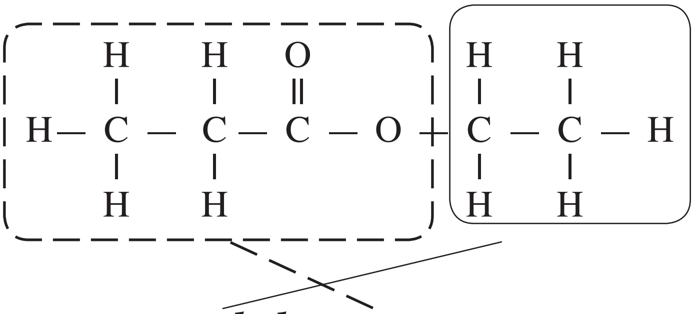
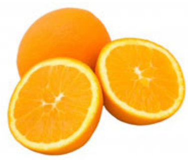
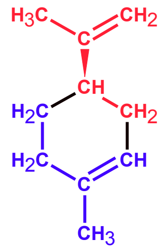
Higher Chemistry



ethyl propanoate





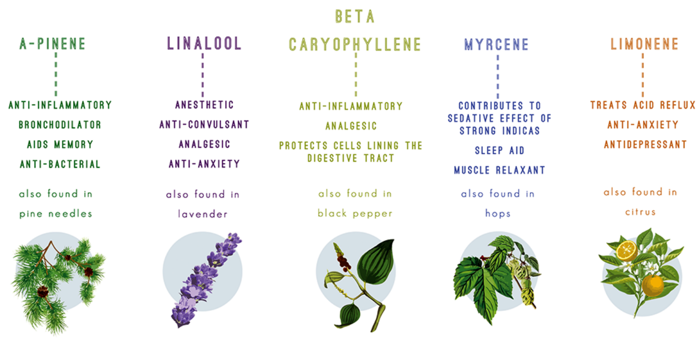
Limonene

(skin of citrus fruits)

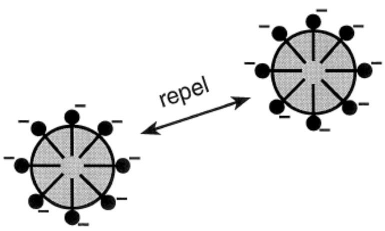
Unit 2:

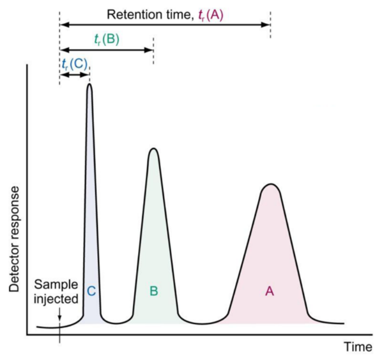
Nature's Chemistry

Student:

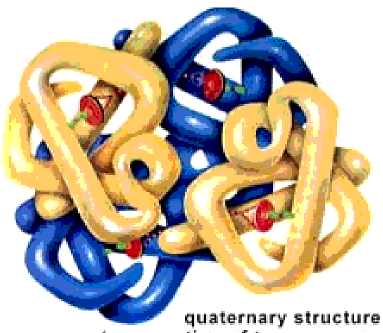


Topic 6

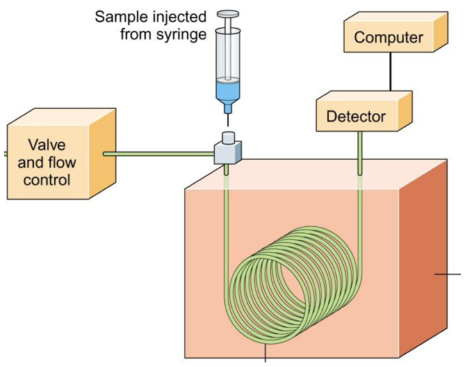




Acids & Esters
Fats & Oils
Soaps, Detergents & Emulsifiers
Terpenes
Proteins



quaternary structure
(aggregation of two or more peptides)



6.1 Alkanoic Acids

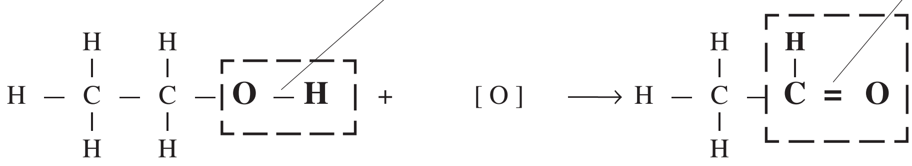
This first topic revises the names, formulae and structures of the family of acids called the alkanoic acids

Ethanoic Acid

This activity considers the formation and structure of the alkanoic acid called ethanoic acid.

Ethanoic acid is normally manufactured from ***ethanol***. The ***oxygen*** required for the ***oxidation*** reaction can come from the ***air*** or from an ***oxidising agent*** such as *copper(II) oxide*.

During the first ***oxidation*** step, the *hydroxyl group* is converted into a *carbonyl group*: *etha**nol*** is converted into *etha**nal***



*C_2H_5**OH***　　　　*CH_3**CHO***

During the second ***oxidation*** step, an ***oxygen*** atom is inserted to convert the *carbonyl group* into a *carboxyl group*: *etha**nal*** is converted into *etha**noic** acid*.

carboxyl group is the *functional group* of an acid

*CH_3**CHO***　　　　*CH_3**COOH***

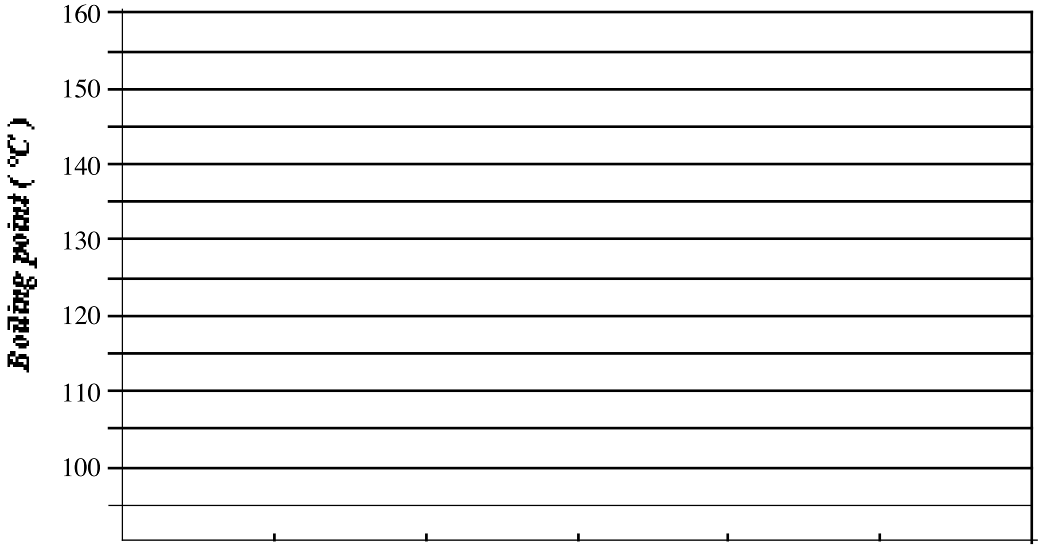
Alkanoic Acids

This activity considers the alkanoic acids as a homologous series.

a)

Chemical properties	***Ethanoic acid***	***Propanoic acid***
Smell & Appearance	'vinegary' colourless liquid	'cheesey' colourless liquid
Universal indicator	soluble pink, pH < 7	soluble pink, pH < 7
Magnesium	'fizzes' (hydrogen gas)	'fizzes' (hydrogen gas)
Calcium carbonate	'fizzes' (CO_2 gas)	'fizzes' (CO_2 gas)

b) Boiling point trend



c) General formula

The general formula for the alkanoic acids is:-

$$C_nH_{2n+1}\ \boxed{COOH}$$

Notice that one of the ***carbon*** atoms is not included in the C_n '*chain*'. This is to enable the ***carboxyl functional group*** to be emphasised. ***WARNING !*** - this means that for each acid **n** is one less than you'd expect; *methanoic* **n** = **0**, *ethanoic* **n** = **1**, etc.

