

**Pioneer Junior College
Higher 2 Chemistry (9647)
Carboxylic Acids and Derivatives**

References

- 1 **Chemistry for Advanced Level, Peter Cann & Peter Hughes (Pg. 540 – 562)**
- 2 **A Level Chemistry (Fourth Edition), E. N. Ramsden (Pg. 631 – 661)**

Learning Outcomes

You should be able to:

- (a) describe the formation of carboxylic acids from alcohol, aldehydes and nitriles
- (b) describe the reactions of carboxylic acids in the formation of
 - (i) salts
 - (ii) esters on reaction with alcohols, using ethyl ethanoate as an example
 - (iii) acyl chlorides, using ethanoyl chloride as an example
- (c) explain the acidity of carboxylic acids and of chlorine-substituted ethanoic acids in terms of their structures
- (d) describe the hydrolysis of acyl chlorides
- (e) describe the reactions of acyl chlorides with alcohols, phenols and primary amines
- (f) explain the relative ease of hydrolysis of acyl chlorides, alkyl chlorides and aryl chlorides
- (g) describe the formation of esters from acyl chlorides, using phenyl benzoate as an example
- (h) describe the acid and base hydrolysis of esters

Lecture Outline**I Carboxylic acid**

- A Structure and nomenclature
- B Physical properties
- C Preparation of carboxylic acids
- D Chemical properties
- E Acid strength & effect of substituents on acidity

II Acyl chlorides

- A Structure and nomenclature
- B Physical properties
- C Preparation of acyl chlorides
- D Chemical properties

III Esters

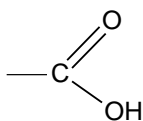
- A Structure and nomenclature
- B Preparation of esters
- C Physical properties
- D Chemical properties
- E Fats and oils; soap and detergent (not required by syllabus)

IV Summary of reactions

I Carboxylic acids

A Structure and nomenclature

1 Functional group



carboxylic acid group: a combination of a **carbonyl** and a **hydroxyl** group

2 General formula

RCO_2H $\text{R} = \text{H}$, alkyl (if R is $\text{C}_n\text{H}_{2n+1}$) or aryl group

3 Nomenclature

Carboxylic acids (highest priority in naming)

- Identify the longest continuous carbon chain, numbering the carboxylic acid carbon as position one (if not directly attached to benzene ring). The number is not indicated in the name.
- Name by replacing the '**e**' of the corresponding alkane with '**-oic acid**'.
- For benzoic acids, the C of COOH is already included in the parent name.

Structural Formula	Name
HCO_2H	methanoic acid
	2-hydroxypropanoic acid
	ethanedioic acid
	benzene-1,4-dicarboxylic acid
	3-bromobenzoic acid

Salts of carboxylic acids

- named by replacing '**ic acid**' with the suffix **-ate**

For example,

$\text{CH}_3\text{CO}_2^-\text{Na}^+$ sodium ethanoate

$\text{K}_2\text{C}_2\text{O}_4$ potassium ethanedioate

B Physical properties

1 Physical states

Aliphatic carboxylic acids (C_1 to C_9) are colourless liquids with pungent odours. Higher members (> 10 C atoms) are wax-like solids. Dicarboxylic acids and the aromatic acids are white crystalline solids.

2 Melting and boiling points

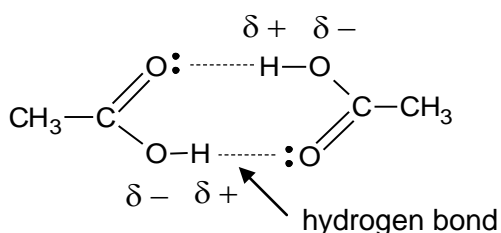
Carboxylic acids have higher melting and boiling points than alcohols of same or similar M_r

E.g. CH_3CO_2H	$M_r = 60.0$	no. of electrons = 32	b. pt. = $118^\circ C$
$CH_3CH(OH)CH_3$	$M_r = 60.0$	no. of electrons = 32	b. pt. = $97^\circ C$

Reasons:

- Extensive hydrogen bonding (more hydrogen bonding sites per molecule).
- Stronger hydrogen bonds than alcohols because the O-H bond in the acids is more polarised due to presence of electron withdrawing C=O group.

Carboxylic acid molecules dimerise in liquid state, in vapour phase and in non-polar solvents such as benzene and hexane. E.g. M_r of ethanoic acid is found to be 120.0 in benzene and in the vapour phase, and 60.0 in aqueous solution.



Include the following when drawing hydrogen bond:

- draw the $\delta+$ and $\delta-$ of the O-H bond
- draw the lone pair on the O
- draw the dotted line to indicate the bond
- label the name "hydrogen bond"

3 Solubility

Aliphatic carboxylic acids (C_1 to C_4) are completely miscible with water because the carboxylic acid molecules can form hydrogen bonding with water molecules.

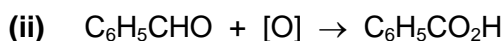
As the length of the hydrophobic alkyl chain increases, the solubility decreases. Benzoic acid ($C_6H_5CO_2H$) is only slightly soluble in cold water but dissolves readily in hot water.

