3055 BA SANGAM COLLEGE

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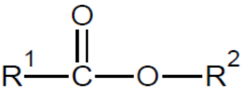
WORKSHEET 20

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 esters and name them using IUPAC nomenclature.** **-Describe the physical properties of esters.** **-Describe methods of ester preparation and write reaction equations for these reactions.**

Esters

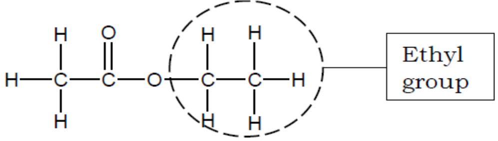
A carboxylic acid contains the -COOH group, and in an ester, the hydrogen in this group is replaced by a hydrocarbon group.



(Esters)

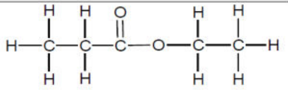
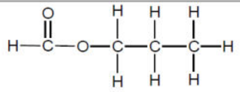
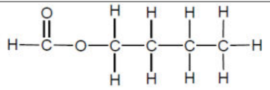
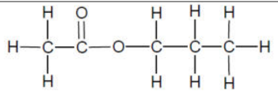
Example: Ethyl ethanoate

In ethyl ethanoate, the hydrogen in the -COOH group in carboxylic acid has been replaced by an ethyl group.



Ethyl ethanoate

Other Examples

Structural Formula	Name
	Ethyl propanoate
	Propyl methanoate
	Butyl methanoate
	Propyl ethanoate

Physical Properties of Esters

1. Boiling point

The small esters have boiling points similar to those of aldehydes and ketones with the same number of carbon atoms.

Like aldehydes and ketones, they are polar molecules and so have dipole dipole interactions. However, they do not form hydrogen bonds, and so their boiling points are not high when compared to carboxylic acids with the same number of carbon atoms.

2. Solubility in water

The small esters are fairly soluble in water but solubility falls with increasing chain length.

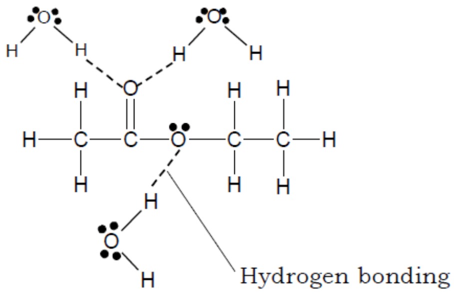
Example

Ester	Formula	Solubility (g per 100 g of water)
Ethyl methanoate	$HCOOCH_2CH_3$	10.5
Ethyl ethanoate	$CH_3COOCH_2CH_3$	8.7
Ethyl propanoate	$CH_3CH_2COOCH_2CH_3$	1.7

The reason for the solubility in water is that esters can form hydrogen bonds with water molecules (even though they cannot form hydrogen bonds with themselves).
Slightly positive hydrogen atoms in a water molecule are sufficiently attracted to the lone pair of electrons on the oxygen atoms of an ester, forming hydrogen bonds.

As chain length increases, the hydrocarbon part of the ester molecules start to get in the way. By forcing themselves between water molecules, they break the relatively strong hydrogen bonds between water molecules. This decreases the solubility of esters.

Hydrogen bonding in ester and water molecule



Preparation of Esters

a. Making esters using carboxylic acids

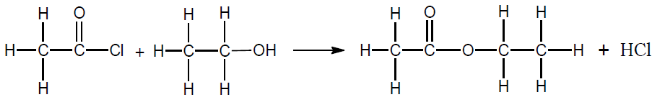
Esters are produced when carboxylic acids are heated with alcohols in the presence of an acid catalyst. The catalyst is usually concentrated sulphuric acid. The esterification reaction is both slow and reversible.

b. Making esters using acyl chlorides

If an acyl chloride is added to an alcohol, a vigorous reaction occurs (even at room temperature) producing an ester and clouds of steamy acidic fumes of hydrogen chloride.

Example

When the liquid ethanoyl chloride is added to ethanol, a burst of hydrogen chloride is produced together with the ester ethyl ethanoate.