From all this it can be seen that the ***alkanoic** acids* have:

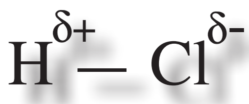
① ***similar chemical** properties*

② ***physical** properties* that show a *steady **trend***

and ③ a *common **general** formula,* so they belong to a ***homologous** series*

d) 'Normal' Acid Reactions

Alkanoic acids do all the'normal' acid reactions

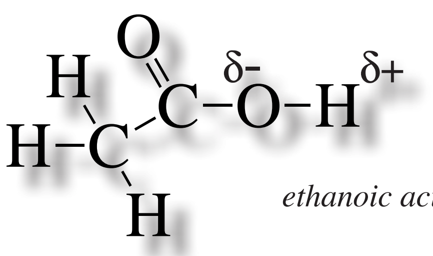


hydrogen chloride

$H^+\ Cl^-_{(aq)}$

hydrochloric acid

*acids are substances which dissolve in water to produce **hydrogen ions, $H^+_{(aq)}$**.*



ethanoic acid

$H^+\ CH_3COO^-_{(aq)}$

ethanoic acid

Acid + metal → salt + hydrogen

e.g *magnesium* + *sulfuric acid* → *magnesium sulfate* + *hydrogen*

$Mg_{(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_{2(g)}$

magnesium + *ethanoic acid* → *magnesium ethanoate* + *hydrogen*

$Mg_{(s)} + CH_3COOH_{(aq)} \rightarrow Mg(CH_3COO)_{2(aq)} + H_{2(g)}$

Acid + metal oxide → salt + water

e.g *iron (III) oxide* + *nitric acid* → *iron(III) nitrate* + *water*

$Fe_2O_{3\,(s)} + 6\,HNO_{3\,(aq)} \rightarrow 2\,Fe\,(NO_3)_{3\,(aq)} + 3\,H_2O_{\,(l)}$

sodium oxide + *methanoic acid* → *sodium methanoate* + *water*

$Na_2O_{\,(s)} + 2\,HCOOH_{\,(aq)} \rightarrow 2\,Na\,HCOO_{\,(aq)} + H_2O_{\,(l)}$

Acid + alkali → salt + water

e.g *potassium hydroxide* + *hydrochloric acid* → *potassium chloride* + *water*

$KOH_{(s)} + HCl_{(aq)} \rightarrow KCl_{(aq)} + H_2O_{(l)}$

lithium hydroxide + *ethanoic acid* → *potassium ethanoate* + *water*

$LiOH_{(s)} + CH_3COOH_{(aq)} \rightarrow LiCH_3COO_{(aq)} + H_2O_{(l)}$

Acid + metal carbonate $\rightarrow$ salt + water + carbon dioxide

e.g calcium carbonate + hydrochloric acid $\rightarrow$ calcium chloride + water + carbon dioxide

$$CaCO_{3\,(s)} + 2\,HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$

sodium carbonate + methanoic acid $\rightarrow$ sodium methanoate + water + carbon dioxide

$$Na_2CO_{3\,(s)} + 2\,HCOOH_{(aq)} \rightarrow 2\,NaHCOO_{(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$

e) ***'Organic' Acid Reactions***

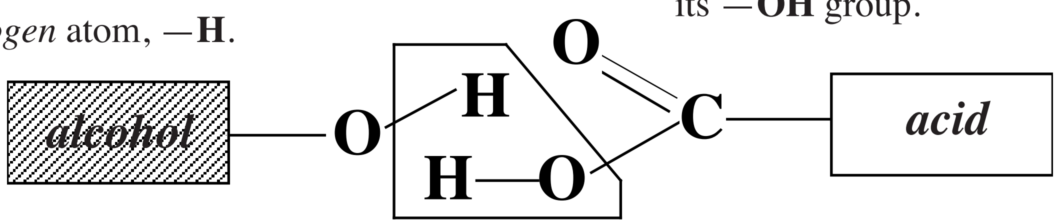
Alkanoic acids also have reactions that are characteristic of ***organic carboxylic acid*** reactions

Condensation: *reaction in which two molecules join together, usually in the presence of a catalyst, with elimination of water or some other simple molecule.*

To ***join together***, each molecule must ***lose*** some of the existing atoms attached to the ***carbon*** atom with the ***functional group***.

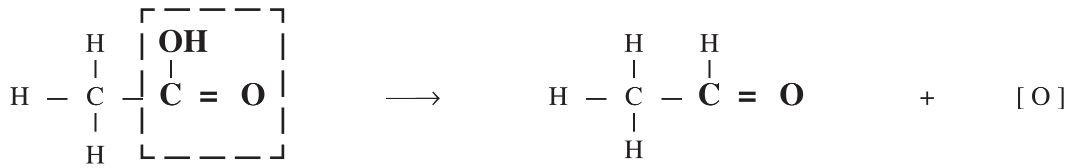
The ***hydroxyl group*** on the ***alcohol*** will have to lose its *hydrogen* atom, —**H**.

The ***carboxyl group*** on the ***acid*** loses its —**OH** group.



The whole reaction is helped by the fact that an —**OH** group and an —**H** atom will then be able to form a ***stable molecule***, *water* (H_2O).

Reduction: *reaction in which the oxygen:hydrogen ratio decreases*



CH_3COOH *CH_3CHO*

In other words, it is possible to ***reverse*** the ***oxidation*** reactions met earlier using a ***reducing agent*** such as $LiAlH_4$:

carboxylic acid $\longrightarrow$ ***aldehyde*** $\longrightarrow$ ***primary alcohol***

ketone $\longrightarrow$ ***secondary alcohol***

Structures, Names & Formulae

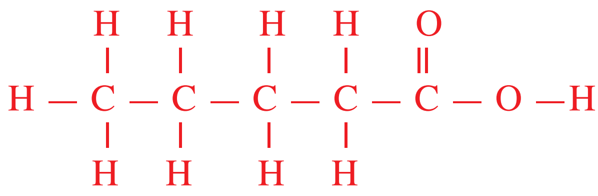
This activity considers the structures, formulae and systematic names of some of the members of the alkanoic acid family.

Any molecule that contains the *carboxyl group*, —COOH, can be considered as a *carboxylic acid*. The molecule could have a ***chain*** structure, a ***ring*** structure or even be ***aromatic***, it could be ***saturated*** (C—C) or ***unsaturated*** (C=C or C≡ C).

*The **alkanoic acids** are compounds which contain the **carboxyl group** joined to a hydrocarbon **chain** in which all the carbon atoms are joined by **single** bonds.*

As usual, there are three ways to represent the formula of, for example, *pentanoic acid*

full structural formula



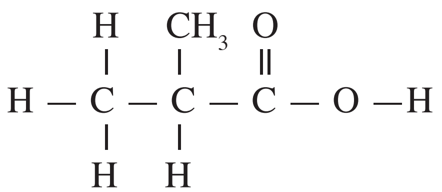
shortened structural formula

$CH_3CH_2CH_2CH_2COOH$

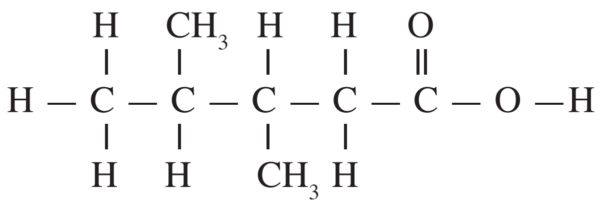
functional molecular formula

C_4H_9COOH

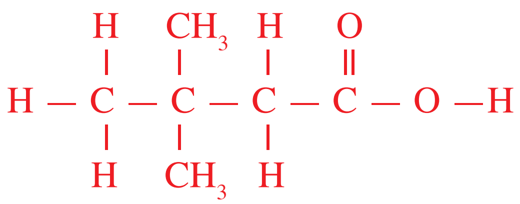
For naming purposes, the ***carbon*** of the ***carboxyl functional*** *group* is always taken as number 1, and the *'longest'* chain always starts with the ***functional*** *group*. ***Branches*** must then be ***numbered*** accordingly. For example:



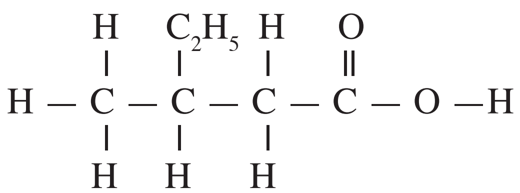
2-methylpropanoic acid



3,4-dimethylpentanoic acid



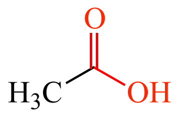
3,3-dimethylbutanoic acid



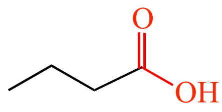
3-methylpentanoic acid

Uses of Acids

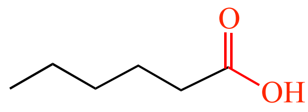
This activity is looks at the variety of acids and some of their uses



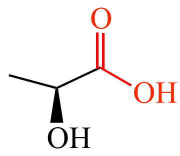
ethanoic acid
responsible for the pungent smell of vinegar



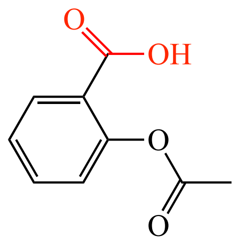
butanoic acid
responsible for the rancid odour of sour butter



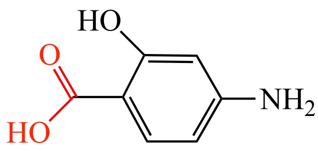
hexanoic acid
responsible for the odour of smelly feet