C Preparation of carboxylic acid

(a) Describe formation of carboxylic acids from alcohols, aldehydes and nitriles

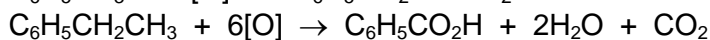
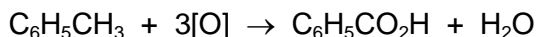
1 (a) Oxidation of primary alcohols (RCH_2OH) or aldehyde ($RCHO$)

Reagent & conditions: $KMnO_4(aq)$ or $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$, heat



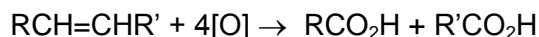
(b) Oxidation of alkylbenzene to benzoic acid

Reagent & conditions: $\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$, heat



2 Oxidative cleavage of alkenes

Reagent & conditions: $\text{KMnO}_4(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$, heat



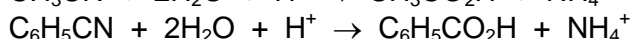
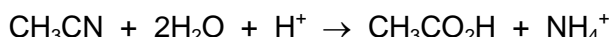
Quick Check 1

Suggest the reagents and conditions for the synthesis of acrylic acid, $\text{CH}_2=\text{CHCO}_2\text{H}$ from $\text{CH}_2=\text{CHCH}_2\text{Br}$. Give the structural formulae of the intermediate compounds formed.

Note: KMnO_4 could not be used as it would cause the oxidative cleavage of the $\text{C}=\text{C}$ bond.

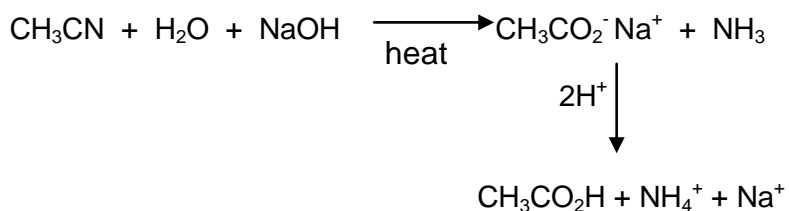
3 (a) Acid hydrolysis of nitriles ($\text{RC}\equiv\text{N}$)

Reagent & condition: $\text{H}_2\text{SO}_4(\text{aq})$ or $\text{HCl}(\text{aq})$, heat



(b) Alkaline hydrolysis of nitriles ($\text{RC}\equiv\text{N}$)

Reagent & conditions: Heat with $\text{NaOH}(\text{aq})$, then acidify with $\text{H}_2\text{SO}_4(\text{aq})$



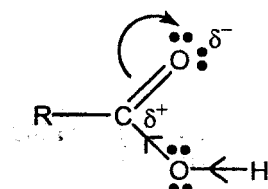
Quick Check 2

Butanedioic acid, $\text{HO}_2\text{CCH}_2\text{CH}_2\text{CO}_2\text{H}$, can be synthesised from ethene by a 3-stage reaction sequence. Suggest the reagents and conditions for each of the steps and give the structural formulae of the intermediate compounds formed.

D Chemical properties

Carboxylic acids contain a carbonyl and a hydroxyl group on the **same carbon** atom. The proximity of the 2 groups modifies each other's properties. Carboxylic acids do not behave exactly like alcohols or carbonyl compounds.

Carboxylic acids are more acidic than alcohols. The electronegative O atom in the polar C=O group attracts electrons away from the O-H bond and weakens it. This makes it easier for the H atom to ionise as compared to alcohols.



Carboxylic acids (and acyl chlorides and esters) do **not** undergo both nucleophilic addition and condensation reactions of the carbonyl compounds. E.g. they do not undergo reaction with HCN or 2, 4-dinitrophenylhydrazine (2, 4-DNPH).

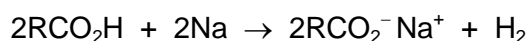
1 Cleavage of the O-H bond (i.e. acid behaviour)

(b)(i) describe the reaction of carboxylic acids in the formation of salts

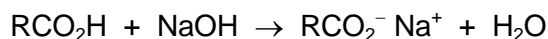
1.1 Formation of salts

Solutions of carboxylic acids turn blue litmus red and react with metals, alkalis and carbonates under normal conditions to form salts.

(a) Redox reaction with reactive metals (e.g. Na, Mg, Fe, Zn etc.)



(b) Acid-base reaction with alkalis



(c) Acid-base reaction with carbonates



The reaction with carbonates e.g. $\text{Na}_2\text{CO}_3(\text{aq})$ is a **test for carboxylic acids**. For a positive test, effervescence is observed. Colourless gas (CO_2) evolved forms a white precipitate with limewater.

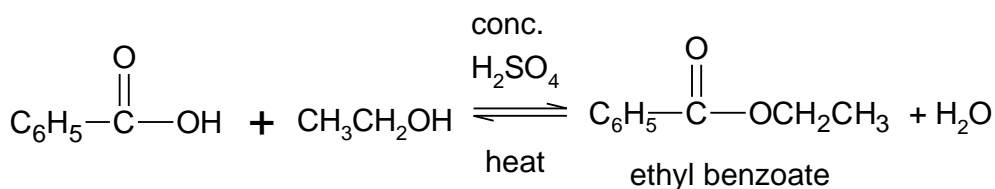
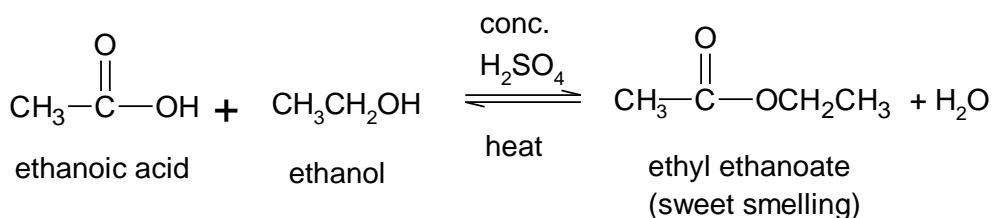
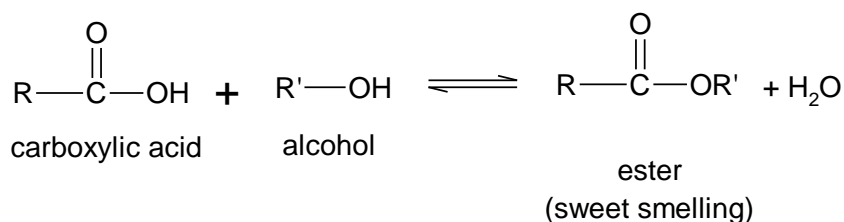
2 Cleavage of the C-O bond