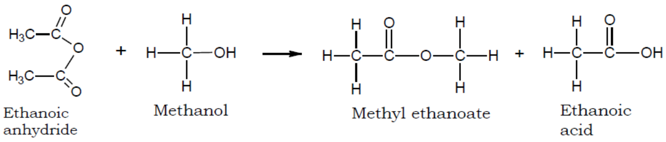
c. Making esters using acid anhydrides

Alcohols can be reacted with acid anhydrides to give esters. The reactions are slower than the corresponding reactions of alcohol with acyl chlorides.

In this case, usually the mixture needs to be warmed to increase the rate of the reaction.

Example

When methanol reacts with ethanoic anhydride, a mixture of methyl ethanoate and ethanoic acid is formed. The reaction is slow at room temperature and the reaction rate increases upon warming. There is no visible change in the colourless liquids.



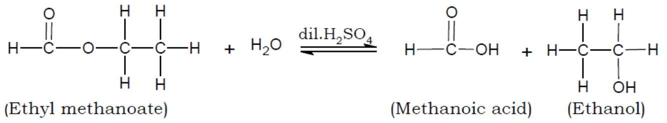
Reactions of Esters

1. Hydrolysis using acids

Hydrolysis means reacting with water. The reaction with pure water is so slow that it is never used. The reaction is catalysed by dilute acids such as hydrochloric acid or sulphuric acid. Thus, for the acid hydrolysis of esters, the ester is heated under reflux with a dilute acid.

Example

Ethyl methanoate is heated under reflux with dilute sulphuric acid. The ester reacts with the water present to produce methanoic acid and ethanol.



2. Hydrolysis using alkali

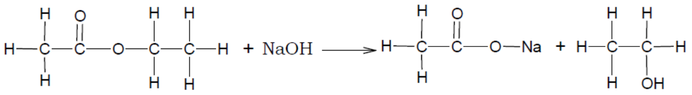
This is the most common way of hydrolysing esters. The ester is heated under reflux with a dilute alkali, such as sodium hydroxide solution.

Note:

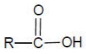
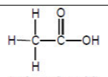
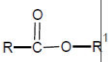
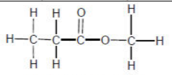
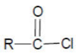
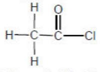
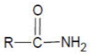
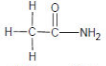
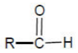
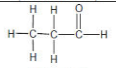
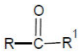
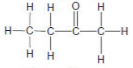
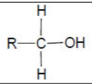
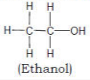
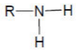
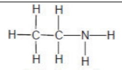
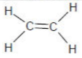
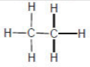
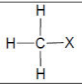
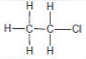
The advantages of alkali hydrolysis over an acid hydrolysis are:

1. The reactions are one-way rather than reversible.
2. The products are easier to separate.

Example



Summary - Priority of Organic Functional Groups

Functional Group	Formula of the Functional Group	General Formula	Functional group ending	Example	Priority
Carboxylic acid	 $R-C(=O)-OH$	$C_nH_{2n+1}COOH$	**- oic acid**	 (Ethanoic acid)	**Highest**
Ester	 $R-C(=O)-O-R^1$	$C_nH_{2n+2}COO$	**- oate**	 (Methyl propanoate)	
Acyl chloride	 $R-C(=O)-Cl$	$C_nH_{2n+1}COCl$	**- oyl chloride**	 (Ethanoyl chloride)	
Amide	 $R-C(=O)-NH_2$	$C_nH_{2n+1}CONH_2$	**- amide**	 (Ethanamide)	
Aldehyde	 $R-C(=O)-H$	$C_nH_{2n}O$	**- al**	 (Propanal)	
Ketone	 $R-C(=O)-R^1$	$C_nH_{2n}O$	**- one**	 (Butan-2-one)	
Alcohol	 $R-CH_2-OH$	$C_nH_{2n+1}OH$	**- ol**	 (Ethanol)	
Amine	 $R-NH-H$	$C_nH_{2n+1}NH_2$	**- amine**	 (Ethylamine)	
Alkene	C=C	CnH_2n	**- ene**	 Ethene	
Alkyne	C≡C	C_nH_{2n-2}	**- yne**	H—C≡C—H (Ethyne)	
Alkane	C-C	C_nH_{2n+2}	**- ane**	 (Ethane)	
Alkyl Halides	 $H-CH_2-X$	$C_nH_{2n+1}X$	**- ane**	 (Chloroethane)	**Lowest**

