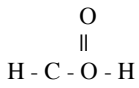
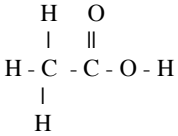
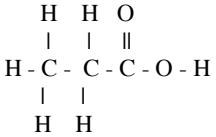
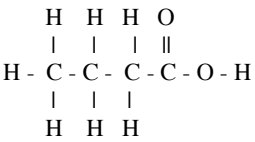
Acids, esters and fats 7

7.1 Alkanoic acids

Name of acid	Molecular Formula (with functional group)	Structural Formula
methanoic	HCOOH	
ethanoic	CH_3COOH	
propanoic	C_2H_5COOH	
butanoic	C_2H_5COOH	

Homologous Series
A group of compounds with similar chemical properties which can be represented by a General Formula.
The General Formula for the alkanoic acids is $C_nH_{2n+1}COOH$.

Chemical Properties
Alkanoic acids react as typical weak acids [Not fully ionised]

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

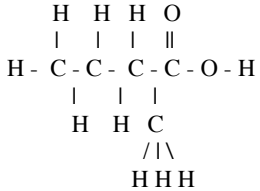
acid + reactive metal => salt + hydrogen — $2\ CH_3COOH + Mg \Rightarrow Mg(CH_3COO)_2 + H_2$

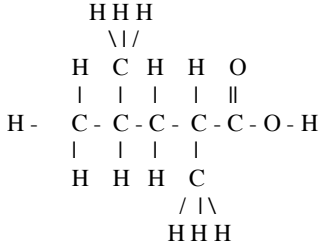
acid + metal oxide => salt + water — $2\ CH_3COOH + CuO \Rightarrow Cu(CH_3COO)_2 + H_2O$

acid + alkali => salt + hydrogen — $CH_3COOH + NaOH \Rightarrow Na\ CH_3COO + H_2O$

acid + metal carbonate => salt + carbon dioxide + water — $CH_3COOH + CaCO_3 \Rightarrow Ca(CH_3COO)_2 + CO_2 + H_2O$

Alkanoic acids with branched chains



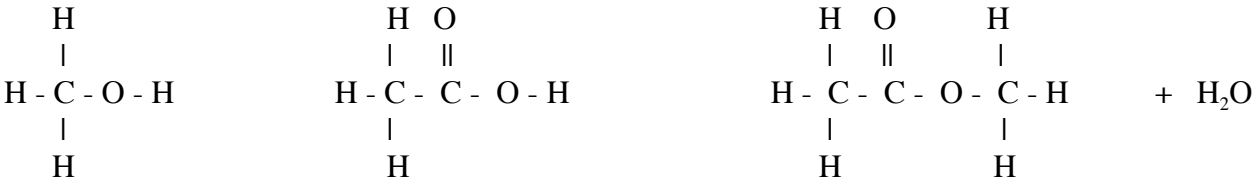


Flavour Molecules 7.2

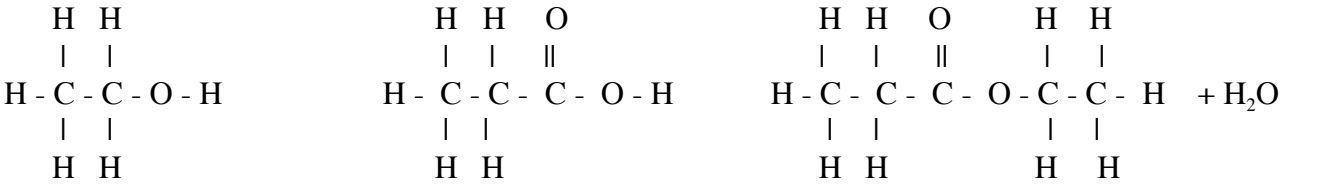
Some of the flavours in fruits, jams, ice creams, wines and sweets are made by esters. Esters are made by condensation reactions between alcohols and alkanoic acids. In a condensation reaction a small molecule, usually but not always water, is lost when two molecules combine.