2.1 Formation of esters (esterification)

(b)(ii) describe the reaction of carboxylic acids in the formation of esters on reaction with alcohols, using ethyl ethanoate as an example

Carboxylic acids react with alcohols on heating with concentrated H_2SO_4 to form esters.

Type of reaction: condensation

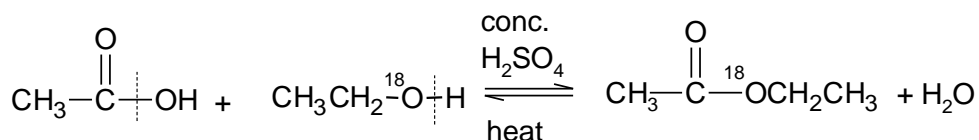


Note:

The reaction is **reversible**. The name of the forward reaction is **esterification**. The backward reaction is called **acid hydrolysis of ester**.

The concentrated sulfuric acid not only catalyses the reaction, it absorbs the water produced, thus favouring the forward reaction.

The bonds that are broken in esterification are:



If the alcohol is labelled with ^{18}O , all the ^{18}O is found to be present in the ester and none in the water.

2.2 Formation of acyl chlorides

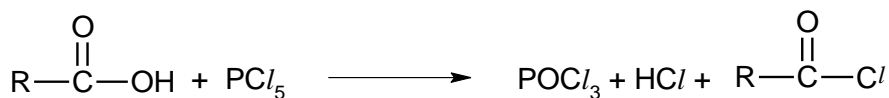
(b)(ii) describe the reaction of carboxylic acids in the formation of acyl chlorides, using ethanoyl chloride as an example

Carboxylic acids can be converted to acyl chlorides using PCl_5 at room temperature or warm with SOCl_2 .

Type of reaction: nucleophilic substitution

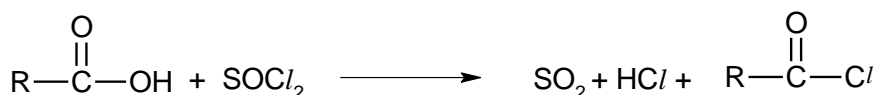
With PCl_5

Condition: room temperature



With SOCl_2

Condition: warm

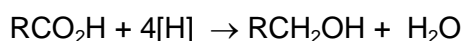


The use of SOCl_2 is preferred as the by-products ($\text{SO}_2 + \text{HCl}$) are gaseous and easily removed. [Note: Unlike alcohols, HCl(g) cannot be used as a chlorinating agent for RCOOH]

3 Reduction to primary alcohols

Carboxylic acids can **only** be reduced to primary alcohol using lithium tetrahydridoaluminate, LiAlH_4 , in dry ether at room temperature.

Reagent and condition: LiAlH_4 , in dry ether at room temperature



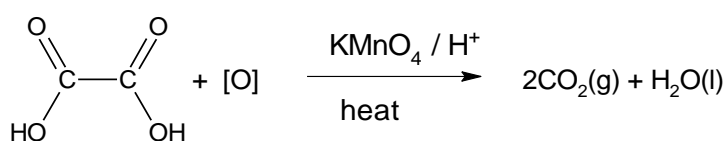
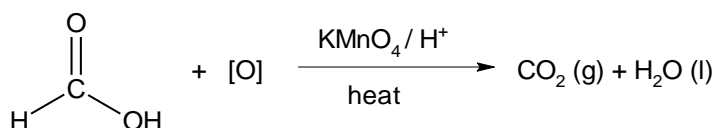
Other reducing agents, e.g. H_2 , Ni at 200°C or NaBH_4 in methanol, are **not** able to reduce carboxylic acid.

4 Special chemical properties of methanoic acid and ethanedioic acid

These two acids show the typical reactions of carboxylic acids. However, unlike most carboxylic acids, both can be readily oxidised and dehydrated.

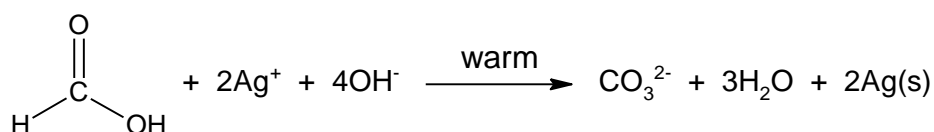
4.1 Oxidation by heating with acidified KMnO_4

Both acids are readily oxidised to give carbon dioxide and water.



4.2 Oxidation using Tollens' reagent, warm

Methanoic acid contains the aldehyde (H-C=O) group and is thus oxidised by Tollens' reagent on warming, resulting in the formation of silver mirror.

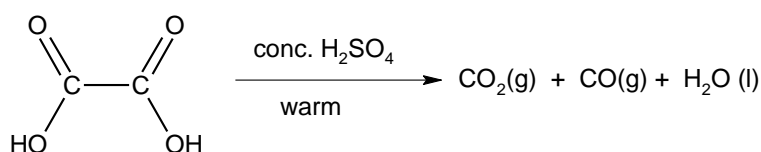
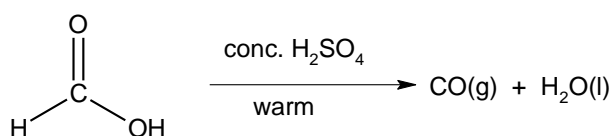


Ethanedioic acid has no aldehyde group and is not oxidised by Tollens' reagent.

