{2CH_3COOH} + Na_2CO_3 \rightarrow \underset{\text{(Sodium ethanoate)}}{2CH_3COONa} + H_2O + CO_2$$

b) **With bicarbonates:**

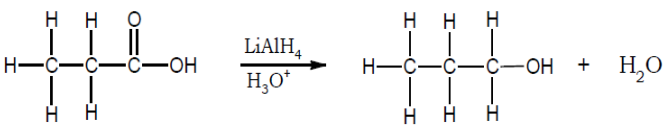
If some dilute ethanoic acid is poured onto some white sodium bicarbonate crystals, there is an immediate fizzing as carbon dioxide gas is produced. A colourless solution of sodium ethanoate is formed.

$$\underset{\text{(Ethanoic acid)}}{CH_3COOH} + NaHCO_3 \rightarrow \underset{\text{(Sodium ethanoate)}}{CH_3COONa} + H_2O + CO_2$$

4. Reduction of carboxylic acids

Carboxylic acids are easily reduced to alcohols by strong reducing agents, such as lithium aluminum hydride (LiAlH4). Most reductions of carboxylic acids lead to the formation of primary alcohols.

Example



Exercise

1. Explain the following statements.

a. Carboxylic acids have high boiling points.

_____
_____
_____
_____
_____

b. Small carboxylic acids are soluble in water.

_____
_____
_____
_____
_____

2. a. Describe a dimer?

_____
_____
_____
_____

b. Illustrate dimerisation using ethanoic acid as an example.

_____
_____
_____
_____
_____
_____
_____

3. Which of the following carboxylic acids may have the highest boiling point?
   A. Heptanoic acid
   B. Octanoic acid
   C. Nonanoic acid
   D. Decanoic acid

4. Which of the following compounds would be most soluble in water?
   A. Ethane
   B. Ethanoic acid
   C. Pentane
   D. Octanoic acid

5. Which of the following reaction types can be used to synthesise carboxylic acids?
   A. Oxidation of an aldehyde
   B. Reduction of an aldehyde
   C. Oxidation of a ketone
   D. Reduction of a ketone

6. Complete and balance the following reactions and name the major organic product(s) formed.

a. $CH_3CH_2CH_2COOH + Mg \rightarrow$ _____

b. $CH_3CH_2COOH + NaOH \rightarrow$ _____

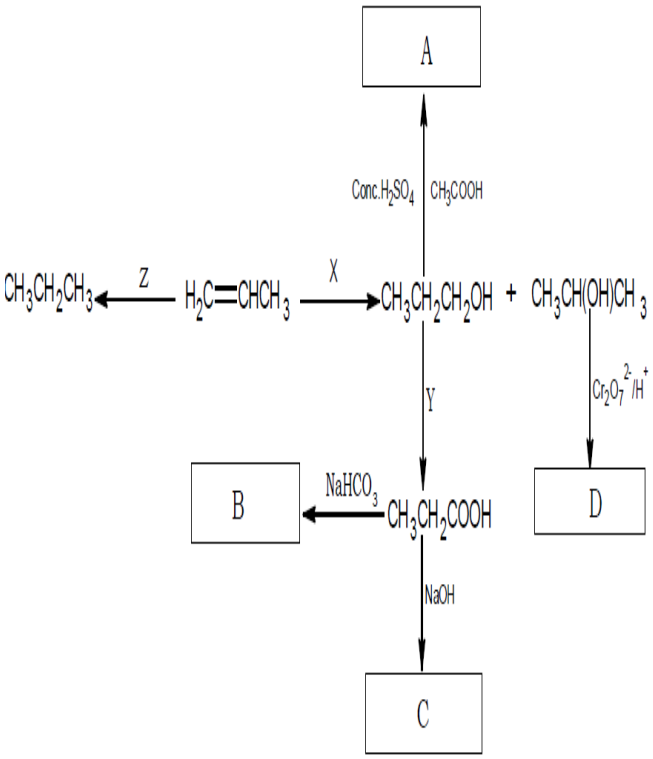
c. $CH_3CH_2COOH + Na_2CO_3 \rightarrow$ _____

d. $CH_3COOH + NaHCO_3 \rightarrow$ _____

7. Carboxylic acids are easily reduced to alcohols by strong reducing agents. Complete the equation below which shows the reduction of ethanoic acid and name the major organic product formed.

$$CH_3COOH \xrightarrow[H_3O^+]{LiAlH_4}$$ _____

8. Complete the reaction diagram, by writing the correct reagents and reaction conditions X, Y, Z and also name the organic products A-D.