Indicates a reversible reaction

Alcohol + ***Alkanoic acid*** ⇌ ***Ester*** + ***Water***



methanol + ethanoic acid ⇌ methylethanoate + water

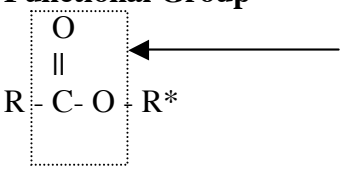


ethanol + propanoic acid ⇌ ethylpropanoate + water

propanol + butanoic acid ⇌ propylbutanoate + water

butanol + propanoic acid ⇌ butylpropanoate + water

Functional Group

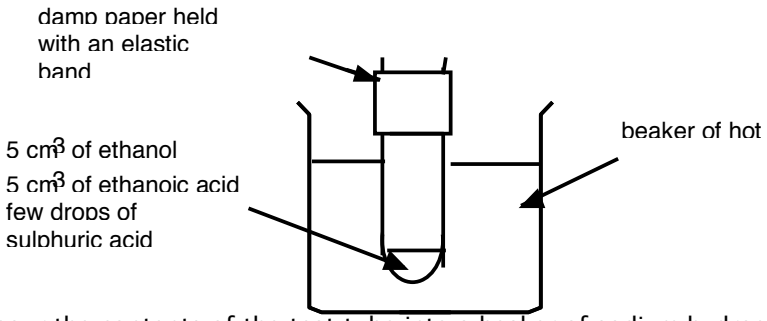


carboxylate or ester group

R and R* are alkyl groups

MAKING ETHYL ETHANOATE

a) Mix $5cm^3$ of ethanol with $5cm^3$ of glacial (concentrated) ethanoic acid in a test tube. Wrap a piece of damp paper towel round the end of the test tube and hold it in place with an elastic band. This helps to prevent loss of the volatile compounds by cooling and condensing them, allowing them to drip back into liquid..
b) Carefully add a few drops of concentrated sulphuric acid to the reaction mixture.
c) Warm the reaction mixture by placing the test tube in a beaker of hot (not boiling) water. As both reactants and product are flammable heating with a Bunsen should be avoided.

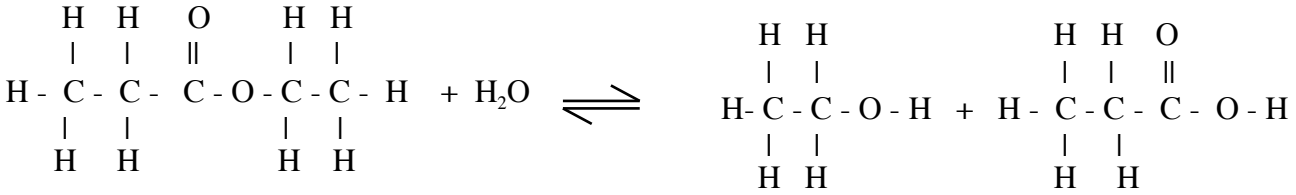


d) After warming for about 5 minutes pour the contents of the test tube into a beaker of sodium hydrogen carbonate solution. Any unreacted acid present will react with the hydrogen carbonate ions to form carbon dioxide gas – look for bubbles of CO_2.
The ester is insoluble in water and should separate out as an oily layer on top of the sodium hydrogen carbonate solution.

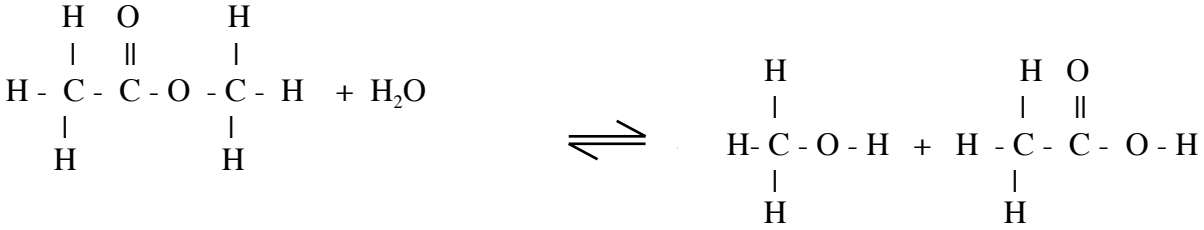
WHY USE CONCENTRATED SULPHURIC ACID?

The purpose of the sulphuric acid in the esterification reaction is two fold:–
i) the presence of $H^+_{(aq)}$ ions in the reaction mixture acts as a catalyst i.e. it speeds up the reaction.
ii) concentrated sulphuric acid has a great affinity for water and so it removes the water formed in the forward reaction. By removing the water molecules present the back reaction (the hydrolysis of the ester) is prevented and so a higher yield of ester is obtained.