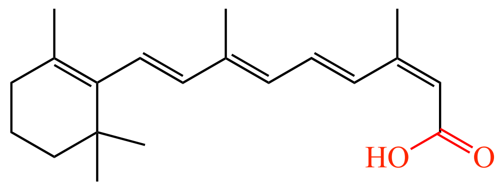
lactic acid
responsible for the taste of sour milk



acetylsalicylic acid
Aspirin: a widely used analgesic



p-aminosalicylic acid
used in the treatment of tuberculosis



isotretinoin
used in the treatment of acne

Carbon atoms	Common name	IUPAC name	Chemical formula	Common location or use
1	Formic acid	Methanoic acid	$HCOOH$	Insect stings
2	Acetic acid	Ethanoic acid	CH_3COOH	Vinegar
3	Propionic acid	Propanoic acid	CH_3CH_2COOH	Preservative for stored grains
4	Butyric acid	Butanoic acid	$CH_3(CH_2)_2COOH$	Butter
5	Valeric acid	Pentanoic acid	$CH_3(CH_2)_3COOH$	Valerian
6	Caproic acid	Hexanoic acid	$CH_3(CH_2)_4COOH$	Goat fat
7	Enanthic acid	Heptanoic acid	$CH_3(CH_2)_5COOH$	
8	Caprylic acid	Octanoic acid	$CH_3(CH_2)_6COOH$	Coconuts and breast milk
9	Pelargonic acid	Nonanoic acid	$CH_3(CH_2)_7COOH$	Pelargonium
10	Capric acid	Decanoic acid	$CH_3(CH_2)_8COOH$	Coconut and Palm kernel oil
11	Undecylic acid	Undecanoic acid	$CH_3(CH_2)_9COOH$	
12	Lauric acid	Dodecanoic acid	$CH_3(CH_2)_{10}COOH$	Coconut oil and hand wash soaps.
13	Tridecylic acid	Tridecanoic acid	$CH_3(CH_2)_{11}COOH$	
14	Myristic acid	Tetradecanoic acid	$CH_3(CH_2)_{12}COOH$	Nutmeg
15		Pentadecanoic acid	$CH_3(CH_2)_{13}COOH$	
16	Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$	Palm oil
17	Margaric acid	Heptadecanoic acid	$CH_3(CH_2)_{15}COOH$	
18	Stearic acid	Octadecanoic acid	$CH_3(CH_2)_{16}COOH$	Chocolate, waxes, soaps, and oils
19		Nonadecylic acid	$CH_3(CH_2)_{17}COOH$	Fats, vegetable oils, pheromone
20	Arachidic acid	Icosanoic acid	$CH_3(CH_2)_{18}COOH$	Peanut oil

Self Check 6.1

Q1. Which of the following is a word equation for the manufacture of ethanoic acid?

A copper + ethanol ⟶ oxygen + ethanoic acid
B oxygen + ethanol ⟶ copper + ethanoic acid
C oxygen + ethanol ⟶ water + ethanoic acid
D water + ethanol ⟶ oxygen + ethanoic acid.

Q2. The functional group in an ethanoic acid molecule is called the

A methyl group
B carboxyl group
C carbonyl group
D hydroxyl group.

Q3. Which result is obtained when magnesium is put in 0.1 M ethanoic and propanoic acids?

	ethanoic acid	*propanoic acid*
A	bubbles	bubbles
B	no bubbles	bubbles
C	bubbles	no bubbles
D	no bubbles	no bubbles

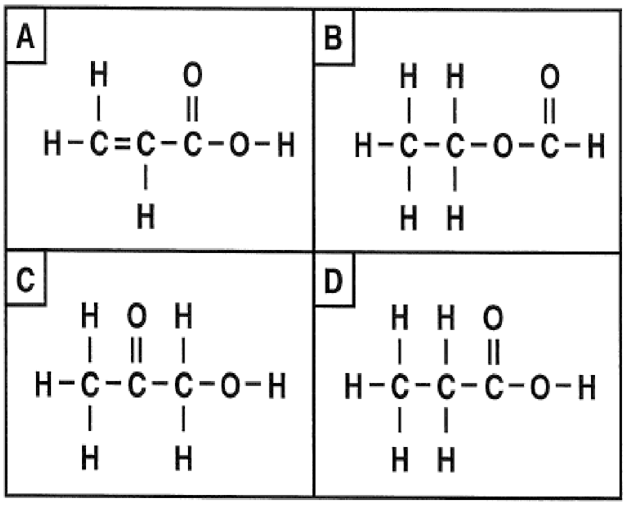
Q4. What is the general formula for an alkanoic acid?

A $C_nH_{2n}COOH$
B $C_nH_{2n+1}COOH$
C $C_nH_{2n-1}COOH$
D $C_nH_{2n+2}COOH$

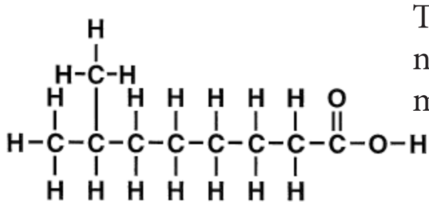
Q5. Which of the following formulae could represent hexanoic acid?

A $C_6H_{13}COOH$
B C_5H_9COOH
C $C_5H_{11}COOH$
D $C_6H_{11}COOH$

Q6. Which of the following structures represents an alkanoic acid?



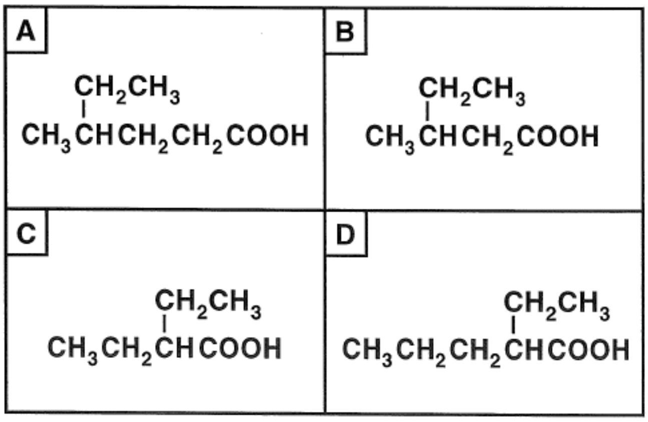
Q7.



The systematic name for this molecules is

A 2-methylheptanoic acid.
B 2-methyloctanoic acid.
C 6-methylheptanoic acid.
D 7-methyloctanoic acid.

Q8. What is the shortened structural formula for 2-ethylbutanoic acid?



Q9. The conversion of butanoic acid to butanal is known as

A condensation
B oxidation
C reduction
D substitution

Home Practice 6.1

Q1. Name each of the following molecules.

a) C_2H_5COOH **1**

b) $CH_3CH_2CH_2CH_2COOH$ **1**

Q2. Draw the full structural formula for each of the following substances.

a) methanoic acid **1**

b) 2-methylbutanoic acid **1**

Q3. Draw the shortened structural formula for each of the following substances.

a) hexanoic acid **1**

b) 4-methylpentanoic acid **1**

Q4. All of the substances above are examples of one type of organic compound.

a) Name the homologous series to which they belong. **1**

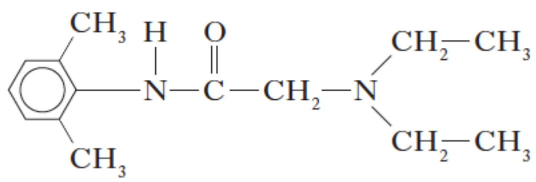
b) Name the wider class of organic compound to which they also belong. **1**

c) Name the functional group which characterises these compounds. **1**

d) ***Explain*** of the three acids - butanoic, octanoic, or hexanoic acid - would you expect to have the highest boiling point? **1**

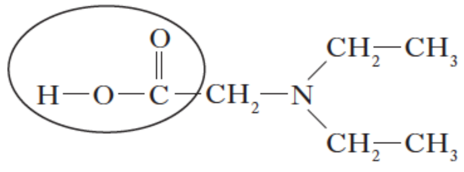
Q5. Dental anaesthetics are substances used to reduce discomfort during treatment.

Lidocaine is a dental anaesthetic.



Lidocaine causes numbness when applied to the gums. This effect wears off as the lidocaine is hydrolysed.

One of the products of the hydrolysis of lidocaine is compound C.



compound **C**

a) Name the functional group circled above. **1**

b) Draw a structural formula for the organic compound formed when compound **C** reacts with $NaOH_{(aq)}$ **1**

c) Draw a structural formula for ***both*** organic compounds that could be formed when compound **C** is reduced by reacting with $NaAlH_4$. **2**

Total ***(14)***

6.2 ESTERS - Flavour Molecules

This second topic revises the group of substances known as esters and looks at their properties, their uses, and how they are related to alcohols and carboxylic acids.

Properties & Uses

This activity is about the properties and uses of esters, in particular an ester called pentyl ethanoate (amyl acetate)

Property	*Result*
Appearance	***clear, colourless liquid***
Smell	***sweet , pleasant - 'pear drops'***
Solubility	***immiscible in water - separate layers***
pH	***neutral , pH = 7 , no H^+ or OH^-***
Solvent action	***dissolves many non-polar & polar substances***

The 3 main uses of esters are as:

① ***flavourings*** - in foodstuffs

② ***solvents*** - e.g used in ***nail varnish***

and ③ ***perfumes*** - are ***volatile***, so quickly releases ***vapour***

Being ***volatile*** often makes them very ***flammable***.

