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Fats, oils and detergents

Department of Chemistry
The Open University of Sri Lanka

Fats, oils and detergents

Introduction

In this lesson we will study the chemistry and applications of biological esters, **fats** and **oils**. The production of edible fats is worth millions of dollars involving many people who cultivate oil-bearing plants and suppliers of animal fats, and industries that extract, process, store and distribute the final products.

Fats and oils are naturally occurring **lipids** found in plants and animals and are **triesters** of **glycerol** or **glycerin**. The name lipid is derived from the Greek word *lipos*, means fat. Unlike carbohydrates, proteins and nucleic acids, lipids are not soluble in polar solvents, *but they are soluble in non-polar solvents such as hexane, chloroform or diethyl ether*. Waxes, steroids and prostaglandins are also considered as lipids. Before we study more complex molecules such as triesters derived from *glycerol and fatty acids*, let us consider the chemistry and applications of simple carboxylic acids, alcohols and esters.

1. Simple carboxylic acids, alcohols and esters

You must have learnt about these compounds before under organic chemistry. Let us refresh our memories.

1.1 Carboxylic acids

The sour taste of food is generally caused by the presence of one or more carboxylic acids. Vinegar contains acetic acid, lemons and other citrus fruits contain citric acid, and the tart taste of apples is caused by malic acid. Butyric acid occurs in rancid butter; it is a component of perspiration and responsible for the odour of unwashed socks. Two carboxylic acid molecules are held together by hydrogen bonding to form a dimer. Organic acids (R**COOH** or R$\mathbf{CO_2H}$; R = H or an organic group) contain a carboxyl –C(=O)OH group (*i.e*. oxo group and OH group). Some important organic acids and their uses are given in Table 1.

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Table 1 Some important carboxylic acids

Common name	IUPAC name	Chemical formula	Characteristics and uses
Formic acid	Methanoic acid	HCO_2H	Stinging agents of red ants and nettles; food preservative
Acetic acid	Ethanoic acid	CH_3CO_2H	Active ingredient in vinegar; food preservative
Propionic acid	Propanoic acid	$CH_3CH_2CO_2H$	Salts used as mould inhibitors
Oxalic acid	Ethanedioic acid	HO_2CCO_2H	Cleaning agent for rust stains on fabric and porcelain
Adipic acid	1,6-Hexanedioic acid	$HO_2C(CH_2)_4CO_2H$	Production of textile
Citric acid	2-Hydroxy-1,2,3-propane-tricarboxylic acid	See figure 3	Found in citrus fruits and cells; flavouring agent in food
Lactic acid	2-Hydroxypropanoic acid	$CH_3CH(OH)CO_2H$	Found in sour milk; formed in muscles during exercise

1.2 Alcohols, diols and triols

Simple alcohols such as methanol (MeOH) and ethanol (EtOH) contain C–OH functionality. Over one million gallons of MeOH is produced annually by reacting H_2 with CO. Major application of MeOH is for the production of formaldehyde (HCHO) which is used for the production of plastics. Ethanol is produced by the direct hydration of ethylene. EtOH is now used to power automobiles. World ethanol production as a transport fuel increased significantly between 2000 and 2007 from 17 to 52 billion litres. Bio-ethanol is produced from agricultural products such as corn, sugar cane, manioc and potato. Some important alcohols and their uses are given in Table 2.

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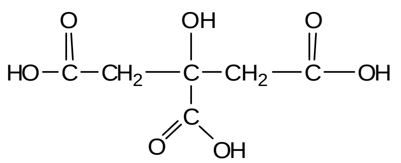
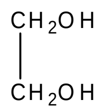
Table 2 Some important alcohols

Name (common name)	Chemical formula	Uses
Methanol (methyl alcohol)	CH_3OH	Solvent, car fuel, making formaldehyde
Ethanol (ethyl alcohol)	CH_3CH_2OH	Solvent, alcoholic beverages
2-Propanol (isopropyl alcohol)	$CH_3CH(OH)CH_3$	Rubbing alcohol, solvent, antiseptic
1,2-Ethanediol (ethyleneglycol)	$HOCH_2CH_2OH$	Automobile antifreeze, polyester fibres
1,2,3-Propanetriol (glycerine, glycerol)	$CH_2(OH)CH(OH)CH_2(OH)$	Moisturizer in food, tobacco and cosmetics

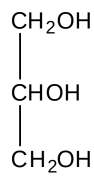
When an organic molecule has **two** and **three** hydroxyl (OH) groups it is called a “diol” and “triol” respectively. The structures of the most important diol (*e.g*. ethylene glycol) and triol (*e.g*. glycerol) are given in figure 1.