Esters can be broken down by hydrolysis. i.e. breaking down by the addition of water.



ethylpropanoate + water ethanol + propanoic acid



methylethanoate + water methanol + ethanoic acid

butylpropanoate + water

pentylethanoate + water

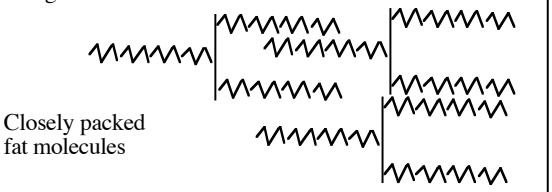
Fats and Oils **7.5**

Fats and oils are **naturally occurring esters**. Fats and oils can be classified according to their origin as animal, vegetable or marine.

FATS ARE SOLID, OILS ARE LIQUID.

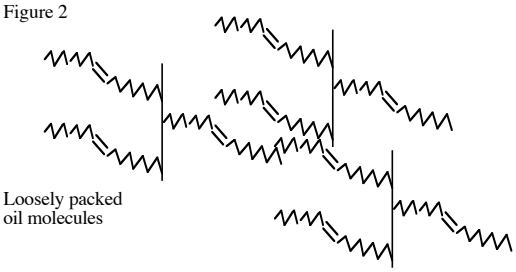
At room temperature **fats are solids** whereas **oils are liquids**. The low melting points of oils are caused by more of their molecules being unsaturated i.e. containing carbon to carbon double bonds. Their degree of unsaturation is higher than that of fats as can be seen from the fact that oils decolourise bromine solution quickly.

Figure 1



Closely packed fat molecules

Figure 2



Loosely packed oil molecules

If the chains are saturated the molecules can pack neatly together, event at high temperatures.If the chains contain one, or more, double bonds, the zig-zag chains become more distorted and the molecules cannot pack closely together. Since the molecules are not packed as closely together they can be more easily separated as the van der Waals forces between the molecules will be smaller. This results in oils having lower melting and boiling points than fats.

Animal sources generally provide fats, for example, dripping from beef, lard from pork and tallow from lamb. These fats are solid at room temperature and only become liquid when heated.

Vegetable sources generally provide oils. Ester oils can be obtained from olives and seeds such as corn seed, sunflower seed, peanuts and soya beans. Liquids at room temperature.

Marine sources can provide both fats and oils, Sea mammals providing fats and oils being obtained from fish.

Health and Diet

Fats and oils provide us with lots of energy. Fats and oils provide twice as much energy as sugars.

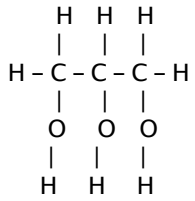
As they contain so much energy eating too much can lead to obesity.

There is mounting evidence that eating too much saturated fat can be linked to heart disease.

Vitamins are contained in fatty foods such as butter whilst vegetable oils contain little in way of vitamins.

Structures OF FATS AND OILS 7.6

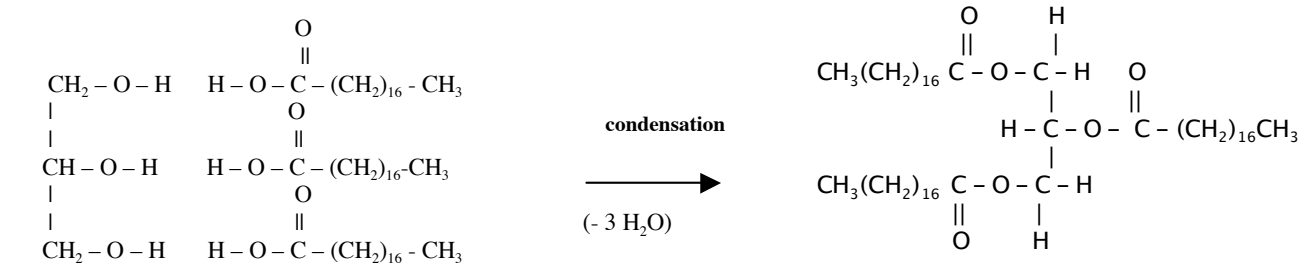
Fats (and oils) are esters derived from the alcohol, propane-1,2,3-triol (commonly called glycerol).



Glycerol is a trihydric alcohol
i.e. It contains contains 3 hydroxyl groups per molecule.

This molecule has the capacity to combine with one, two or three molecules of alkanoic acid. In practice, most fats and oils are triesters (also known as glycerides) derived from glycerol and a variety of long chain alkanoic acids, sometimes called fatty acids.