4.3 Dehydration

Both acids undergo dehydration in the presence of concentrated H₂SO₄.

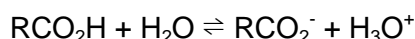
Type of reaction: elimination



E Acid strength & effect of substituents on acid strength

(c) Explain the acidity of carboxylic acids and of chlorine-substituted ethanoic acids in terms of their structures

Carboxylic acids are weak acids, dissociating slightly in aqueous solution.



$$K_a = \frac{[\text{RCO}_2^-][\text{H}_3\text{O}^+]}{[\text{RCO}_2\text{H}]}$$

1 Strength of carboxylic acids compared to alcohols, water and phenol

The acid-strength depends on the stability of the anion. The more stable the anion, the greater the extent of its dissociation (i.e. the forward reaction is favoured more), the greater is the acid strength.

Acid strength: alcohols (ROH) < H₂O < phenol < H₂CO₃ < carboxylic acids (RCO₂H)

Stability of the anion: alkoxide ion (RO⁻) < OH⁻ < phenoxide < HCO₃⁻ < carboxylate ion (RCO₂⁻)

	alcohol	phenol	carboxylic acid
Reaction with strong base (e.g. NaOH)	x	✓	✓
Reaction with NaHCO ₃ or Na ₂ CO ₃	x	x	✓

The phenoxide and carboxylate anions are stabilised by the delocalisation of the negative charge.

In the carboxylate ion, the *p* orbital of the carbon atom overlaps with the *p* orbitals from both of the oxygen atoms. This allows the delocalisation of negative charge over the two electronegative oxygen atoms (resonance stabilised).

The phenoxide ion is also stabilised by charge delocalisation due to the overlap of the *p* orbitals of carbon atoms with the *p* orbital of the oxygen atom. Thus, negative charge can be delocalised into the benzene ring. However, this delocalisation is less effective than that of the carboxylate anion as there is only one electronegative oxygen atom.

2 Effect of substituents on acid strength

The following table shows the acid dissociation constant, K_a , of some carboxylic acids at 298 K. **The larger the value of K_a , the stronger is the acid.**

Electron-withdrawing groups such as -Cl, -NO₂ will disperse the negative charge on the carboxylate anion and stabilise it, thus making the acid stronger.

Acid	$K_a / \text{mol dm}^{-3}$	Carboxylate anion
CH ₂ FCO ₂ H	2.2×10^{-3}	CH ₂ FCO ₂ ⁻
CH ₂ ClCO ₂ H	1.4×10^{-3}	CH ₂ ClCO ₂ ⁻
CH ₂ BrCO ₂ H	1.3×10^{-3}	CH ₂ BrCO ₂ ⁻

Position of the substituent also affects the acidity. The nearer the electron-withdrawing group to the acid group, the stronger the acid.

Acid	$K_a / \text{mol dm}^{-3}$	Carboxylate anion
CH ₂ Cl/CH ₂ CH ₂ CO ₂ H	3.0×10^{-5}	CH ₂ Cl/CH ₂ CH ₂ CO ₂ ⁻
CH ₃ CHCl/CH ₂ CO ₂ H	8.7×10^{-5}	CH ₃ CHCl/CH ₂ CO ₂ ⁻
CH ₃ CH ₂ CHCl/CO ₂ H	1.4×10^{-3}	CH ₃ CH ₂ CHCl/CO ₂ ⁻

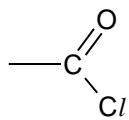
Electron-donating groups (inductive effect) such as -CH₃, when substituted into the acid, tend to increase the negative charge and destabilise the anion, thus making the acid weaker.

Acid	$K_a / \text{mol dm}^{-3}$	Carboxylate anion
HCO ₂ H	1.8×10^{-4}	HCO ₂ ⁻
CH ₃ CO ₂ H	1.8×10^{-5}	CH ₃ CO ₂ ⁻

II Acyl chlorides

A Structure and nomenclature

1 Functional group



acyl chloride group

2 General formula

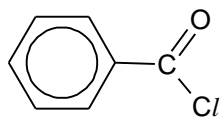
RCOCl , where R = alkyl or aryl group.

Note: acyl halide has the formula RCOX , where X can be Cl, Br or I. For the case of acyl chloride, $\text{X} = \text{Cl}$

3 Nomenclature

CH_3COCl ethanoyl chloride

$\text{CH}_3\text{CH}_2\text{COCl}$ propanoyl chloride



benzoyl chloride

B Physical properties

Acyl chlorides are usually liquids which fume in moist air. They are cannot be said to dissolve in water because they react readily with it.

Acyl chlorides are polar molecules which have permanent dipole-dipole attractions and van der Waals forces between its molecules. As they do not form hydrogen bonds, their boiling points are higher than alkanes but lower than that of alcohols of similar M_r .

C Chemical properties

The electronegativity of the oxygen and the easily polarised $\text{C}=\text{O}$ bond have a dramatic effect on the reactivity of acyl chlorides compared to that of chloroalkanes.