Priority of Organic Functional Groups

When compounds contain more than one functional groups, the order of priority determines which groups are named with prefix or suffix forms. The highest priority group takes the suffix, with all others taking the prefix form. However, double and triple bonds (-ene and -yne) only take suffix form and are used with other suffixes.

The order of priority of the functional groups is:

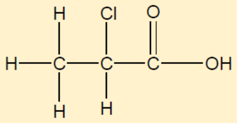
Carboxylic acids > Esters > Acyl chlorides > Amides > Aldehydes > Ketones > Alcohols > Amines > Alkenes > Alkynes > Alkane > Alkyl halides

This means that carboxylic acids have the highest priority and alkyl halides have the least.

Generally, the more oxidised a functional group, the higher its priority. This is why carboxylic acids (-COOH) have the highest priority while hydrocarbons have the lowest priority.

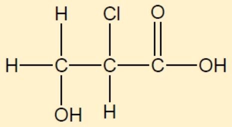
Example: Consider the name and structure of the organic compounds given below.

1.



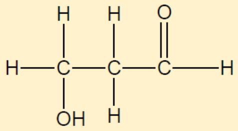
2-chloropopanoic acid

2.



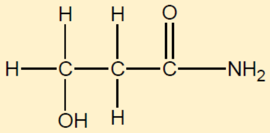
2-chloro-3-hydroxypropanoic acid

3.



3-hydroxypropanal

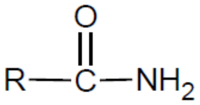
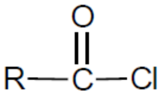
4.



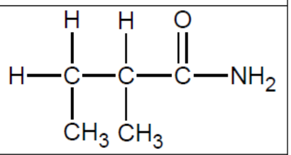
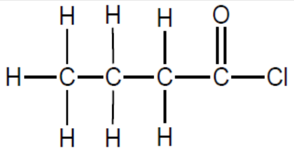
3-hydroxypropanamide

Exercise

1. Complete the table below which shows the names and general formula of some carboxylic acid derivatives.

Name	**General Formula**
Acid anhydrides	**a.**
b.	 $R-C(=O)-NH_2$
Esters	**c.**
d.	 $R-C(=O)-Cl$

2. Complete the table below which shows the names and structures of some carboxylic acid derivatives.

Name	Structure
a.	
Ethanoic anhydride	**b.**
c.	
Ethyl propanoate	**d.**

3. Complete and balance the following reaction equations.

a. $CH_3COOH + PCl_5 \rightarrow$ ______________ $+ POCl_3 + HCl$

b. __________ $+ PCl_3 \rightarrow 3CH_3COCl + H_3PO_3$

c. $CH_3COOH + CH_3CH_2OH \xrightarrow{con.H_2SO}$ _____________ $+ H_2O$

4. With the help of reaction equations, explain how the organic compound ethyl ethanoate can be made by using ethanoic anhydride and ethanol.

____

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____

____

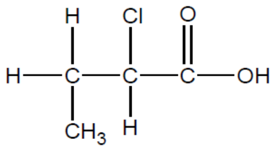
____

____

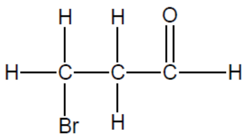
____

5. Name the following organic compounds.

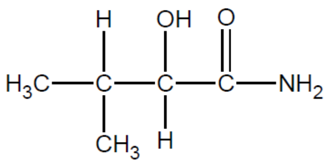
a.



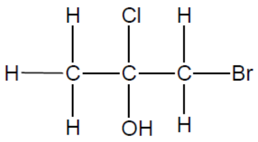
d.