Ester Names

This activity considers the names of esters and how they relate to the alcohol and carboxylic acid from which the ester can be made

*An **ester** is a substance which is formed by the **condensation** reaction of an alcohol with a carboxylic acid.*

Each ***ester*** can thought of as having a ***'parent' alcohol*** from which it is formed. The ***'parent alcohol'*** provides the *'christian name'* of the ***ester***. The ***alcohol*** name has the '*—ol*' ending replaced with an '*—yl*' ending.

'parent alcohol'	***ester 'christian name'***
*meth**anol***	*meth**yl***
*eth**anol***	*eth**yl***
*prop**anol***	*prop**yl***
*but**anol***	*but**yl***

Each ***ester*** also has a ***'parent' carboxylic acid*** from which it is formed. The ***'parent acid'*** provides the *'surname'* of the ***ester***. The ***acid*** name has the *'—oic'* ending replaced with an *'—oate'* ending.

'parent acid'	***ester 'surname'***
methanoic	*methanoate*
ethanoic	*ethanoate*
propanoic	*propanoate*
butanoic	*butanoate*

For example,

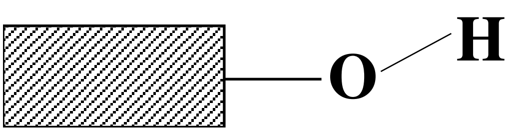
pentyl ethanoate

parent alcohol = ***pentanol*** *parent acid* = ***ethanoic acid***

parent alcohol	***parent carboxylic acid***	***ester name***	***ester flavour***
ethanol	*methanoic acid*	***ethyl methanoate***	*rum*
ethanol	*ethanoic acid*	***ethyl ethanoate***	*sweet wine*
pentan-1-ol	***ethanoic acid***	*pentyl ethanoate*	***pear drop***
ethanol	***butanoic acid***	*ethyl butanoate*	*pineapple*

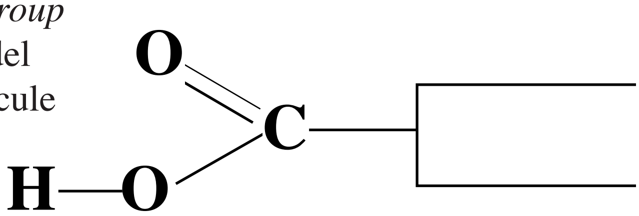
Functional Group

This activity considers the functional group in an ester molecule by looking at how it is formed from the parent alcohol and the parent carboxylic acid



Since all ***alcohols*** have the ***hydroxyl*** *functional group* they can be all be represented by the simple model shown. The block stands for the rest of the molecule which, in *alkanols*, would be a ***hydrocarbon chain***.

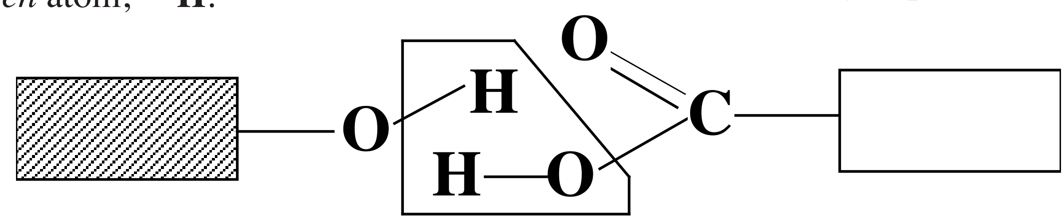
Since all ***acids*** have the ***carboxoxyl*** *functional group* they can be all be represented by the simple model shown. The block stands for the rest of the molecule which, in *alkanoic acids*, would be a ***hydrocarbon chain***.



To ***join together***, each molecule must ***lose*** some of the existing atoms attached to the ***carbon*** atom with the ***functional group***.

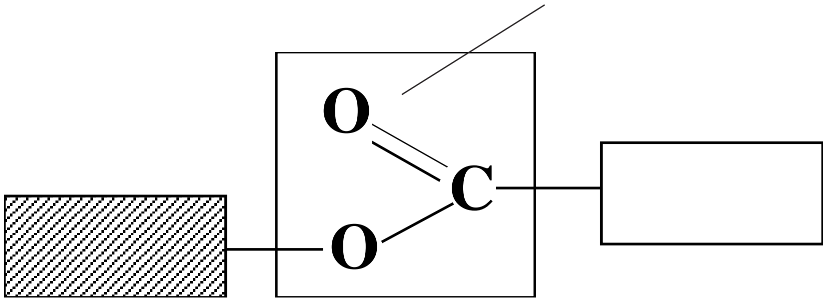
The ***hydroxyl group*** on the ***alcohol*** will have to lose its *hydrogen* atom, **—H**.

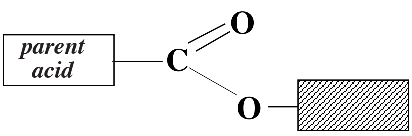
The ***carboxyl group*** on the ***acid*** loses its **—OH** group.

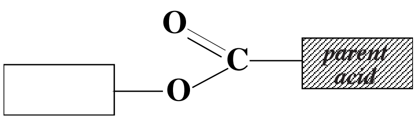


The whole reaction is helped by the fact that an **—OH** group and an **—H** atom will then be able to form a ***stable molecule***, *water* (H_2O).

The resulting ***ester*** molecule, formed by *joining* an ***alcohol*** to an ***acid***, owes its *properties* to the group of atoms that now *link* the two molecules together. This can be called the ***carboxylate group***, but is more often referred to as the ***'ester link'.***







It is important to be able to recognise the ***ester link*** no matter how it is drawn.

You will also be expected to be able to redraw the ***parent acid*** and ***parent alcohol*** molecules, so whichever ***carbon chain*** is directly attached to the ***carbonyl group***, C = O, must have been the ***parent acid*** and the other chain belonged to the ***alcohol***.

SELF CHECK 6.2

Q1. Esters are substances which

A often have poisonous vapours
B are very soluble in water
C often have pleasant tastes and smells
D are liquids with acidic properties.

Q2. Which of the following is ***not*** a use for pentyl ethanoate ?

A colouring in food dyes
B scent in perfume
C flavouring in sweets
D solvent in nail varnish.

Q3. An ester can be made from

A a carboxylic acid and an alkane
B an alcohol and a carboxylic acid
C an alkane and an alcohol
D a carboxylic acid and an alkene.

Q4. Which of the following substances is an example of an ester?

A 2-methylbutane
B methylpropanoic acid
C methylpropanoate
D 3-methylbutan-1-ol

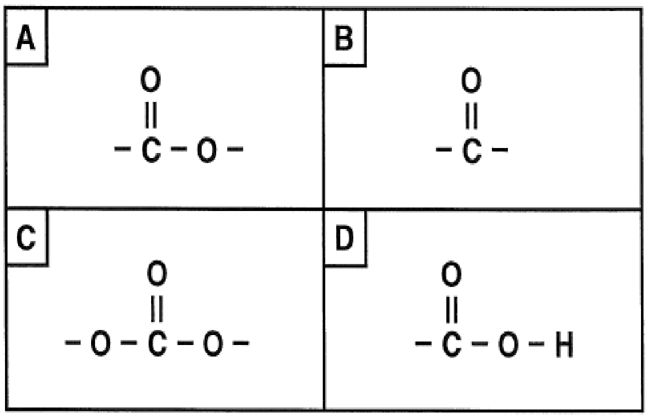
Q5. What is the parent alkanoic acid for pentyl ethanoate?

A heptanoic acid
B pentanoic acid
C methanoic acid
D ethanoic acid

Q6. What is the parent alkanol for pentyl ethanoate?

A heptanol
B pentanol
C methanol
D ethanol

Q7. What is the structure of the functional group in an ester molecule?



Q8. The functional group in an ester is caled the

A carbonate group
B carboxyl group
C carbonyl group
D carboxylate group.

Q9. An ester has the following structural formula

$$CH_3CH_2CH_2COOCH_2CH_3$$

The name of this ester is

A propyl propanoate
B ethyl butanoate
C butyl ethanoate
D ethyl propanoate.