1 Hydrolysis

(d) describe the hydrolysis of acyl chlorides

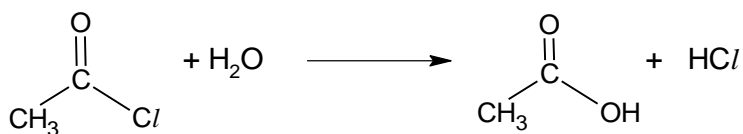
(f) explain the relative ease of hydrolysis of acyl chlorides, alkyl chlorides and aryl chlorides

1.1 Reaction with water

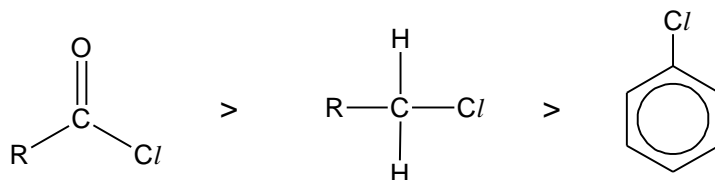
Acyl chlorides react readily with water, producing formation of steamy white fumes of HCl .

Type of reaction: hydrolysis / nucleophilic substitution

Condition: room temperature



1.2 Ease of hydrolysis compared with alkyl and aryl chlorides



The carbon atom in RCOCl is attached to **two** strongly electronegative atoms i.e. O and Cl, therefore, carries a **larger** partial positive charge (δ^+) than the carbon atom in RCH_2Cl . Hence, the carbon atom in RCOCl is *more* susceptible to nucleophilic attack than the alkyl chlorides.

Chlorobenzene is least reactive because:

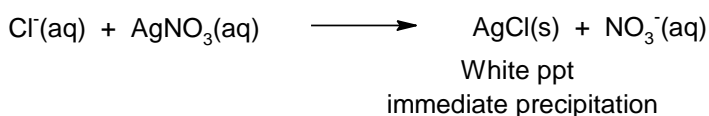
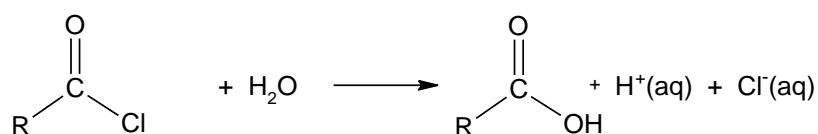
- the C-Cl bond is strengthened by delocalisation of one of the lone pairs of electrons on the Cl atom into the benzene ring,
- the high electron density on the aromatic ring tends to repel the approaching nucleophile (e.g. OH^-). (*Refer to Halogen Derivatives Notes*)

The different rates at which these three compounds undergo hydrolysis can be used as a means to differentiate and identify them.

1.3 Chemical test for halogen containing organic compounds

Test for acyl chloride (RCOCl):

Add $\text{AgNO}_3(\text{aq})$ to compound at room temperature. White precipitate of AgCl will be observed **immediately**.



Quick Check 3

Describe a separate simple chemical test in each case to distinguish $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ from

(a) $\text{CH}_3\text{COC}\text{Cl}$

(b) $\text{C}_6\text{H}_5\text{Cl}$

For each test, give reagents and conditions. State what would be seen with each compound.

Answer

(a) To each compound in separate test tubes, add $\text{AgNO}_3(\text{aq})$.

For test tube containing $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$, _____.

For test tube containing $\text{CH}_3\text{COC}\text{Cl}$, _____.

(b) To each compound in separate test tubes, add $\text{NaOH}(\text{aq})$ and heat. Cool the mixture. Acidify mixture with $\text{HNO}_3(\text{aq})$. Add $\text{AgNO}_3(\text{aq})$

For test tube containing $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$, _____.

For test tube containing $\text{C}_6\text{H}_5\text{Cl}$, _____.

2 Reactions with alcohols and phenols

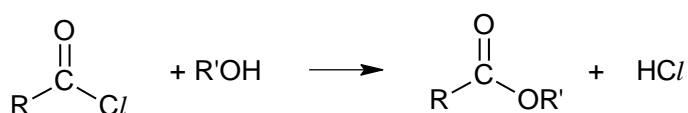
(e) describe the reactions of acyl chlorides with alcohols, phenols and primary amines

2.1 Reaction with alcohols

Acyl chlorides react readily with alcohols to form esters

Type of reaction: condensation / nucleophilic substitution

Condition: room temperature



Note:

This reaction is rapid and does not require heating. Unlike esterification which is reversible, this reaction goes to completion. It is thus useful for preparing esters.

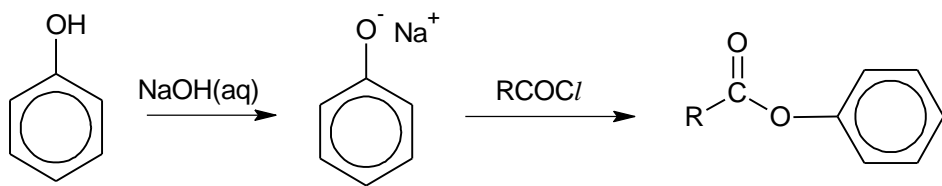
2.2 Reaction with phenol in alkaline medium

Phenol does **not** react with carboxylic acids to form ester. To make esters of phenol, acyl chlorides are made to react with phenol in alkaline solution.

Reagents and conditions:

- (1) Add $\text{NaOH}(\text{aq})$ to phenol
- (2) Add acyl chloride.

Phenol first reacts with sodium hydroxide to generate phenoxide ion (a strong nucleophile). This is followed by the nucleophilic substitution between the phenoxide ion and acyl chloride to form the ester.

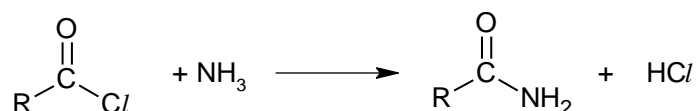


3 Reactions with ammonia, primary and secondary amines to form amides

Acyl chloride reacts vigorously with ammonia at room temperature to form a primary (1°) amide.