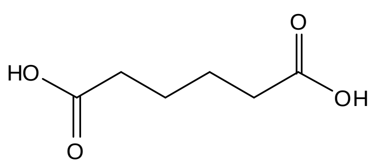
Citric acid



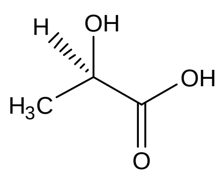
Ethylene glycol



Glycerol



Adipic acid



Lactic acid

Figure 1 *Structures of citric acid, ethylene glycol, glycerol, lactic acid and adipic acid*

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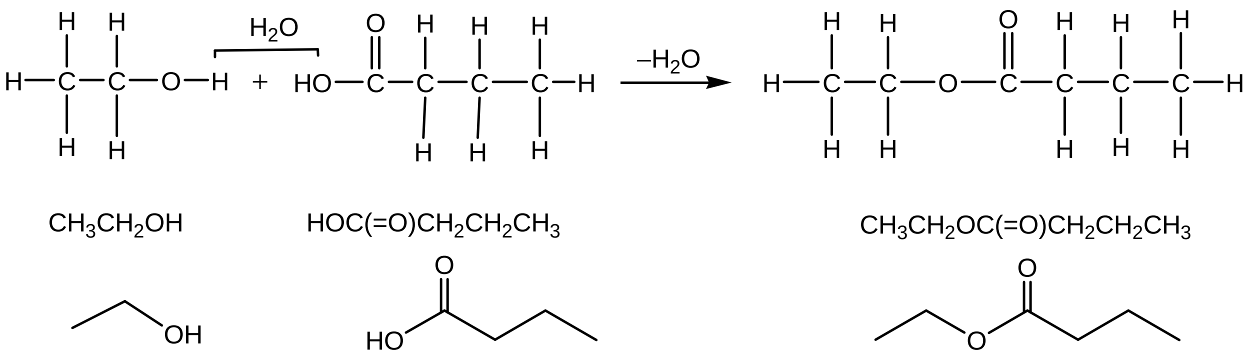
Activity

1. How would you carry out the following conversions?
   (i) Ethylene → ethylene glycol
   (ii) Glyceraldehyde → glycerol

1.3 Simple organic esters

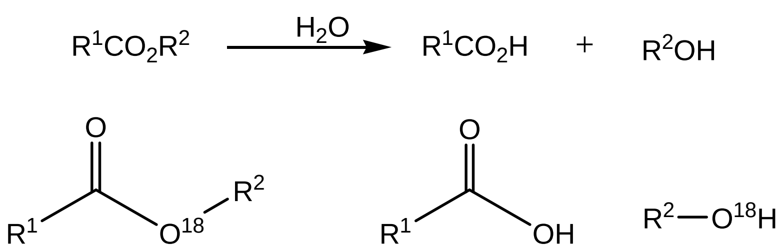
We know that alcohols (R^1OH) react with organic acids (R^2CO_2H) to form esters ($R^2CO_2R^1$ or R^2COOR^1 or $R^2C(=O)OR^1$). For example, ethanol reacts with butanoic acid to give ethyl butanoate (IUPAC name).



Ethanol **Butyric acid (common name)** **Ethyl butyrate (common name)**

Figure 2 *Formation of an ester, ethyl butyrate from ethanol and butyric acid*

These esters can be hydrolysed to give the corresponding alcohol and acid.



Ester **Acid** **Alcohol**

Figure 3 *Hydrolysis of an ester*

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Q: Write the chemical formulae of (i) ethyl acetate and (ii) methyl propionate.

A: Both ethyl acetate and methyl propionate have the same **empirical formula** $C_4H_8O_2$. When you write or look at a formula of an ester, you should be able to identify fractions derived from the acid and alcohol. Note that there are four formulae given for each **ester**. The valencies of each carbon and oxygen are four and two, respectively.

(i) $CH_3CH_2OC(=O)CH_3$ or $CH_3CO_2CH_2CH_3$ or EtO_2CMe or $MeCO_2Et$

(ii) $CH_3OC(=O)CH_2CH_3$ or $CH_3CH_2CO_2CH_3$ or $EtCO_2Me$ or MeO_2CEt

Et = ethyl group ($-CH_2CH_3$) ; Me = methyl group ($-CH_3$)

Q: Draw the structure of the diester formed between ethylene glycol ($HOCH_2CH_2OH$) and acetic acid.

A:

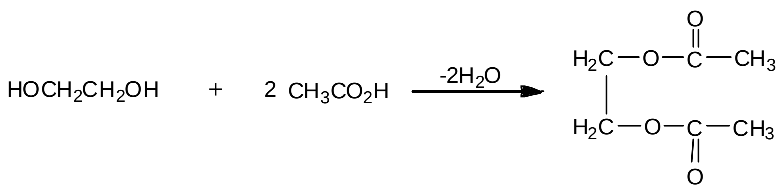

Figure 4 *Formation of the diester between ethylene glycol and acetic acid*

3.1 2. Fatty acids

Fatty acids are carboxylic acids, obtained from fats and oils, having carbon chains containing 4 to 25 carbon atoms. For example, butyric acid is a short-chain fatty acid, responsible for the characteristic flavour in butter. Linoleic acid plays an important role in lowering cholesterol levels.