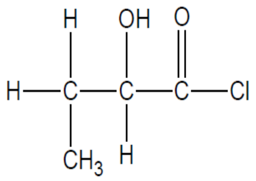
b.



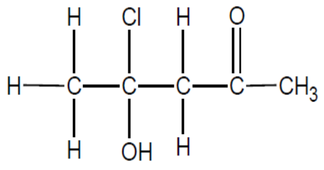
e.



c.



f.



In an **esterification reaction** an

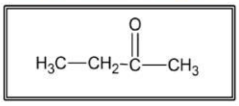
A. ester reacts with water.
B. ester reacts with an amine.
C. alcohol reacts with sodium metal.
D. alcohol reacts with a carboxylic acid.

Tollens reagent can be used to distinguish between

A. esters and amines.
B. aldehydes and ketones.
C. primary, secondary and tertiary amines.
D. primary, secondary and tertiary alkyl halides.

Additional Notes

12. The organic molecule shown below is an example of a/an

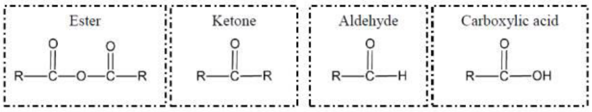


A. ester.
B. ketone.
C. aldehyde.
D. carboxylic acid.

Answer: B

Additional Notes

- A ketone has the carbonyl group (C=O) in the middle of the carbon chain (non-terminal) whereas an aldehyde has the carbonyl group (C=O) at the end of the carbon chain terminal).
- There general structure of the organic compounds mentioned in options A-D is shown below.



13. In the presence of an aldehyde, Fehling's reagent produces a ________ precipitate.

A. red
B. blue
C. white
D. silver

Answer: A

Additional Notes

- The table below shows some of the important tests for organic compounds and the expected positive results.

Test	Class of Organic Compound Tested	Positive Result
1. Test for saturation using bromine solution/ bromine water (Br_2)	• Alkanes • Alkenes • Alkynes	• No decolourisation seen • Bromine gets decolourised • Fastest rate of decolourisation
2. Lucas test/ Lucas reagent – used to differentiate between the classes of alcohols	➢ Alcohols • Primary • Secondary • Tertiary	➢ Differentiated based on difference in reactivity of each class • Very slow to no reaction • Mixture gets cloudy after few minutes • Mixture gets cloudy immediately
3. Acidified $K_2Cr_2O_7$ solution	• Aldehydes • Ketones	• Orange to green colour change – oxidised to carboxylic acid • No change – does not get oxidised
4. Acidified $KMnO_4$ solution	• Aldehydes • Ketones	• Purple to colourless – oxidised to carboxylic acid • No change
5. Tollens reagent/ Silver mirror test	• Aldehydes • Ketones	• Silver mirror seen inside the test-tube – oxidised to carboxylic • No change
6. Benedict's/ Fehling's solution	• Aldehydes • Ketones	• Blue solution changes to reddish orange precipitate – oxidised to a salt of the corresponding carboxylic acid • No change

14. The reaction of an ester with water is an example of a/an _________ reaction.

A. oxidation
B. hydrolysis
C. condensation
D. hydrogenation

Answer: B

Additional Notes

- An ester is produced by reacting an alcohol and a carboxylic acid in the presence of concentrated sulphuric acid (dehydrating agent). This is an example of a **condensation** reaction.
- The reverse of this reaction is **hydrolysis**, where the ester is broken down into an alcohol and a carboxylic acid.

11. In an **esterification reaction** an

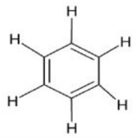
A. ester reacts with water.
B. ester reacts with an amine.
C. alcohol reacts with sodium metal.
D. alcohol reacts with a carboxylic acid.

Answer: D

Additional Notes

- A. Ester reacts with water – hydrolysis
- B. Ester reacts with an amine – nucleophilic substitution
- C. Alcohol reacts with sodium metal – substitution
- D. Alcohol reacts with a carboxylic acid – esterification reaction

(a) The structure of benzene is shown below.