HOME PRACTICE 6.2

Q1. Name the ester formed from each of the following pairs of compounds.

a) ethanol and butanoic acid **1**

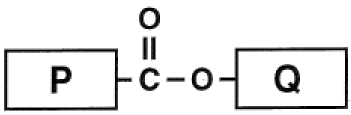
b) propanoic acid and butanol **1**

Q2. Identify three typical uses for esters from the selection given below.

fertilisers	flavourings
pigments	perfumes
explosives	solvents
vitamins	neutralisers

3

Q3. The diagram shows a simplified model of an ester molecule.



a) Name the functional group in this molecule. **1**

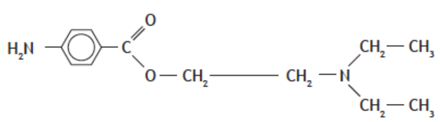
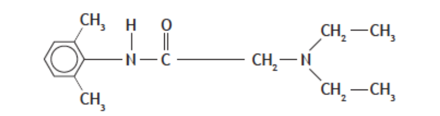
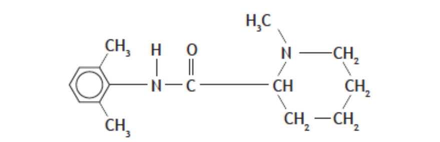
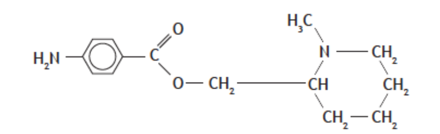
b) Which part of the molecule, P or Q, came from the parent acid? **1**

Q4. Name ***i)*** the parent acid and ***ii)*** the parent alcohol used to make each of the following esters.

a) propyl hexanoate **2**

b) methyl octanoate **2**

Q5. The table below shows the duration of numbness for common anaesthetics.

Name of anaesthetic	*Structure*	*Duration of numbness (minutes)*
procaine		7
lidocaine		96
mepivacaine		114
anaesthetic X		

a) Which of the anaesthetics are esters? **1**

b) Which of the anaesthetics have amide links? **1**

c) Estimate the duration of numbness, in minutes, for anaesthetic **X**. **1**

Total ***(14)***

6.3 ESTERS - Condensation & Hydrolysis Reactions

This topic looks in more detail at how esters can be made from their parent compounds and how esters can then be broken down to produce the original alcohol and carboxylic acid molecules.

Formation Reaction

This activity considers the structural formulae of the molecules involved in the formation of an ester by the condensation reaction between methanol and ethanoic acid

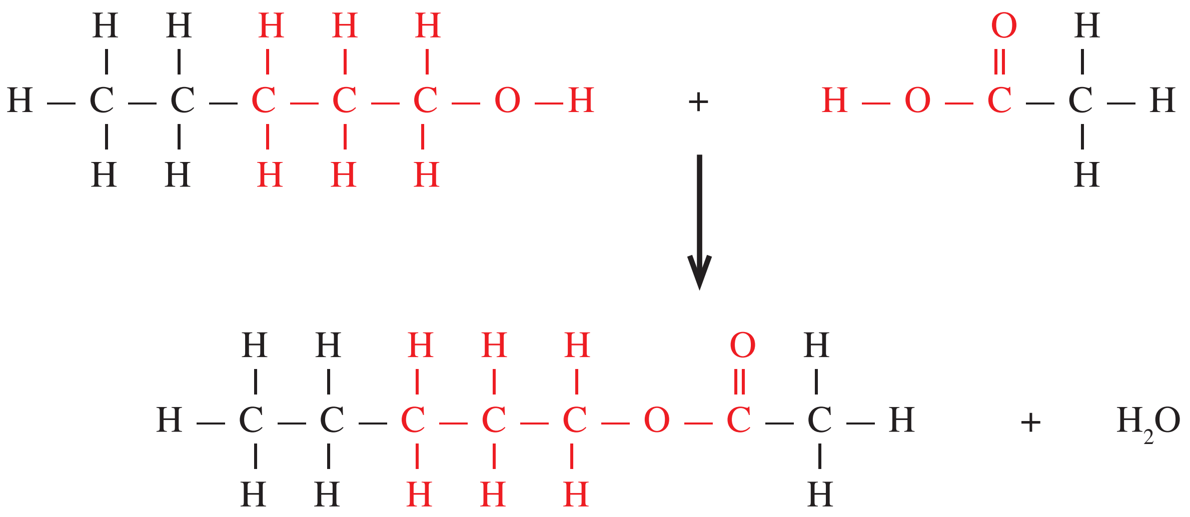
*A **condensation reaction** occurs when **two molecules** each lose one or more atoms in order to **join together**. Another small molecule is also formed by the 'lost' atoms.*

The other small molecule formed is often ***water***, hence the use of the name ***condensation***. However, other reactions that *'form water'* , such as *neutralisation* or the *dehydration of alkanols* to form alkenes, are ***not*** condensations because they ***do not*** result in the ***joining together*** of two molecules.

Word equation:

pentanol* + *ethanoic acid* ⇌ *pentyl ethanoate* + *water

Equation using full structural formulae:



A ***general word equation*** can be written for the ***formation*** of an ***ester***.

alcohol* + *carboxylic acid* ⇌ *ester* + *water

Condensation

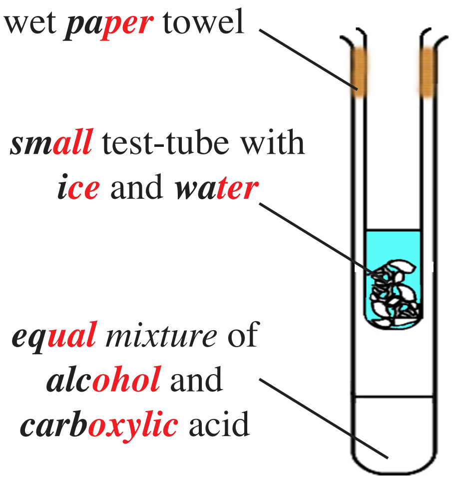
The aim of this activity is to prepare an ester using the condensation reaction and to confirm the formation of an ester by its smell

conc.
H_2SO_4

The *reagent* needed for the ***condensation*** reaction is ***concentrated*** H_2SO_4. It has two functions:

Catalyst: it provides $H^+_{(aq)}$ which help ***form*** the ***ester link*** but are then ***reformed***.

Dehydrating agent: it ***absorbs*** *water* molecules which ***slows*** down the ***reverse*** reaction and helps push the ***equilibrium*** *mixture* to the ***right***.



Water Bath: A ***beaker*** of water is heated until ***boiling*** and then the ***bunsen burner*** is put out - both ***alcohols*** and ***esters*** are very ***volatile*** / ***flammable*** - ***Safety***

Cold Finger: To ***prevent*** loss of ***volatile*** chemicals during ***heating***.

conc H_2SO_4 : 5 drops of ***conc***. H_2SO_4 were added by the ***teacher*** - ***Safety***

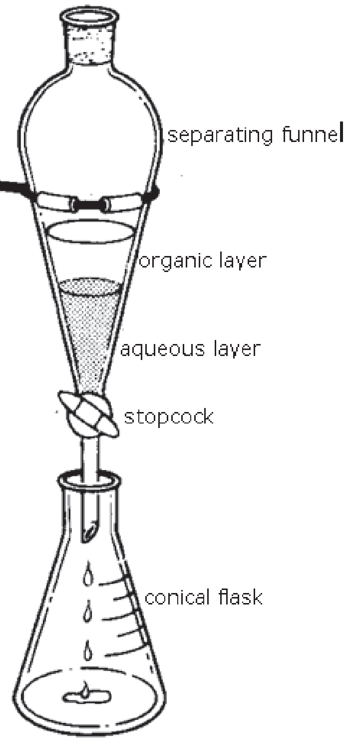
By this stage, ***two layers*** may have formed. The *very* ***polar alcohol*** and ***carboxylic acid*** in one ***layer*** and the *less* ***polar ester*** floating above.