A list of common fatty acids is given in Table 3.3. Note that saturated fatty acids (SFAs) are solids with melting points (m.pt.) greater than 32 ^{o}C, while unsaturated fatty acids (UFAs) are liquids with melting points less than 16 ^{o}C. SFAs are mainly obtained from animal fats and UFAs are from plant sources with the exceptions that coconut and palm oils are low in UFAs and high in SFAs. The double bond in UFAs causes the molecules to fold back (or bend), reducing its ability to pack tightly. Some UFAs (*e.g*. linoleic acid and linolenic acid) are termed essential because human body cannot synthesise them.

You may have noticed that each fatty acid has a **terminal** carboxyl group. *Saturated* fatty acids (*e.g*. stearic acid) have the chemical formula $CH_3(CH_2)_nCO_2H$ (n = an integer) and therefore they have *no double bonds* between carbon atoms.

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Table 3 The structures, sources, and uses of some fatty acids

Common name(m.pt.)	Structure/ Shorthand notation	Main source	Some uses
	Saturated fatty acids		
Capric acid (32 °C)	$CH_3(CH_2)_8COOH$ **(10:0)**	coconut oil	fruit flavours, perfumes
Lauric acid (44 °C)	$CH_3(CH_2)_{10}COOH$ **(12:0)**	coconut oil	surfactants, cosmetics, insecticides
Myristic acid (54 °C)	$CH_3(CH_2)_{12}COOH$ **(14:0)**	coconut oil	soaps, cosmetics, flavours, perfumes
Palmitic acid (63 °C)	$CH_3(CH_2)_{14}COOH$ **(16:0)**	natural fats	soap, lube oil, waterproofing
Stearic acid (70 °C)	$CH_3(CH_2)_{16}COOH$ **(18:0)**	animal fats	soap, polishes, lubricants
	Unsaturated fatty acids		
Arachidic acid (77 °C)	$CH_3(CH_2)_{18}COOH$ **(20:0)**	peanuts, plants	lubricating greases, waxes
Palmitoleic acid (0 °C)	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$ **(16:1)9**	marine oils	organic synthesis
Oleic acid (16 °C)	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ **(18:1)9**	olive oil	soap, cosmetics, ointments, lubricants
Linoleic acid (5 °C)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$ **(18:2)9,12**	linseed oil, safflower oil	soap, coatings, margarine, medicine
α-Linolenic acid (-11 °C)	$CH_3CH_2(CH{=}CHCH_2)_2CH{=}CH(CH_2)_7COOH$ **(18:3)9,12,15**	linseed oil, seed fats	drying oil (paints), medicine
Arachidonic acid (-50 °C)	$CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COOH$ **(20:4)5,8,11,14**	lecithin, liver	plastics, lubricants

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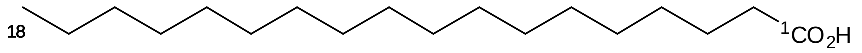
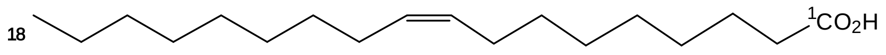
Monounsaturated fatty acids (MUFAs) (*e.g*. oleic acid) have only one carbon-carbon double bond (C=C) and whereas *polyunsaturated* fatty acids (PUFAs) (*e.g*. linoleic acid) have more than one double bond, and naturally these double bonds have the *cis*-arrangement. Structures of some fatty acids are shown below.

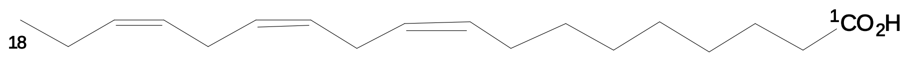
$CH_3(CH_2)_{16}COOH$ ≡ **Stearic acid** (18:0), a saturated fatty acid



$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$ ≡ **Oleic acid** (18:1)9, a mono-unsaturated fatty acid



$CH_3CH_2(CH{=}CHCH_2)_2CH{=}CH(CH_2)_7COOH$ ≡ **α-Linolenic acid** (18:3)9,12,15



$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$ ≡ **Linoleic acid** (18:2)9,12

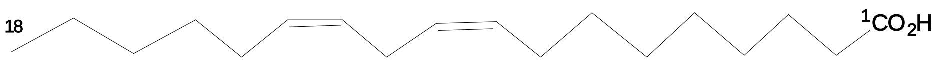


Figure 5 *Stearic acid, oleic acid, α-linolenic acid, and linoleic acid*

2.1 IUPAC Names of fatty acids

Carboxylic carbon is taken as carbon-1; prefixes such as *tetra* (4), *penta* (5),……….*deca* (10),…..*dodeca* (12), ……*icosa* (20),……*doicosa* (22) are used as to describe the length of the carbon chain; endings such as **en**oic, **dien**oic, **trien**oic, and **tetraen**oic are used to indicate the number of double bonds. The number(s) given at the beginning of the IUPAC name indicates the location(s) of the double bond(s), for example, the IUPAC name of the unsaturated fatty acid, oleic acid $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ is *cis*-9-octadecaenoic acid. This name indicates that the acid has 18 carbons with one double bond between carbons 9 and 10. Naturally occurring fatty acids generally have the *cis*-configuration around the double bond.