For example, a simple fat molecule is that derived from a molecule of glycerol and stearic acid ($C_{17}H_{35}COOH$)) [The systematic name of stearic acid is octadecanoic acid]



1 molecule of glycerol

3 molecules of stearic acid

1 molecule of the fat glyceryl tristearate **(a glyceride)**

FATTY ACIDS PRESENT IN FATS AND OILS.

In naturally occurring fats each molecule is derived from **two or three different fatty acids**. The table below shows some common fatty acids, fifty or so are found in nature, the vast majority of them having an **even** number of carbon atoms in their molecules.

STRUCTURE	SYSTEMATIC NAME	COMMON NAME	OCCURRENCE
$CH_3(CH_2)_{16}COOH$	octadecanoic acid	stearic acid	animal fats
$CH_3(CH_2)_{10}COOH$	dodecanoic acid	lauric acid	coconut oil
$CH_3(CH_2)_{14}COOH$	hexadecanoic acid	palmitic acid	palm oil, most fats.
$CH_3(CH_2)_3(CH_2CH{=}CH)_2(CH_2)_7COOH$		lineoleic acid	olive oil

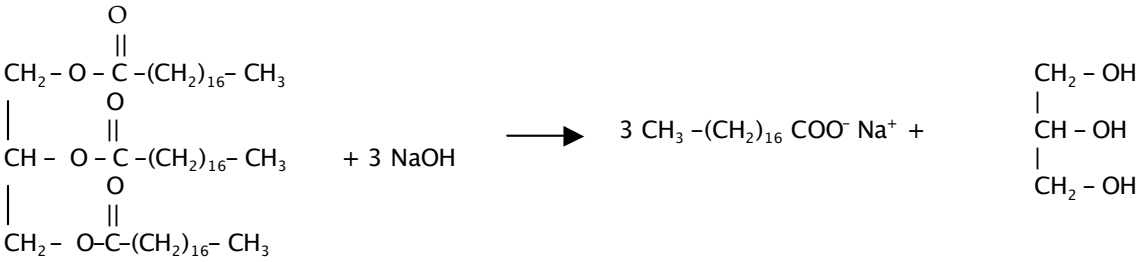
Hardening Oils

Hardening a fat or oil means to increase its melting point. Oils can be hardened by reducing the number of double bonds in the fatty acid part of the molecule. This is done by adding hydrogen a process called hydrogenation. When the double bond is removed the molecules can pack more tightly which increases the strength of the Van der Waals forces between the molecules. When margarine is prepared from vegetable oils the extent of hydrogenation is carefully controlled to make it easy to spread. Saturated fats are thought to less healthy than unsaturated fats being linked to heart disease.

Fats to soaps 7.7

Alkaline hydrolysis of fats and oils.

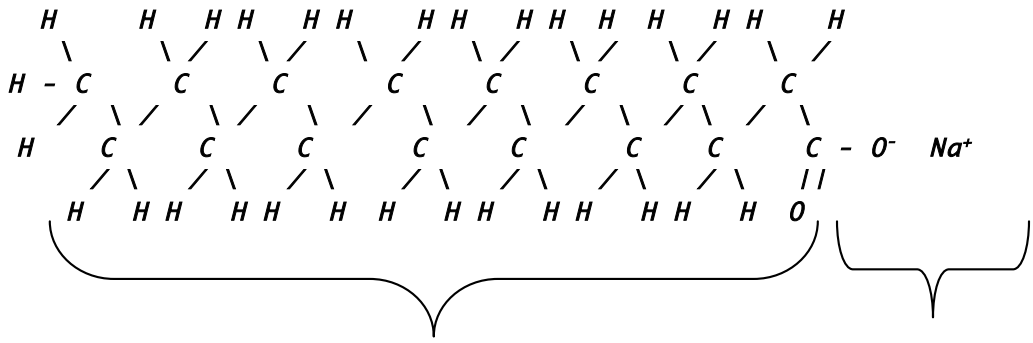
Like all esters, fats and oils can be hydrolysed (broken down by reaction with _____). The products of hydrolysing a fat and oils are propane–1,2,3–triol (glycerol) and a mixture of fatty acids.Hydrolysis can be accomplished by boiling the fat/oil with either a strong acid or a strong alkali. The alkaline hydrolysis is the more efficient method as it is non–reversible. When a fat is hydrolysed using an alkali, such as sodium hydroxide,the products are propane–1,2,3–triol and a mixture of the sodium salts of the fatty acids.



