Beckfoot

Subject: Chemistry	Topic: Carboxylic acids & esters 3.3.9.1	Year Group: 13

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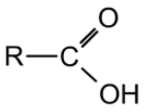
Structure and Properties

1	Functional group is called the carboxyl group…	
2	Nomenclature	The names are based on the carbon skeleton with the ending changed from –ane to –anoic acid, e.g. HCOOH is methanoic acid & CH_3COOH is ethanoic acid. Note that the carbon in the carboxyl group is always carbon 1
3	Weak acids	Only partially dissociate in water to form the carboxylate ion, RCOO- so $HCOO^-$ is called methanoate ion & CH_3COO^- is the ethanoate ion
4	Solubility	Short chain acids very soluble in water due to hydrogen bonding of carbonyl & hydroxyl groups but as non-polar hydrocarbon chain becomes longer, solubility decreases
5	Boiling point (bpt)	Higher than corresponding alcohol as hydrogen bonding occurs between 2 molecules of acid to form a dimer. Since this doubles the size of the molecule, van der Waal's forces also increase, hence increasing bpt

Reactions – as typical acids

1	Example with carbonates	$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + CO_2 + H_2O$
2	Example with metals	$2CH_3COOH + Mg \rightarrow (CH_3COO)_2Mg + H_2$
3	Example with bases	$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
4	With ammonia	$CH_3COOH + NH_3 \rightarrow CH_3COONH_4$
5	Chemical test for identification	Add **sodium carbonate** to a solution of the acid, a positive observation would be effervescence
6	Formation of esters	Carboxylic acids react **with alcohols** to in the **presence of concentrated sulfuric acid** (reflux) to form esters. This is a reversible reaction called esterification / condensation as water is removed – see general reaction below: $R_1COOH + R_2OH \leftrightarrows R_1COOR_2 + H_2O$

Esterification equation examples

1	$CH_3OH + HCOOH \leftrightarrows HCOOCH_3 + H_2O$	Ester = Methyl methanoate
2	$CH_3CH_2OH + CH_3CH_2COOH \leftrightarrows CH_3CH_2COOCH_2CH_3$	Ester = Ethyl propanoate

Key Vocabulary

1	Weak acid	An acid that only partially dissociates in water
2	Plasticiser	An additive (e.g. ester) added to polymers to make them more flexible
3	Condensation reaction	A reaction in which water is formed
4	Trans-esterification reaction	Reacting an ester with an alcohol to produce a different ester & a different alcohol
5	Triglyceride	An ester of propane-1,2,3-triol & 3 fatty acid molecules
6	Fatty acids	Naturally occurring long chain carboxylic acids
7	Saturated fatty acids	Do not have a double bond in the hydrocarbon chain
8	Unsaturated fatty acids	Have at least one C=C double bond in the hydrocarbon chain
9	Saponification	The process used to make soaps through the alkaline hydrolysis of fats to form a mixture of fatty acid salts

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Structure, naming & uses of esters

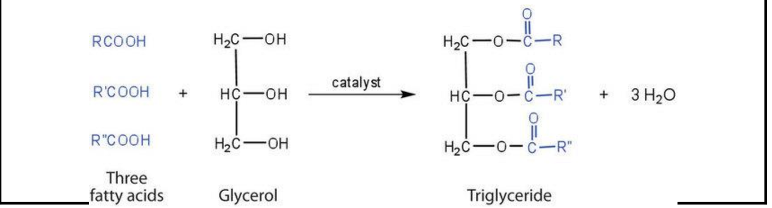
1	Functional group	**R_1COOR_2** for example $HCOOCH_2CH_3$ is called ethyl methanoate
2	Naming / Nomenclature	An ester is named as an alkyl carboxylate. So the alcohol provides the alkyl part of the name & the carboxylic acid provides the carboxylate part of the name. For example, an ester made *from methanol and propanoic acid would be called methyl propanoate*
3	Uses	As **solvents** for organic compounds as they are **volatile**, as **perfumes** since they have **pleasant scents** and **food flavourings** for the same reason. Also, as **plasticisers** to **make plastics / polymers** more flexible
4	Natural esters	These are vegetable oils and fats – ***esters of propane-1,2,3-triol (glycerol) & a long chain carboxylic acid called a fatty acid***. These fats are formed by a condensation reaction & since there are 3 hydroxyl groups in the alcohol, the triglyceride formed has 3 ester linkages, with the removal of 3 H_2O molecules in the formation reaction

Hydrolysis of esters

1	What is it?	The **reverse** of esterification where you split the ester with water and heat, catalysed by either dilute acid or alkali
2	Acid hydrolysis	Reversible / equilibrium reaction where the **acid & alcohol** are formed. Achieved by heating under reflux with dilute acid / alkali. Example: $CH_3COOCH_3 + H_2O \leftrightarrows CH_3COOH + CH_3OH$
3	Alkaline hydrolysis	Reaction goes to completion and is quicker than acid hydrolysis. Products are **alcohol and salt of carboxylic acid** and achieved by heating under reflux with NaOH. To get the free acid from the salt, react with HCl or any dilute acid. This is the basis of how soaps are made using triglycerides. Example: $CH_3COOCH_3 + NaOH \rightarrow CH_3COONa + CH_3OH$ $CH_3COONa + HCl \rightarrow CH_3COOH + NaCl$

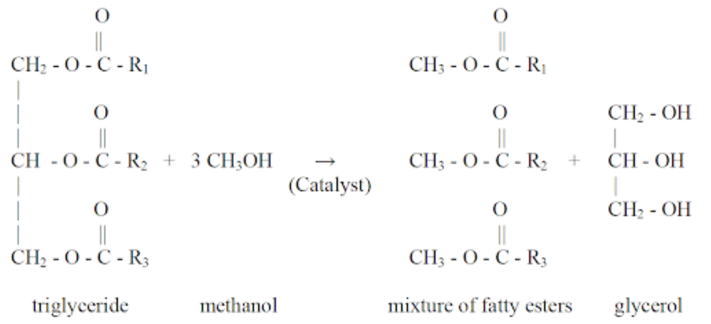
Formation of a triglyceride (natural ester)

Three fatty acids react with propane-1,2,3-triol to form a triester and 3 water molecules are eliminated. Note that as this is an esterification reaction, you need a concentrated H_2SO_4 catalyst



Formation of biodiesel

A **trans-esterification** reaction where a **triglyceride is reacted with methanol in the presence of a KOH catalyst.** The reaction produces a **mixture of methyl esters of fatty acids which is called biodiesel**. The glycerol by-product can be used in cosmetics as a moisturiser.



Formation of soap (saponification)

Alkaline hydrolysis of fats using hot alkali such as NaOH under reflux. The **mixture of salts of the fatty acids are called soaps**. The glycerol formed is a useful by-product used in cosmetics for example.