Activity

2 . Give the IUPAC names of the following fatty acids.

(i) Lauric acid (ii) α-Linolenic acid

(iii) Linoeic acid (iv) $CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COOH$

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2.2 Shorthand notation

Scientists use shorthand notation to represent the names of these long fatty acids. For example, shorthand notation of stearic acid ($C_{18}H_{36}O_2$ or $CH_3(CH_2)_{16}CO_2H$) is (**18:0**), which gives the total number of carbon present in the molecule and the number of double bonds present in the chain. The shorthand notation of linoleic acid is (18:2)9,12 indicating that it has a total number of 18 carbons and 2 double bonds and the positions of them are C-9 and C-12 (see figure 6).

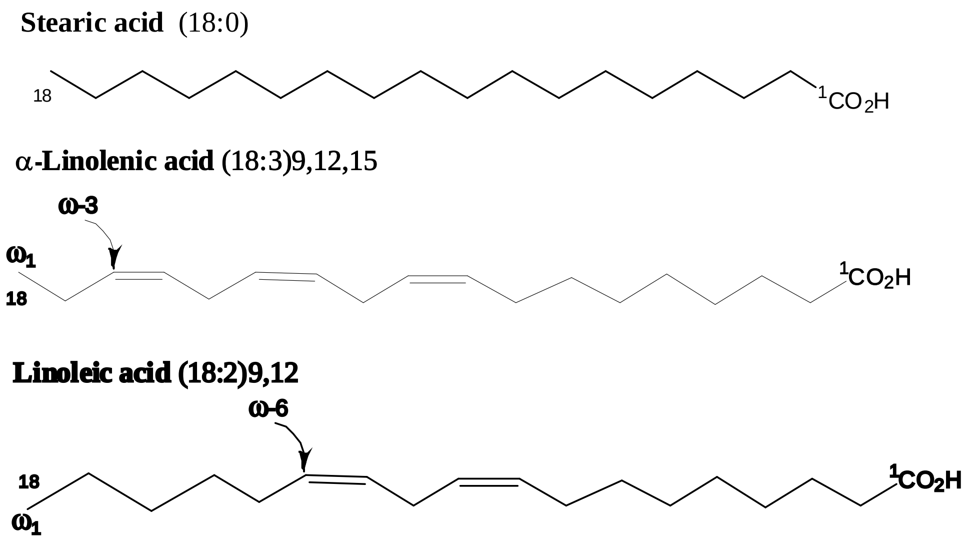

***Figure 6** Shorthand notations of some fatty acids*

2.3 Omega fatty acids and omega (ω) notation

Omega-3 (ω3) and omega-6 (ω6) fatty acids are important **unsaturated** fatty acids that should be taken in with your food as the human metabolism cannot produce them from other fatty acids or biomelecules. Greek letter **omega** is used to identify the *location of the double bonds*. The "alpha" carbon (α-carbon) is the carbon closest to the carboxyl group (*i.e.* carbon number 2), and the **last carbon** of the polymer chain is called the "omega carbon" going by the letter omega as it is the last letter of the Greek Alphabet.

Omega notation

Linoleic acid is an **omega-6 fatty acid** because it has a double bond **six carbons** away from the "omega" carbon (*i.e.* carbon-18 or C-18 according to IUPAC nomenclature). α-linolenic acid is an **omega-3 fatty acid** because it has a double bond **three carbons** away from the "omega" carbon.

How can we use the scientific name to determine the omega value?

By subtracting the highest number given for the last double-bond in the **scientific name** from the total number of carbons in the fatty acid we can obtain the omega value, *i.e.* (ω = total number of carbons - highest number given for a double-bond). When you apply this rule to **oleic acid** you find it to be an omega-9 fatty acid (ω = 18-9 = 9).

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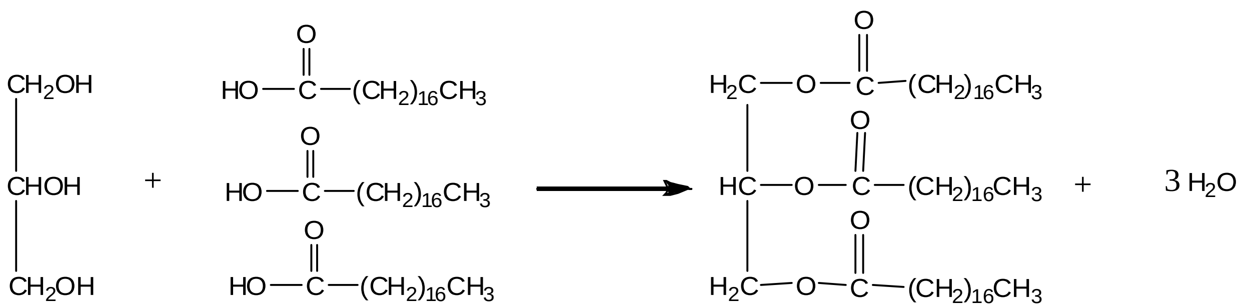
3. Fats and oils

Fats and oils are known as **triglycerides** or **triacylglycerols** (TAG) and both terms mean triesters of glycerol (propane-1,2,3-triol). At room temperature a *fat is solid* and *oil is liquid*. Most triglycerides in animals are fats, while those in plants tend to be oils; hence the terms animal fats (butterfat) and vegetable oils (coconut oil, corn oil) are used.