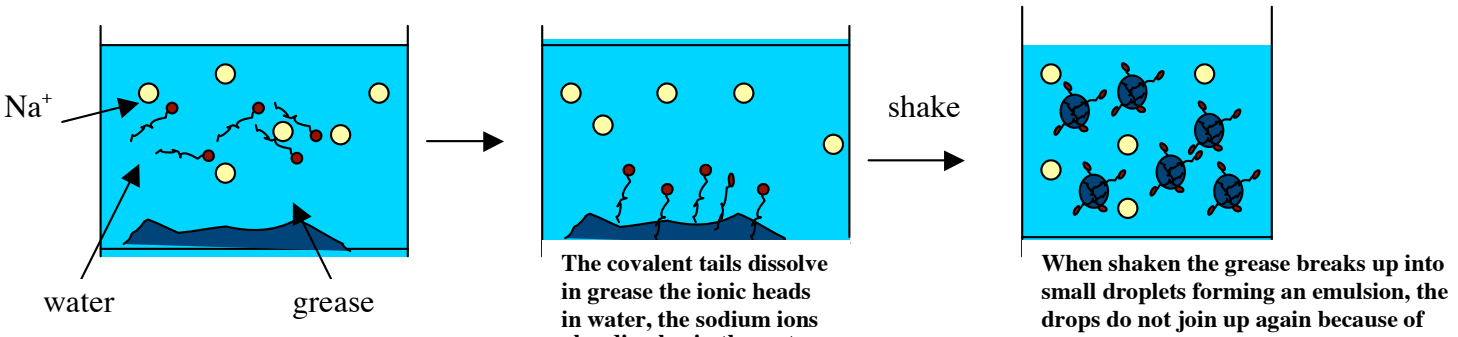
glyceryl tristearate (a glyceride) | **sodium hydroxide** | **sodium stearate (soap)** | **propane - 1,,2,3 - triol**

The sodium and potassium salts of the fatty acids formed by the alkaline hydrolysis of fats and oils are soapmolecules. For example, Palmolive soap is made from palm oil and olive oil. The alkaline hydrolysis of fats and oils to form soap (and glycerol) is called saponification.

Action of soap



The covalent tail is soluble in non - polar solvents such as grease, whilst the ionic head is soluble in water.



The covalent tails dissolve in grease the ionic heads in water, the sodium ions also dissolve in the water

When shaken the grease breaks up into small droplets forming an emulsion, the drops do not join up again because of repulsion of negative charges. The small droplets are easily rinsed away.

% Yield

Balanced equations enable us to calculate the quantity of product that we would expect to obtain from a known quantity of reactant assuming that 100% conversion takes place. The quantity o f product is called the theoretical yield. The actual yield i.e. the quantity obtained is usually less than this.

In industrial processes the highest yield possible is always wanted and where not possible for any reason the reactants are usually recycled

eg. hydration of ethene; Haber Process.

Example 1 A sample of ethyl methanoate weighing 3.6 g was obtained from a mixture containing 4 g of ethanol and excess methanoic acid along with a little concentrated sulphuric acid. Calculate the % yield.

C_2H_5OH + HCOOH $\rightleftharpoons$ $HCOOC_2H_5$ + H_2O

1 mol 1 mol

46 g 74 g

1g 74/46 g

4 g 74/46 x 4 = 6.4 g

% Yield = $\frac{\text{actual yield}}{\text{theoretical yield}}$ x 100 = 3.6/6.4 x 100 = 56.25%

Example 2 A sample of propyl propanoate weighing 7.5 g was obtained from a mixture containing 6.0 g of propanol and excess propanoic acid along with a little concentrated sulphuric acid. Calculate the % yield.

C_3H_7OH + C_2H_5COOH $\rightleftharpoons$ $C_2H_5COOC_3H_7$ + H_2O

1 mol 1 mol

g g

1 g

6.0 g = g

% Yield = = %

Example 3 A sample of butyl ethananoate weighing 12.5 g was obtained from a mixture containing excess butanol and 10.0 g ethanoic acid along with a little concentrated sulphuric acid. Calculate the % yield.

C_4H_9OH + CH_3COOH $\rightleftharpoons$ $CH_3COOC_4H_9$ + H_2O

1 mol 1 mol