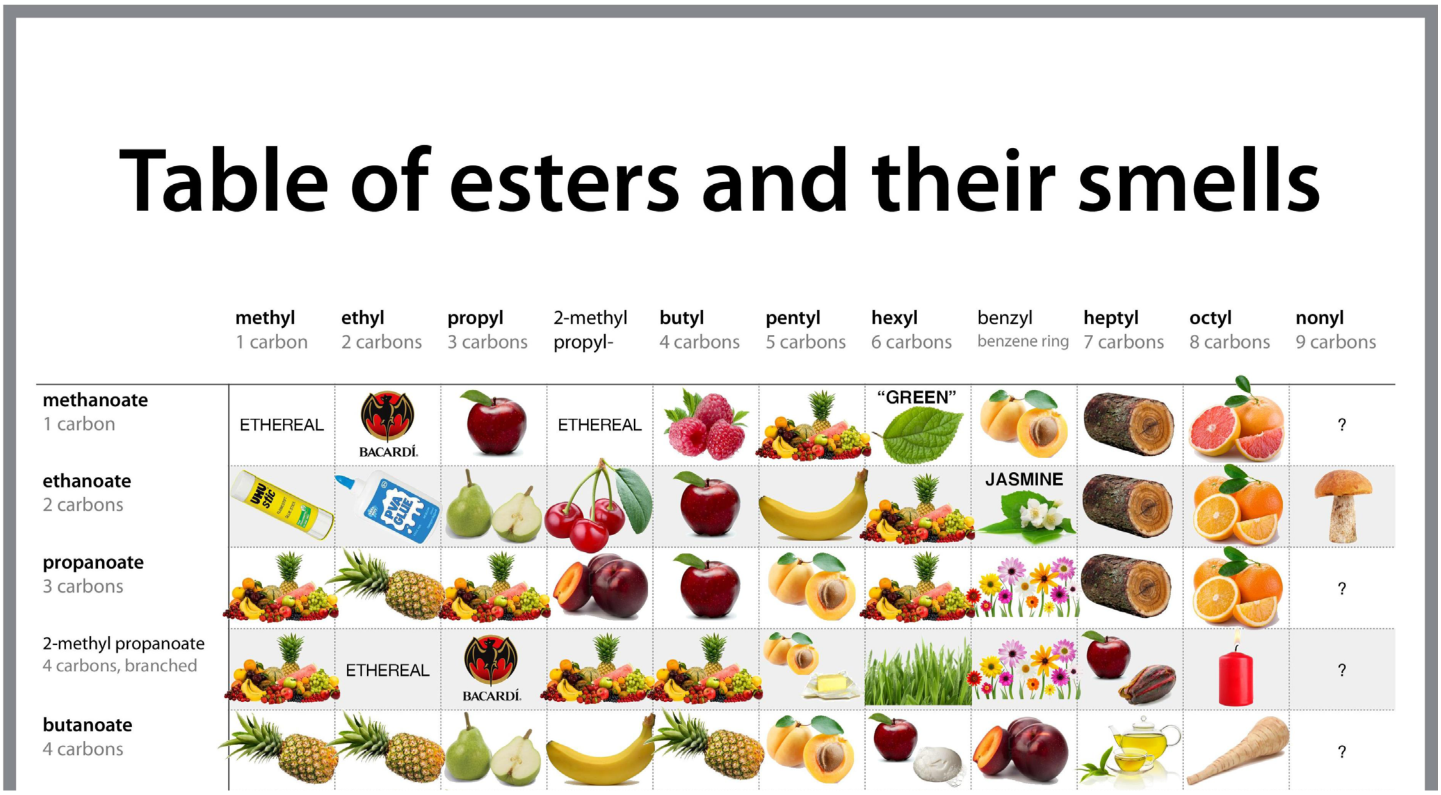
Adding ***water*** (with ***hydrogen bonding***) will ***dissolve*** the ***alcohol*** and the ***acid*** as they also have ***hydrogen bonding*** groups. The ***ester*** only has *polar:polar* (*dipole:dipole*) ***intermolecular*** bonding.

The smell of the ***ethanoic acid*** (*vinegar*) is overpowering, so Na_2CO_3 solution was used instead - the acid is converted to ***ethanoate*** *salt* and ***fizzing*** can be used to tell when enough has been added.

By this stage, ***two definite layers*** will exist and the characteristic ***smell*** of the ***ester*** (top layer) will be obvious.

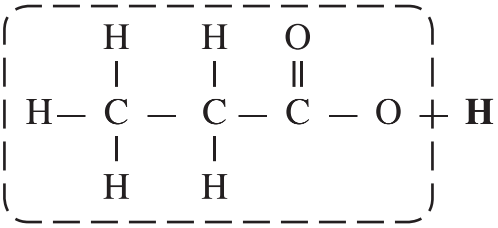
Alternatively, a ***separating funnel*** can be used - the *more dense* ***water layer*** (with *unreacted* ***alcohol*** and ***acid***) can be let out of the *bottom* and then the *less dense* ***ester*** (top layer) is poured out of the *top*.





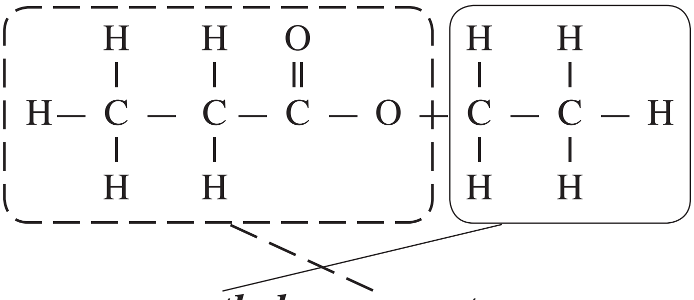
Formulae & Names

This activity deals with naming and drawing full and structural formulae for esters.



The 'best' way to think about an ***ester*** is to consider it as an ***acid molecule*** which has had its ***hydrogen atom*** replaced by a ***carbon chain*** (an *alkyl group*).

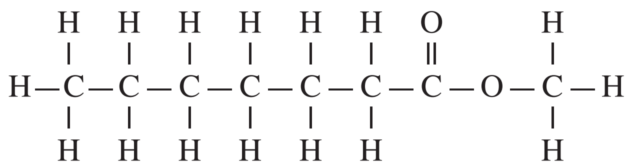
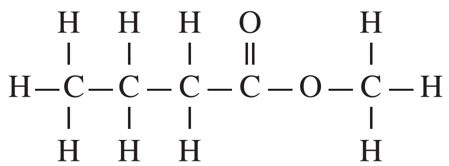
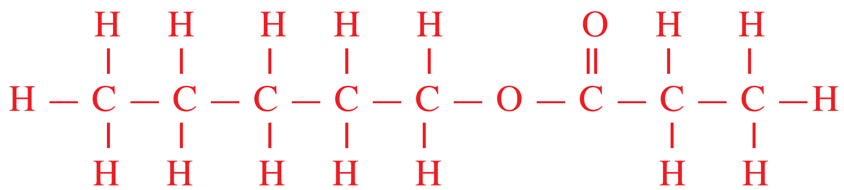
Learn to draw acids and you should find esters easy!



ethyl propanoate

As is often the case, we 'start' at the end of the name. *Identify the acid* (look for the ***carbonyl*** C = O) and give the ***ester*** its ***surname*** by changing the *—oic* ending to ***—oate***.

The *carbon chain* (derived from the parent ***alcohol***) is the ***'christian' name***, *—ol* changed to ***—yl***.

Ester Structures & Names	
Name:	methylheptanoate
Full Structural Formula:	
Shortened Structural Formula:	**$CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2COO\ CH_3$**
Name:	
Full Structural Formula:	
Shortened Structural Formula:	**$CH_3\ CH_2\ CH_2\ COO\ CH_3$**
Name:	pentyl propanoate
Full Structural Formula:	
Shortened Structural Formula:	**$CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ OOC\ CH_2\ CH_3$**

Hydrolysis

The aim of this activity is to consider the hydrolysis of an ester to produce an alcohol and carboxylic acid.

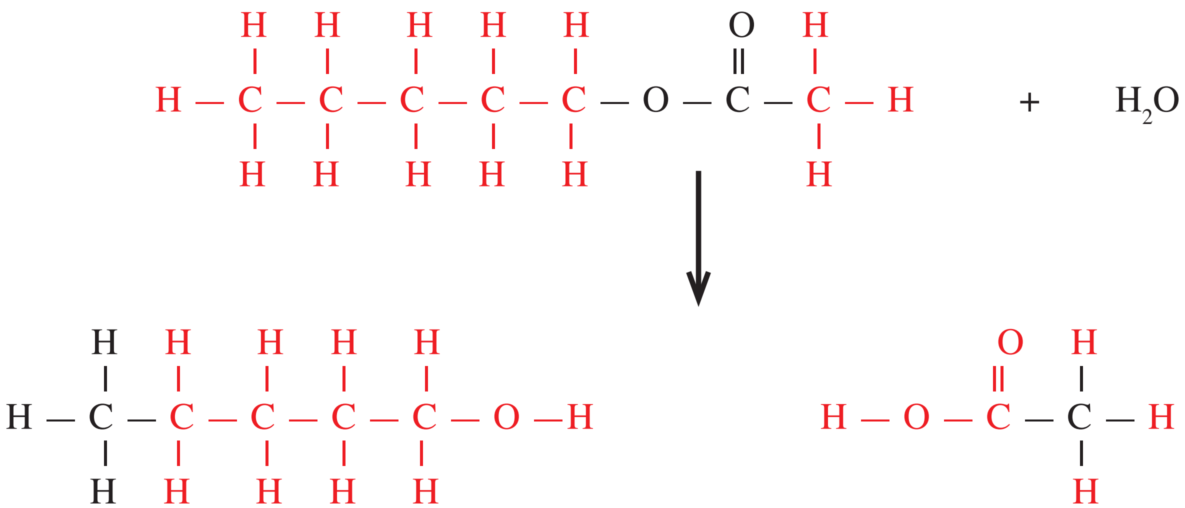
dilute
H_2SO_4

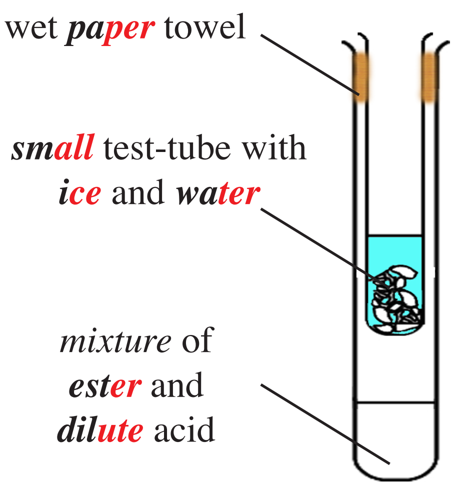
The *reagent* needed for the ***hydrolysis*** reaction is ***dilute*** H_2SO_4. Again, it has two functions:

Catalyst: it provides $H^+_{(aq)}$ which help ***break*** the ***ester link*** but are then ***reformed***.