Triglycerides have lower densities than water (they float on water), and at normal room temperatures may be solid or liquid. Glycerol is a trihydric alcohol (containing three hydroxyl groups) and it can combine with three fatty acids to form triglycerides while releasing three water molecules. Given below is the structure of **tristearin**, a triglyceride with three stearic acid residues.



Glycerol **3 x Stearic acid** **Glyceryl tristearate (tristearin)**

Figure 7 *The structure of tristearin formed from glycerol and stearic acid*

Activity

3. Hydrolysis of a triglyceride gave two residues of oleic acid and one residue of palmitic acid. Draw the structures of two possible isomers of the triglyceride.

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Diglyceride and monoglyceride

A diglyceride, or diacylglycerol (DAG), has **two** fatty acid residues and exists in the 1,2 or 1,3 positions depending on how the fatty acids are attached to the glycerol molecule.

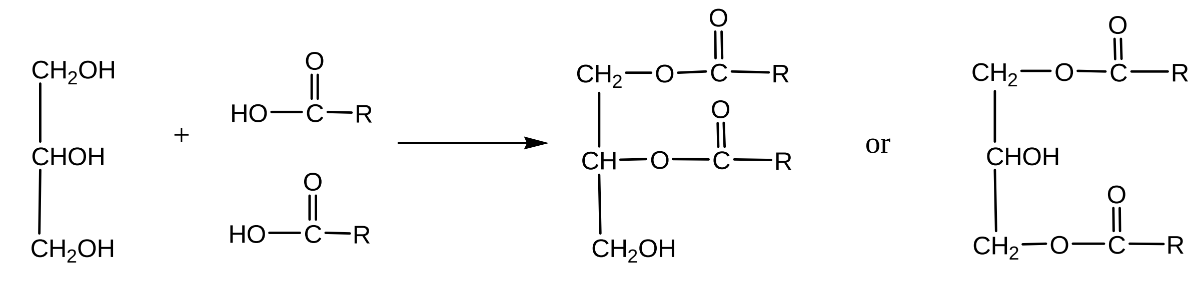

Figure 8 *The two diglycerides formed with the fatty acid, RCO_2H.*

A monoglyceride, or monoacylglycerol (MAG), has only one fatty acid radical per molecule of glycerol. The fatty acid may be attached to carbon 1 or 2 of the glycerol molecule.

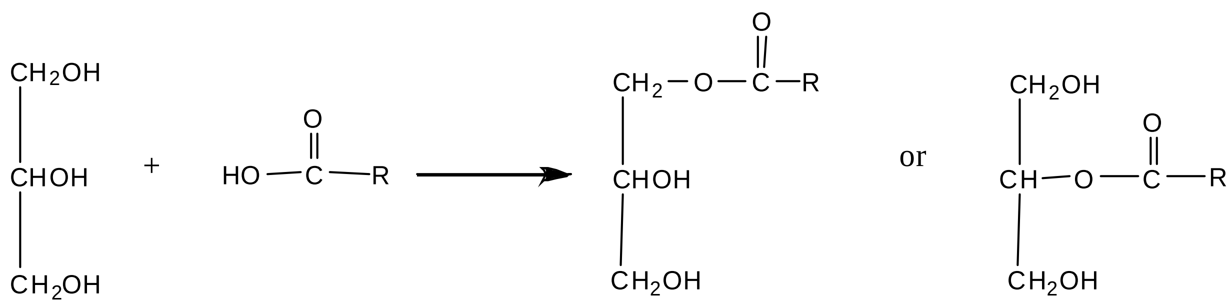

Figure 9 *The two monoglycerides formed with the fatty acid, RCO_2H.*

Esters of glycerol and fatty acids are normally metabolized in the same way as other biomolecules. Monoglycerides, diglycerides and triglycerides all have 38 kJ per gram (*c.f.* 17 kJ per gram for sugars).

Approximate fatty acid compositions of some common fats and oils are given in Table 4 (see page 16; **Appendix-I**). Note that Canola oil has the largest UFA to SFA ratio (15.7) and coconut oil has the lowest UFA to SFA ratio (0.1).