A- _____

B- _____

C- _____

D- _____

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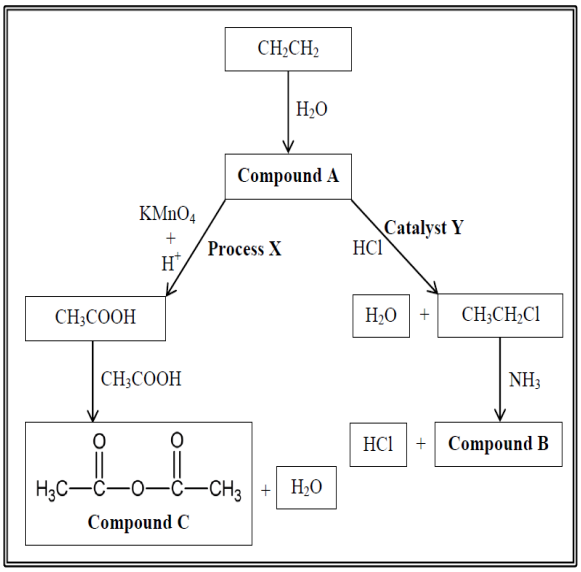
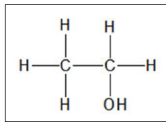
The reaction sequence given below shows some common reactions of organic compounds. Use the information to answer the questions that follow.



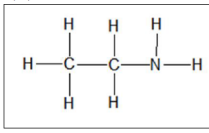
(i) Write the formula of **Compound A**. **(1 mark)**
(ii) Name **Process X**. **(1 mark)**
(iii) Determine the name or formula of **Catalyst Y**. **(1 mark)**
(iv) Write the formula of **Compound B**. **(1 mark)**
(v) Name the class of organic compound to which **Compound C** belongs. **(1 mark)**

Answer:

(i)  **CH_3CH_2OH OR; C_2H_5OH**

(ii) **Oxidation/ Oxidation of alcohol**

(iii) **Zinc chloride/ $ZnCl_2$**

(iv)  **$CH_3CH_2NH_2$ OR; $C_2H_5NH_2$**

(v) **Acid anhydride/anhydride**

Additional Notes

- (i) CH_2CH_2 is an alkene which reacts with water to form an alcohol.
- (ii) Compound A is an alcohol which in the presence of acidified $KMnO_4$, undergoes oxidation to produce a carboxylic acid.
- (iii) The catalyst $ZnCl_2$ is used to convert an alcohol into an alkyl halide.
- (iv) When alkyl halide reacts with NH_3, an amine ($CH_3CH_2NH_2$) is produced.
- (v) Two carboxylic acids react to form anhydride.

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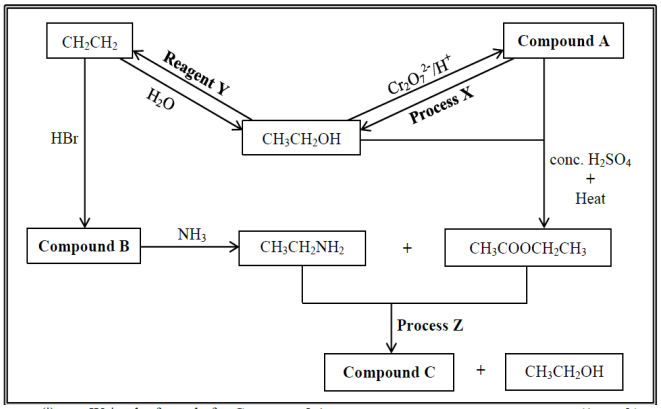
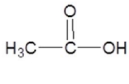
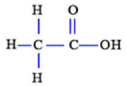
(b) The reaction sequence below shows some common reactions of important classes of organic molecules. Use the information to answer the questions that follow.



(i) Write the formula for **Compound A**. **(1 mark)**

Answer and Additional Notes

CH_3COOH OR;  **OR;** 

- Students should have realised that the reagents $Cr_2O_7^{2-}/H^+$ causes the oxidation of the alcohol, ethanol to ethanoic acid.