Reactant: it ***provides*** the *water* molecules neede which ***speeds*** up the ***forward*** reaction and helps push the ***equilibrium*** *mixture* to the ***right***.

pentyl ethanoate + water $\rightleftharpoons$ pentanol + ethanoic acid





Water Bath: A ***beaker*** of water is heated until ***boiling*** and then the ***bunsen burner*** is put out - both ***alcohols*** and ***esters*** are very ***volatile*** / ***flammable*** - ***Safety***

Cold Finger: To ***prevent*** loss of ***volatile*** chemicals during ***heating***.

dil. H_2SO_4 : to ***provide water*** needed for ***hydrolysis*** and $H^+_{(aq)}$ to ***catalyse*** the reaction.

At the beginning, ***two layers*** will have formed. The *very* ***polar water*** in one ***layer*** with the *less* ***polar ester*** floating above.

Gradually, the ***ester layer*** will get ***smaller*** and the ***smell*** of the ***ethanoic acid*** (*vinegar*) may become strong enough to be ***detected*** over the ***smell*** of the ***ester*** - *pear drops*.

A more reliable way of telling that the ***hydrolysis*** has been successful would be to add a few drops of ***universal indicator*** - it will turn *red*.

SELF CHECK 6.3

Q1. What is the general word equation for the formation of an ester?

A ALCOHOL + CARBOXYLIC ACID $\longrightarrow$ ESTER

B ALCOHOL + CARBOXYLIC ACID $\longrightarrow$ ESTER + WATER

C SULPHURIC ACID + CARBOXYLIC ACID $\longrightarrow$ ESTER + WATER

D ALCOHOL + CARBOXYLIC ACID $\longrightarrow$ ESTER + HYDROGEN

Q2. The formation of an ester is an example of

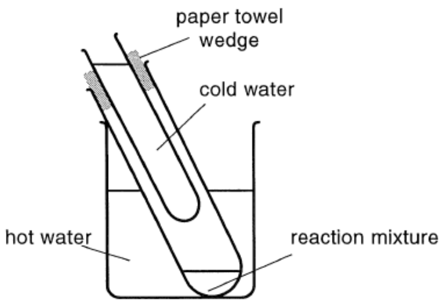
A an addition reaction

B a precipitation reaction

C an oxidation reaction

D a condensation reaction

Questions 3 and 4 refer to this diagram showing the preparation of an ester



Q3. The test-tube with cold water is there to act as a

A catalyst

B condenser

C evaporator

D purifier

Q4. What substance is added to the reaction mixture to speed up the formation of ester?

A concentrated nitric acid

B deionised water

C dilute hydrochloric acid

D concentrated sulphuric acid

Q5. Which of the following is not true of the two molecules in a condensation reaction?

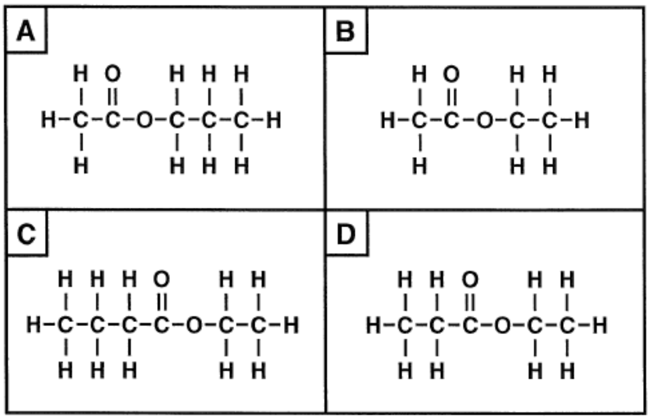
A The two reactant molecules form a larger product molecule.

B A small molecule is formed from atoms taken from two functional groups.

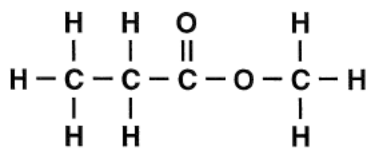
C The reactant molecules add together to form a single product.

D Each reactant molecule must have a reactive functional group

Q6. Which ester is formed by the reaction of CH_3COOH with $CH_3CH_2CH_2OH$?



Q7. What is the name of the following ester?



A propyl methanoate

B methyl ethanoate

C methyl propanoate

D ethyl methanoate

Q8. What is the formula of pentyl butanoate?

A $C_3H_7COOC_5H_{11}$

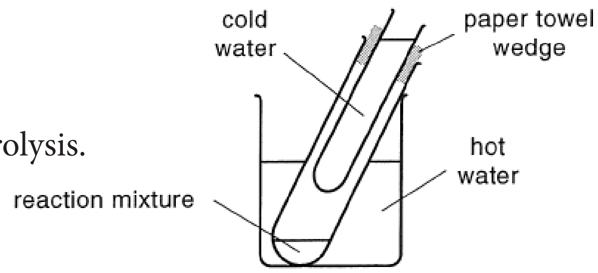
B $C_4H_9COOC_4H_9$

C $C_3H_7COOC_5H_9$

D $C_5H_{11}COOC_3H_7$

HOME PRACTICE 6.3

Q1. Butyl ethanoate can be hydrolysed using the apparatus shown



a) What is the purpose of the cold tube? **1**

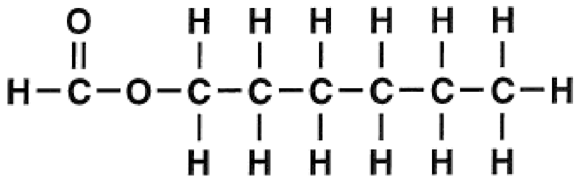
b) Write the word equation for this hydrolysis. **1**

c) Write the formula equation using shortened structural formulae. **2**

d) What does the term 'hydrolysis' mean? **1**

e) How does the hydrolysis equation compare with the equation for the formation of butyl ethanoate? **1**

Q2. The diagram shows the structural formula of an ester.



a) Why can the hydrolysis of this ester be described as a ***reversible reaction***? **1**

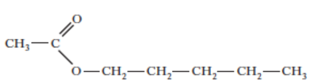
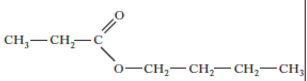
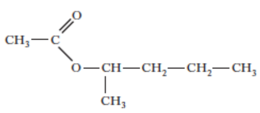
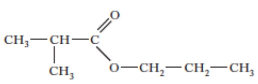
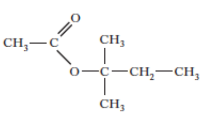
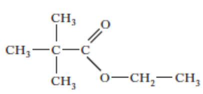
b) What ***sign*** is used in an equation to show that it is reversible? **1**

c) ***Name*** the acid produced by the hydrolysis of this ester. **1**

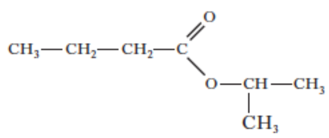
d) Draw the ***shortened*** structural formula for the alcohol produced. **1**

Q3. A team of chemists are developing a fragrance for use in a shower gel for men.

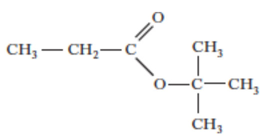
To give the gel a fruity smell the chemists are considering adding an ester. They synthesise six isomeric esters. Volunteers smell each ester and give it a rating out of one hundred depending on how fruity the smell is.

Structure	Fruit-smell rating	Structure	Fruit-smell rating
	100		92
	34		44
	0		32

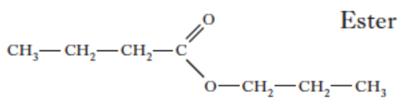
a) Name the ester with the fruit-smell rating of 92. **1**



Ester A



Ester C



Ester B

b) Arrange the three esters (A , B and C) in order of ***decreasing*** fruit-smell rating. **1**

Total **(12)**

6.4 Edible Fats & Oils

This lesson topic introduces edible fats and oils, substances which are both examples of esters and are closely related to each other

'Oil' is a much used word in Chemistry and can refer to quite different molecules from different parts of Chemistry.

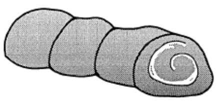
mineral oils:	*mainly hydrocarbon molecules from crude oil*
edible oils:	*esters based on glycerol made by plants & animals*
essential oils:	*volatile aroma molecules that are characteristic of a particular plant*

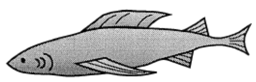
Sources of Fats & Oils

This activity considers the three main sources of edible fats and oils - animal, vegetable and marine.