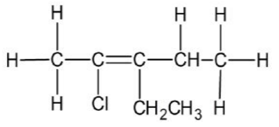


Based on the structure of benzene, explain why it is possible for benzene to undergo substitution reaction but not an addition reaction. **(2 marks)**

Answer and Additional Notes

- ✓ **Benzene ring is highly stable** so it is **very difficult to break the double bonds** for an addition reaction (1 mark). Substitution reaction **does not involve the breakdown of the double bonds** (1 mark) so occurs easily. **OR;**
- ✓ Substitution reaction only **involves the replacement of the hydrogen atom without disrupting the stability** (1 mark) whereas addition reaction **involves the breakdown of double bond from the stable ring/aromatic structure**. (1 mark) **OR;**
- ✓ **Benzene ring is highly stable due to resonance** so it is **very difficult to break the double bonds** for an addition reaction (1 mark). Substitution reaction **does not involve the breakdown of the double bonds** (1 mark) so occurs easily.
- Many students failed to explain what the question required for 2 marks.
- The explanation should have two parts:
  1. Why benzene does not undergo addition reaction?
  2. Why benzene undergoes substitution reaction?

(e) Use the IUPAC system of nomenclature to name the organic compound shown below.



(2 marks)

Answer and Additional Notes

Name

(½ mark)

2-chloro-3-ethyl pent-2-ene

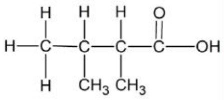
(½ mark) (½ mark) (½ mark)

Steps Involved

- Identify functional group: **alkene**
- Identify parent chain: 5 carbon: **pent**
- Identify position of functional group: 2^{nd} carbon: **pent-2-ene**
- Identify substituent and its position: **chloro** – 2^{nd} carbon
  : **ethyl** – 3^{rd} carbon
  (Number from end where functional group gets lowest value – left to right for this compound)
- Name the compound: **2-chloro written first as alphabetical order is followed.**

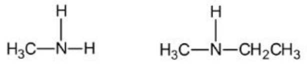
(c) Draw the structural formula of **2,3-dimethylbutanoic acid**. **(2 marks)**

Answer and Additional Notes



- To draw a structural formula from the name:
- Construct parent chain with functional group: **butanoic acid**
- Identify substituents and position: **two methyl groups (CH_3) at carbon number 2 and 3.**
- Once structure is drawn, name it to confirm if correct structure is draw (does not need to be included in the answer).

(d) Use the structure of the amines given below to answer the questions that follow.



Primary amine **Secondary amine**

(i) Identify the amine that is more basic. **(1 mark)**

Answer and Additional Notes

- ✓ **Secondary/ 2° amine** (1 mark)
- To answer this question, students should know the order of basicity of amines.
- Primary amines < Secondary Amines < Tertiary Amines
- Primary amine (1°) - has **one alkyl group** attached the carbon attached to nitrogen atom.
- Secondary amine (2°) - has **two alkyl groups** attached the carbon attached to nitrogen atom.
- Tertiary amine (3°) - has **three alkyl groups** attached the carbon attached to nitrogen atom.

(ii) Provide an explanation for your answer in part (i) above. **(2 marks)**

Answer and Additional Notes

- ✓ **The greater the number of alkyl groups attached, the more basic the amine**. (2 marks) **OR**
- ✓ **A secondary amine has greater number of alky groups**. (2 marks) **OR**
- ✓ **Alkyl groups have the ability to inductively donate electrons to the nitrogen atom** (1 mark) **making it electron rich**. (1 mark)
- ✓ (**Strength of basicity is determined by the number of alkyl groups attached to the nitrogen atom** accepted for 1 mark)
- Amine is a Lewis base (able to donate electron pair). So the more electron rich the N centre, the more basic the amine. Alkyl groups have the ability to inductively push electrons to the nitrogen atom making it electron rich.
- Since secondary amines have 2 alkyl groups, there is a greater electron density build-up on nitrogen due to increased inductive donation of electrons, making them more basic.
- Majority of the students stated that secondary amine has more hydrogens. Students should realise that the hydrogen atom on nitrogen does not have an influence the basicity of amines