Type of reaction: nucleophilic substitution

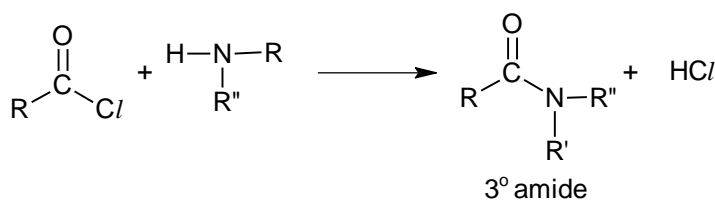
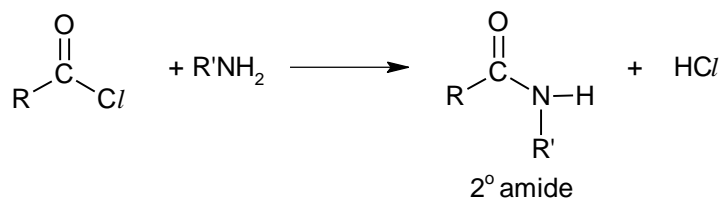
Condition: room temperature



Acyl chloride can also react with primary (2°) amine and secondary (3°) amine at room temperature to form secondary (2°) amide and tertiary (3°) amide respectively.

Type of reaction: nucleophilic substitution

Condition: room temperature



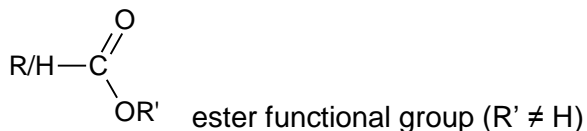
Note:

1. The **acyl group, RCO-**, is introduced. Acyl chlorides are hence called **acylating agents**.
2. Aqueous NH_3 cannot be used as H_2O molecules present will compete with NH_3 molecules as nucleophile to attack the electron deficient C atom of the acyl chloride molecule. Similarly any other solvent that can act as nucleophile is not used. Hence concentrated ammonia is used.

III Esters

A Structure and nomenclature

1 Functional group



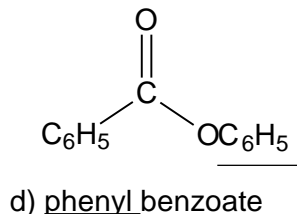
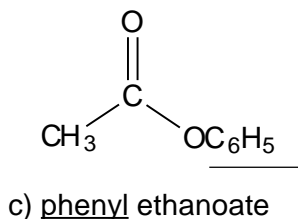
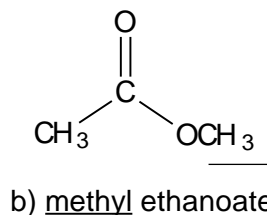
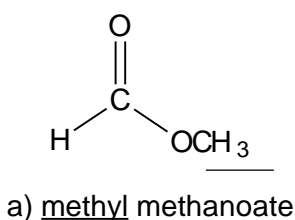
2 General formula

Esters have the general formula, $\text{C}_n\text{H}_{2n}\text{O}_2$. It is the same as carboxylic acid (every ester is isomeric with a carboxylic acid – functional group isomerism)

E.g. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$ and $\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3$ are functional group isomers.

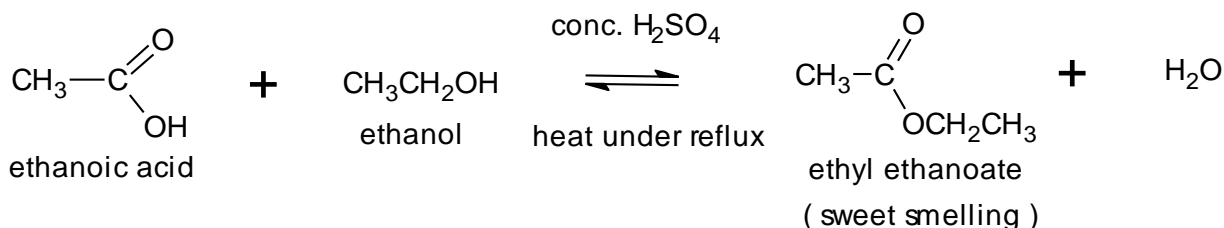
3 Nomenclature

As esters are formed (derived) from acids / acid derivatives and alcohols / phenols, they are regarded as alkyl or aryl derivatives of acids and named as follows:



B Preparation of esters

1 From carboxylic acids



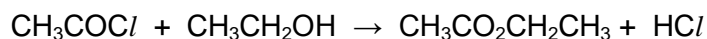
Type of reaction: condensation

Reaction is **reversible** and needs to be heated under reflux with concentrated sulfuric acid.

**Note: Refer to Hydroxy Compounds notes for the heating under reflux set up.*

2 From acyl chlorides

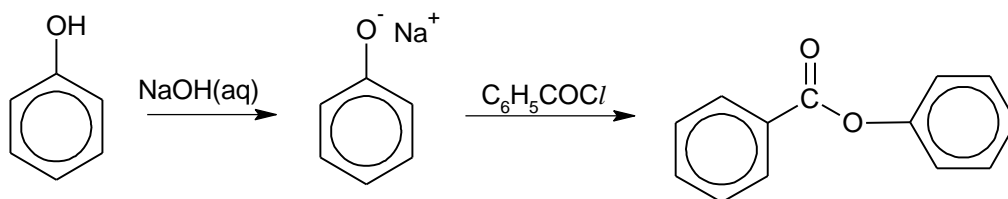
(g) describe the formation of esters from acyl chlorides, using phenyl benzoate as an example



Type of reaction: condensation / nucleophilic substitution

Reaction is rapid and goes to completion. No catalyst or heating is required

For preparation of phenyl benzoate, shake benzoyl chloride with a solution of phenol in aqueous NaOH in a stoppered conical flask for 15 minutes. A white solid is formed.