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3.2 Waxes

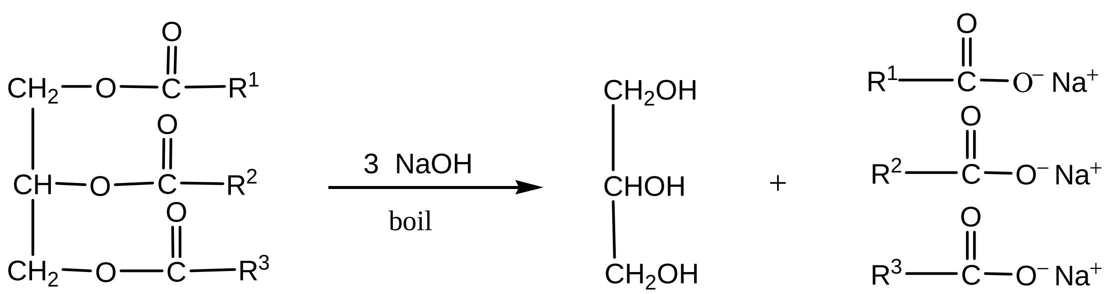
Waxes are low melting, stable solids which are present in nature in both plants and animals. Waxes are **esters** made up of *long chain fatty* acids and **long chain alcohols**. The hydrocarbon chains of both the acid and alcohol in waxes usually contain 10 to 30 carbon atoms. A wax coat protects surfaces of many plant leaves from water-loss and attacks by micro-organisms. Bee wax mainly consists of myricyl palmitate, $CH_3(CH_2)_{14}C(=O)O(CH_2)_{29}CH_3$, *i.e.* the ester formed between myricyl alcohol $CH_3(CH_2)_{28}CH_2OH$ and palmitic acid $CH_3(CH_2)_{14}CO_2H$.

Hydrogenation of unsaturated fats

When exposed to air, *unsaturated fats* tend to get oxidised and to have an unpleasant odour and flavour. By hydrogenating, *i.e.* treating the fat with hydrogen gas in the presence of a catalyst (Ni), the degree of unsaturation can be decreased (*partial hydrogenation*) or completely removed. Fully saturated fats are too waxy and solid to be used as food or food additives. Major problem with partial hydrogenation of fats is the conversion of some of the natural *cis*-double bonds to *trans*-double bonds. It is known that dietary *trans*-fats raise the level of low-density lipoproteins (LDL) increasing the risk of coronary heart diseases. *trans*-fats also reduce high density lipoproteins (HDL) and raise the level of triglycerides in the blood.

3.3 Soap and detergents

Soaps are *sodium* or *potassium* salts of long chain fatty acids found in plants and animals. Potassium soaps (soft soaps) tend to be liquids and are used in shaving creams while those containing sodium are usually solid (hard soaps). When we boil fats or oils with sodium hydroxide (NaOH), the sodium salts of the fatty acids (soap) and glycerol are formed as shown below.



Triglyceride **Glycerol** **Sodium salts of fatty acids**

Figure 10 *Formation of soap*

This is an example of alkaline hydrolysis of an ester and is called **saponification**. The four steps in the manufacture of soap are (i) Saponification, (ii) removal of glycerine, (iii) soap purification, and (iv) addition of perfumes and colour.

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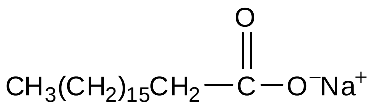
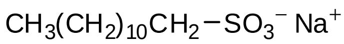
Detergents

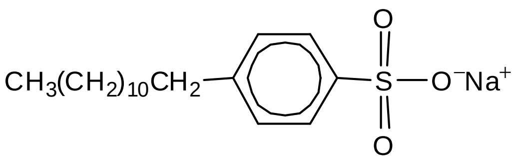
A detergent is a cleaning agent that will remove grease and grime from surfaces. However, it is more common for liquid cleaning agents to be called detergents and solids to be called soaps. Common soaps are prepared from natural fatty acid but detergents are made using synthetic acids such as alkylsulphonic acids and alkylbenzenesulphonic acids.



Sodium stearate (a soap molecule)



an alkylsulphonate (a detergent)



an alkylbenzenesulphonate (a detergent)

Figure 11 *Soap and detergent molecules*

The reason why detergents are so useful is that they do not give precipitates with metal ions such as Ca^{2+} or Mg^{2+} which are responsible for the hardness of water. Ordinary soap gives a precipitate with hard water; this is **scum**. Detergents do not give a scum even with the hardest water. The cleansing action of detergents is similar to that of soap. The long alkyl chains (or the **non-polar tail/ hydrophobic tail**) take out the oily dirt forming micelles with the solubility of **polar heads/ hydrophilic head** (sulphonate/carboxylate groups) in water as shown below.

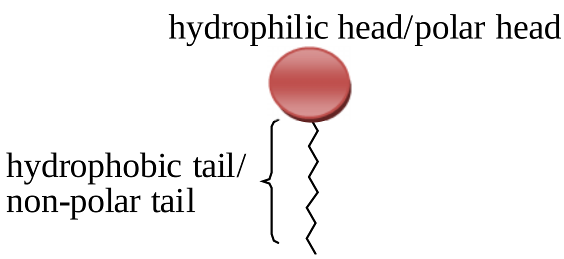


Figure 12 *Structure of a soap molecule*

The early polymer chains used for detergent manufacture suffered a great deal of branching. The hydrocarbon side chains did not interfere with the cleaning power of the detergent, but they did prevent bacteria from attacking and breaking the chains. This meant that detergent molecules containing branched chains degraded very slowly and they are not environmentally friendly.