(ii) Name **Process X** that converts **Compound A** to CH_3CH_2OH. **(1 mark)**

Answer and Additional Notes

- ✓ **Reduction/ Reduction of a carboxylic acid** (1 mark)
- The reverse of oxidation process is reduction as it converts the carboxylic acid back to the alcohol.

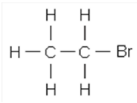
(iii) Identify **Reagent Y**. **(1 mark)**

Answer and Additional Notes

- ✓ **conc. H_2SO_4/ concentrated sulphuric acid** (1 mark)
- The conversion of an alcohol (CH_3CH_2OH) to an alkene (CH_2CH_2) is a dehydration reaction and is initiated by conc. H_2SO_4. Few students lost partial marks by stating H_2SO_4, and not conc. H_2SO_4.
- Students should realise that sulphuric acid should be concentrated and then only it can act as dehydrating agent.

(iv) Write the formula for **Compound B**. **(1 mark)**

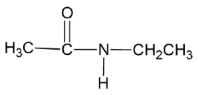
Answer and Additional Notes

CH_3CH_2Br OR; 

- Reacting hydrogen halide (HBr) with an alkene (CH_2CH_2) will produce an alkyl halide, for this case bromo-ethane.

(v) Write the formula for **Compound C**. **(1 mark)**

Answer and Additional Notes

$CH_3CONHCH_2CH_3$ OR; 

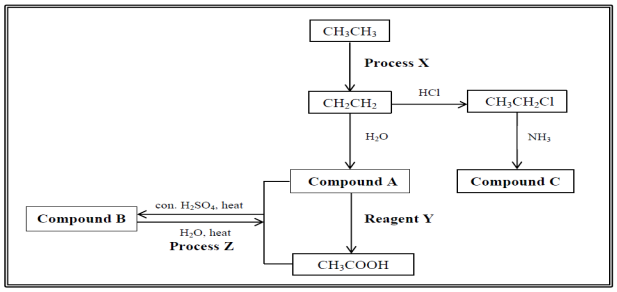
- Process Z shows the reaction between an amine and an ester. The product formed is an amide.

(vi) Name the specific **type of bond** formed during **Process Z**. **(1 mark)**

Answer and Additional Notes

- ✓ **Amide bond** (1 mark)
- The bond formed between the carbon of the ester and the nitrogen of the amine (C – N) is specifically termed as an amide bond.

(a) The reaction sequence below shows some common reactions of important classes of organic molecules. Use the information to answer the questions that follow.



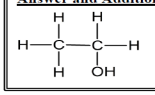
(i) Name the **Process X**. **(1 mark)**

Answer and Additional Notes

- ✓ **Dehydrogenation OR Elimination** (1 mark)
- Process X involves the conversion of an alkane (CH_3CH_3) to an alkene (CH_2CH_2). Two hydrogen atoms are eliminated so the process can be elimination or specifically dehydrogenation.

(ii) Write the formula for **Compound A**. **(1 mark)**

Answer and Additional Notes

 **CH_3CH_2OH OR C_2H_5OH**

- Compound A is a product of an addition reaction.
- Alkenes (ethene: CH_2CH_2) reacts with water to produce an alcohol (ethanol: CH_3CH_2OH).

(iii) Identify **Reagent Y**. **(1 mark)**

Answer and Additional Notes

- ✓ **Acidified $KMnO_4$/ K_2CrO_7/ Any other oxidising agent** (1 mark)
- Compound A (alcohol) gets oxidised to a carboxylic acid by reagent Y. Reagent Y can be any oxidising agent.

(iv) Name the **Process Z** (forms **Compound A** and CH_3COOH) **(1 mark)**

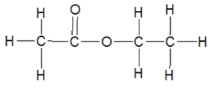
Answer and Additional Notes

- ✓ **Hydrolysis/ desterification** (1 mark)

(v) Write the formula for organic **Compound B** (formed by reacting **Compound A** and CH_3COOH) and **Compound C**. **(2 marks)**

Answer and Additional Notes

Compound B

$CH_3COOCH_2CH_3$ OR 

- Compound B is an **ester** as it is a product of an esterification reaction. When an alcohol and a carboxylic acid reacts in the presence of conc. H_2SO_4 and heat, an ester is produced.