C Physical properties

Esters are isomers of carboxylic acids but they are neutral liquids with fruity smells.

Ester	Smell	Ester	Smell
ethyl methanoate	rum	pentyl ethanoate	banana
3-methylbutyl ethanoate	pear	pentyl butanoate	apricot
methyl butanoate	apple	octyl ethanoate	orange
ethyl butanoate	pineapple	methyl 2-hydroxybenzoate (methyl salicylate)	Wintergreen oil

They are insoluble in water (little hydrogen bonding with water) and widely used as organic solvents. Generally, esters are less dense than water.

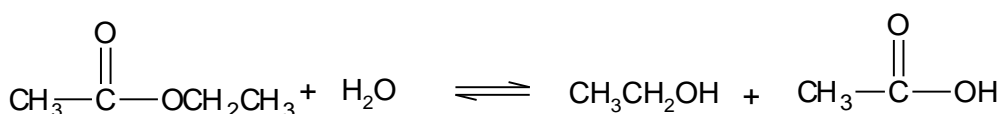
They have lower boiling points (no hydrogen bonding between molecules) compared to their isomeric acids.

D Chemical properties

(h) describe the acid and base hydrolysis of esters

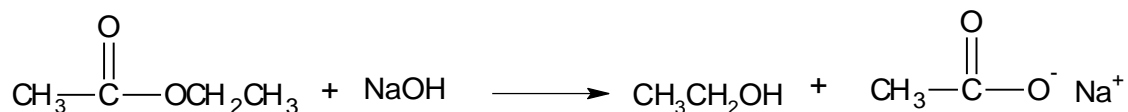
1 Acid hydrolysis (reverse of esterification)

Reagent and condition: $\text{H}_2\text{SO}_4(\text{aq})$ or $\text{HCl}(\text{aq})$, heat

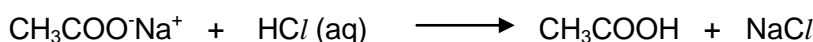


2 Alkaline hydrolysis (saponification)

Reagent and condition: NaOH(aq), heat



Upon acidification:

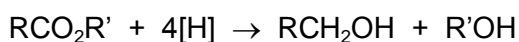


Note:

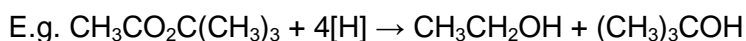
Reaction is essentially irreversible and takes place faster than acid hydrolysis. High yield of carboxylic acid obtained on acidification of the salt.

3 Reduction of ester

Reagent and conditions: LiAlH₄ in dry ether, room temperature



Products: Two alcohols, at least one of which is a primary alcohol.



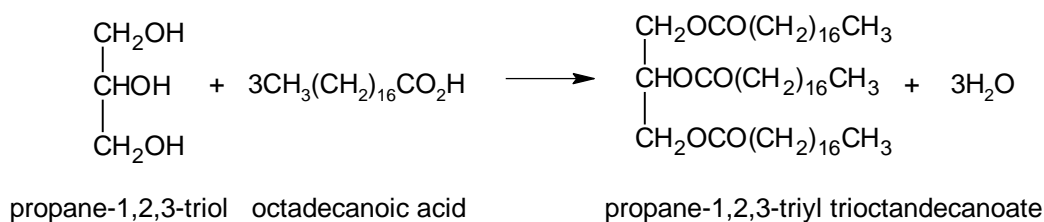
CH₃CH₂OH is a primary alcohol while (CH₃)₃COH is a tertiary alcohol.

E Fats and oils; soap and detergent (not required by syllabus)

Fats and oils are naturally occurring esters which are used as energy storage compounds by plants and animals. They are members of a larger class of naturally occurring compounds called lipids, which are insoluble in water but soluble in organic solvents.

Fats are derived from propane-1,2,3-triol, CH₂(OH)CH₂(OH)CH₂(OH) commonly known as glycerol or glycerine). This molecule has the capacity to combine with one, or two or three molecules of carboxylic acid. In practice, most fats are *triesters* derived from propane-1,2,3-triol and a variety of long chain carboxylic acids, sometimes known as fatty acids.

For example,



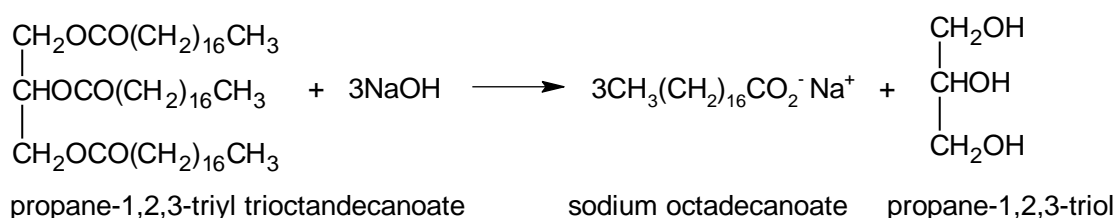
The following table gives some of the common fatty acids. There are about fifty found in nature. Most of them have an even number of carbon atoms in their molecule.