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How soap works?

Soap is a mixture of salts of medium chain length carboxylic acids, with a combination of ionic and organic characteristics. They have an uncharged hydrocarbon tail (non-polar) and a charged head (polar head). The hydrocarbon tail is likely to be hydrophobic (water hating), and the head hydrophilic (water loving).

Grease and dirt is mainly organic in nature, so the hydrophobic tails will be able to mix happily with it and the polar heads can be solvated by water molecules instead. When you add soap or detergent to fat or greasy dirt, the non polar tails mix with non polar dirt. By adding more soap there comes a point at which the molecules gather together into clumps called *micelles*. The tails stick inwards into the roughly spherical oil/grease balls and the heads stick outwards into the water medium.

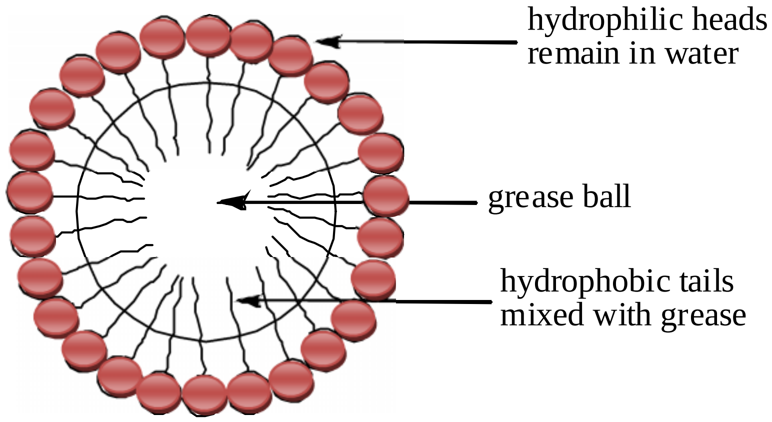

Figure 13 *Micelle formations due to soap action on grease*

Summary

- Simple alcohols and carboxylic acids have a wide range of applications.
- Fats and oils are lipids found in plants and animals and are triesters of glycerol, which are insoluble in water but are soluble in non-polar solvents.
- Fatty acids are carboxylic acids, obtained from fats and oils, having carbon chains containing 4 to 25 carbon atoms.
- Fats and oils are known as triglycerides. At room temperature a *fat is solid* and *oil is liquid*.
- The short hand notation of linoeic acid is (18:2)9,12 indicating that it has a total number of 18 carbons and two double bonds; the positions of double bonds are C-9 and C-12.
- Waxes are esters made up of long chain fatty acids and long chain alcohols, containing 10 to 30 carbon atoms.

- Unsaturated fats can be hydrogenated to reduce the degree of unsaturation (*partial hydrogenation*); but during partial hydrogenation some of the naturally occuring *cis*-double bonds can undergo isomerization to give to *trans*-double bonds
- Soaps are sodium or potassium salts of long chain fatty acids that are found in plants and animals. Alkaline hydrolysis of esters in a lipid is called saponification.
- Common soaps are prepared from natural fatty acid but detergents are made using synthetic acids such as alkylsulphonic acids and alkylbenzenesulphonic acids.
- Detergents are so useful as they do not give precipitates with metal ions such as Ca^{2+} or Mg^{2+} which are responsible for the hardness of water.
- Soap molecules gather on oil to form *micelles* in which non-polar tails stick into spherical oil ball and the polar heads stick outwards into the water medium.

Learning Outcomes

Once you have finished studying this lesson you should be able to

- describe uses of carboxylic acids and alcohols given in this lesson
- discuss preparation, properties and applications of fatty acids
- give IUPAC names, short hand notations and omega notations of fatty acids
- describe effects of hydrogenation and partial hydrogenation of fats
- describe preparation of soap and waxes
- explain the differences between soap and detergents
- explain the action of soap/detergents on oil and grease

Activity

4. (i) Draw the structure of the dimer-form of acetic acid.

   (ii) How would you convert acetic acid into acetyl chloride and glycine, respectively?
5. What are the applications of ethylene glycol?
6. Give the IUPAC name of lactic acid.
7. Write a short account on fats and oils.
8. Give the shorthand notation of the following fatty acids.

   (i) $CH_3(CH_2)_{18}COOH$

   (ii) $CH_3(CH_2)_6CH=CH(CH_2)_8COOH$
9. Name two saturated fatty acids found in coconut oil.

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10. Which acid causes the rancidity in butter?

11. How is methanol produced industrially?

12. Write the chemical formulae of the fatty acids with the following shorthand notations.

    (i) (12:0) (ii) (14:0) (iii) (18:2) 9,12

    (iv) (18:1)ω9 (v) (18:3)ω3,6,9

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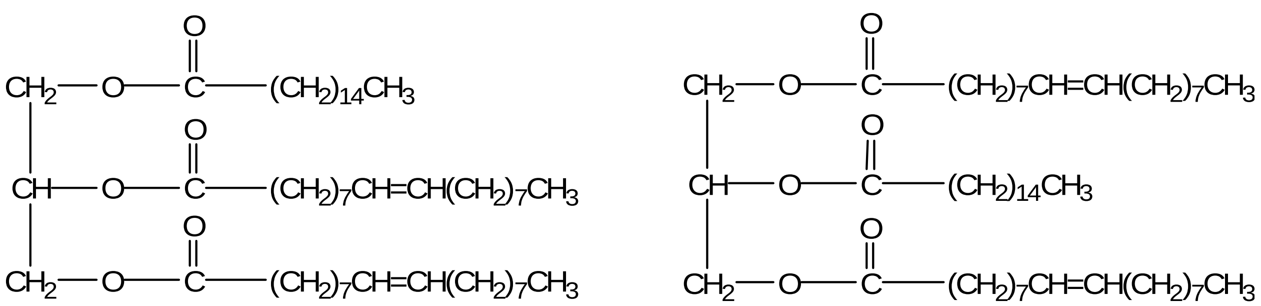
Answer guide to activities

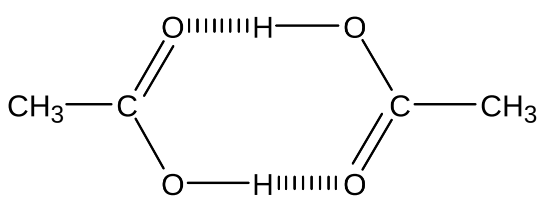
1. (i) By hydrating ethene ($CH_2=CH_2$)
   (ii) By reducing glyceraldehyde with $LiAlH_4$

2. (i) Dodecanoic acid
   (ii) 9,12,15-Octadecatrienoic acid
   (iii) 9,12-Octadecadienoic acid
   (iv) 5,8,11,14-Icosatetraenoic acid

3. The two possible isomers are



4. (i)



   (ii) (a) By reacting CH_3CO_2H with PCl_5

$$CH_3CO_2H \xrightarrow{PCl_5} CH_3COCl$$

   (b)

$$CH_3CO_2H \xrightarrow[Cl_2]{h\nu} ClCH_2CO_2H \xrightarrow{\text{conc } NH_3} H_2NCH_2CO_2H + NH_4Cl$$

Chloroacetic acid Glycine

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5. Refer Table 2

6. 2-Hydroxypropanoic acid, refer Table 1

7. Refer section 3

8. (i) (20:0) and (ii) (18:1)10

9. Capric acid, lauric acid, and myristic acid (any two); see Table 4 and Appendix 1.

10. Butyric acid

11. MeOH is produced by reacting H_2 with CO.
$CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$

12. (i) $CH_3(CH_2)_{10}CO_2H$
(ii) $CH_3(CH_2)_{12}CO_2H$
(iii) $CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7CO_2H$
(iv) $CH_3(CH_2)_7CH=CH(CH_2)_7CO_2H$
(v) $CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_6CO_2H$

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Study Questions

1. What are fats?
2. What is meant by fatty acids?
3. What is the main difference between fats and oils?
4. Name two unsaturated fatty acids found in canola oil.
5. Name three saturated fatty acids found of plant origin.
6. Name fatty acids with the short hand notation (18:2)9,11.
7. Name fatty acids with the omega notation (18:3)ω6,9,11.
8. Give the IUPAC names of the following fatty acids.

   (i) $CH_3(CH_2)_{14}COOH$
   (ii) $CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$

9. How is EtOH produced industrially?
10. Draw all possible structures of mono, di, and tri-glycerides of *stearic acid* (*RCOOH*).
11. Triglyceride contains butyric and stearic acid in the ratio of 2:1. Draw the structures of the possible isomers.

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Appendix- I

Table 4 Fatty acid composition of some common edible fats and oils

Source	**Unsat. /Sat. ratio**	**Percentage by weight of total fatty acid**							
		Capric acid **(10:0)**	Lauric acid **(12:0)**	Myristic acid **(14:0)**	Palmitic acid **(16:0)**	Stearic acid **(18:0)**	Oleic acid **(18:1)**	Linoleic acid **(18:2)**	α-linolenic acid **(18:3)**
Beef Tallow	0.9	-	-	3	24	19	43	3	1
Butter fat (cow)	0.5	3	3	11	27	12	29	2	1
Butter fat (human)	1.0	2	5	8	25	8	35	9	1
Canola oil	15.7	-	-	-	4	2	62	22	10
Coconut oil	0.1	6	47	18	9	3	6	2	-
Lard (pork fat)	1.2	-	-	2	26	14	44	10	-
Olive oil	4.6	-	-	-	13	3	71	10	-
Palm oil	1.0	-	-	1	45	4	40	10	1
Palm kernel oil	0.2	4	48	16	8	3	15	2	-
Safflower oil	10.1	-	-	-	7	2	13	78	-
Soybean oil	5.7	-	-	-	11	4	24	54	7
Sunflower oil	7.3	-	-	-	7	5	19	68	1

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