Structure	Systematic name	Common name	Occurrence
$\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2\text{H}$	octadecanoic acid	stearic acid	mainly in animal fats
$\text{CH}_3(\text{CH}_2)_{10}\text{CO}_2\text{H}$	dodecanoic acid	lauric acid	Coconut oil, palm-kernel oil
$\text{CH}_3(\text{CH}_2)_{14}\text{CO}_2\text{H}$	hexadecanoic acid	palmitic acid	most fats, especially palm oil
$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{CO}_2\text{H}$	octadec-9-enoic acid	oleic acid	most fats, especially olive oil

Fats containing a large proportion of unsaturated acids tend to have low melting points. Many are liquid at room temperature and these are called oils. They can be converted to solid fats by hydrogenation.

Like all esters, fats can be hydrolysed. If the hydrolysis is carried out by boiling the fat with an alkali such as sodium hydroxide, the products are propane-1,2,3-triol and a mixture of sodium salts of fatty acids.

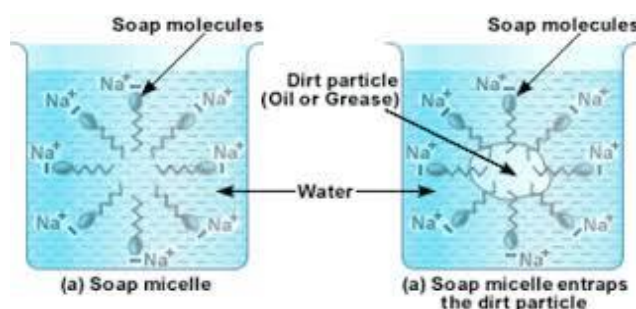
For example,



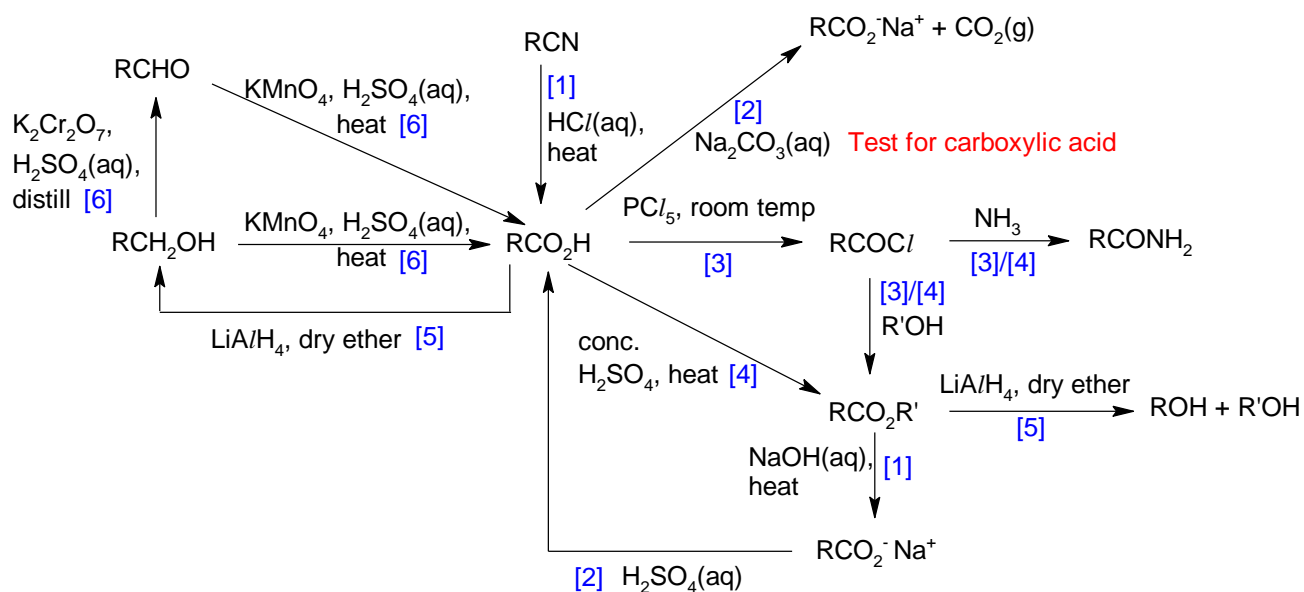
Sodium octadecanoate is a soap.

This reaction is the basis of soap making, one of the oldest chemical manufacturing processes. Soap is manufactured by boiling fat with sodium or potassium hydroxide. The fat is usually tallow (storage fat of cattle and sheep) or vegetable oil such as coconut oil. Because fats contain a mixture of fatty acids, soaps are in practice a mixture of salts of fatty acids. Potassium soaps are milder and more soluble than sodium soaps. Thus, they are used as gels in shampoo.

Soap cleans because it can emulsify fats and oil, i.e. convert them into a suspension of tiny droplets in water. Dirt is held to fabrics by a thin film of oil or grease, this film must be removed before the dirt can be rinsed away. Soap owes its emulsifying action to the combination of polar and non-polar groups in its structure. At one end is a highly polar carboxylate ion, which is hydrophilic (attracted to water) and lipophobic (repelled by oils and fats). At the other end is a long hydrocarbon chain which is hydrophobic and lipophilic. When soap is added to water, it interacts with an interface between oil and water when clothes are washed. The carboxylate end dissolves in the water, and the hydrocarbon end dissolves in the oil. Soap ions arrange themselves around each droplet. If water is agitated, the emulsified oil drop can float free of the fabric. As the surface of each droplet is negatively charged, the drops repel one another and do not coalesce.



IV Summary of reactions



Type of reactions:

- [1] hydrolysis
- [2] acid-base
- [3] nucleophilic substitution
- [4] condensation
- [5] reduction
- [6] oxidation