Both edible ***fats*** and edible ***oils*** are esters - formed by ***joining carboxylic acids*** to ***alcohols***. Both ***fats*** and ***oils*** are ***greasy*** to touch, but ***fats are solid*** while ***oils are liquid*** at ***room temperature***.

They are found in a variety of ***living*** things and form an important part of the ***human diet***. They are usually *classified* according to whether their *source* is ***animal*** , ***vegetable*** or ***marine***.





Types of Edible Fats & Oils (Source)		
Animal	***Vegetable***	***Marine***
dripping (beef)	*fruits (olives)*	***whale blubber***
lard (pork)	*seeds (corn)*	***seal blubber***
tallow (lamb)	*seeds (peanuts)*	***sardine oil***
fat (goose)	*seeds (soya)*	***cod liver oil***

Ester Molecules

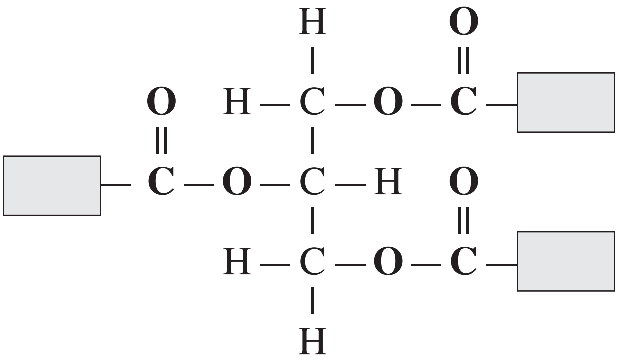
This activity looks at the structures of fats and oils as esters of the same alcohol.

```
        H
        |
   H — C — O — H
        |
H—O— C — H
        |
   H — C — O — H
        |
        H
```

Both ***fats*** and ***oils*** are esters - formed by ***joining carboxylic acids*** to ***alcohols***.

Surprisingly, all ***fat*** and ***oil*** molecules are formed from the ***same alcohol***. It has 3 carbon atoms each of which has a ***hydroxyl*** *group* (—OH) attached - it is the ***triol*** called ***propan-1,2,3-triol***

It is a clear, colourless but very ***viscous*** liquid (*very strong* ***hydrogen bonding*** *between* molecules) and is better known as ***glycerol***.



Having 3 ***hydroxyl groups*** allows 3 ***acid*** molecules to join onto ***glycerol*** - forming 3 ***ester links*** and fats & oils can be described as ***triple esters*** or as *triglycerides*.

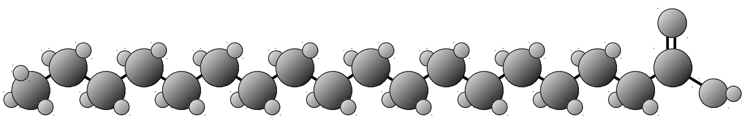
When *hydrolysed*, fats & oils always produce *3 moles* of acid molecules to *1 mole* of ***glycerol***.

Different fats & oils produce *different* ***acids*** when ***hydrolysed***. These acids are called ***fatty acids*** and *differences* in the ***structures*** of these ***acid*** *molecules* account for the *different* ***properties*** of fats and oils.

Fatty Acids

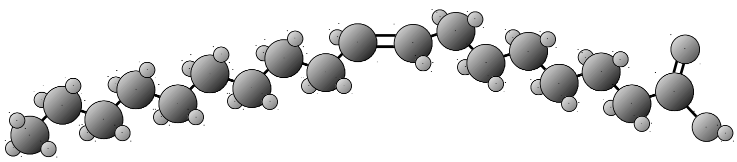
This activity looks at the structures of the carboxylic acids, i.e. the fatty acids, obtained by hydrolysing fats and oils

> ***Fatty acids*** *are saturated or unsaturated carboxylic acids, usually with long carbon chains, which are obtained from the hydrolysis of fats and oils*



stearic acid $C_{17}H_{35}COOH$

Stearic acid is a typical ***saturated fatty acid*** and is found in ***animal fat***. All along its *carbon chain* are found C—C ***single bonds***.



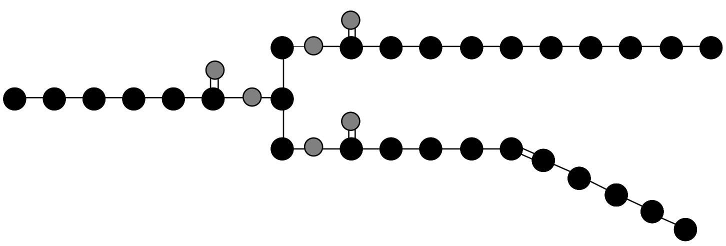
oleic acid $C_{17}H_{33}COOH$

Oleic acid is a typical ***unsaturated fatty acid*** and is found in ***olive oil*** Somewhere along its *carbon chain* is found a C = C ***double bond***.

Fatty acids are quite ***long chained*** *carboxylic acids*, typically 18 carbons per molecule. ***Animal fats*** tend to have *mainly* ***saturated fatty acids*** while ***marine oils*** and ***vegetable oils*** usually have *some* ***unsaturated fatty acids***.

Glycerides & Their Fatty Acid Content

This activity considers glycerides and the effect of their parent fatty acids on their properties.

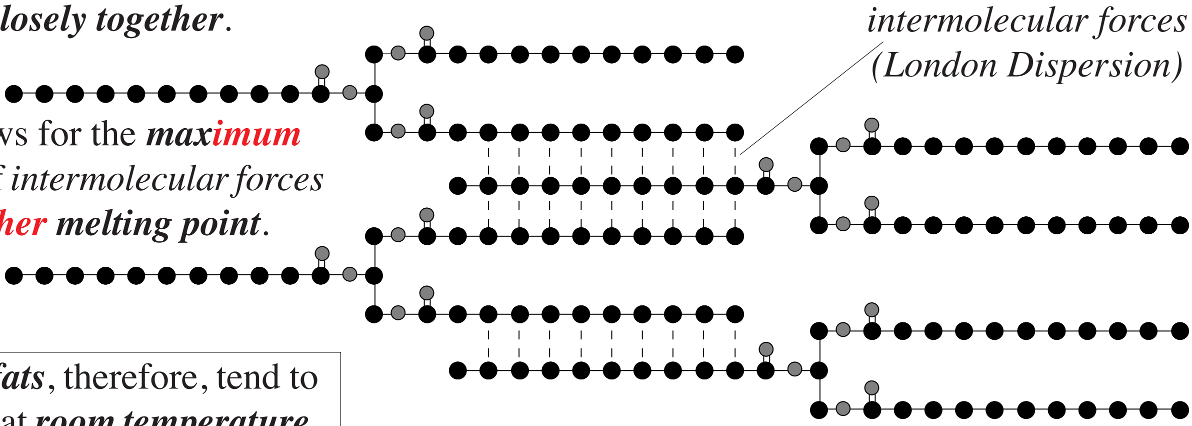


Fatty acids with odd numbers of carbon atoms are rare in nature - they are usually in the range C_2 to C_{24}.

Fats and ***oils*** are ***triple esters*** based on the ***alcohol glycerol***. They are often called *glycerides* or even *triglycerides*.

The 3 ***acids*** linked to the central ***glycerol*** molecule can be *identical* or *different*, ***saturated*** or ***unsaturated***. This explains the variety of fats & oils that exist and their *different* ***properties***.

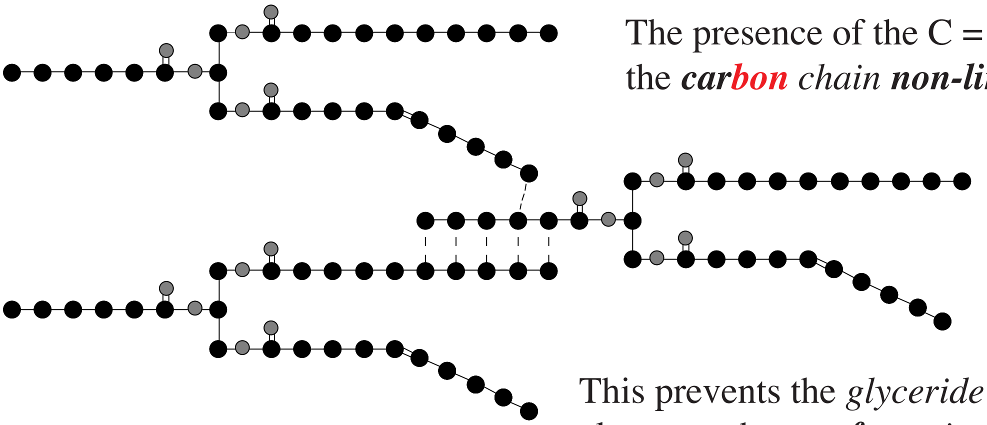
In ***animal fats*** *most* of the ***fatty acids*** are ***saturated***. This makes their ***carbon*** *chains* ***linear***. As a result, the *glyceride* molecules are able to ***pack closely together***.



This allows for the ***maximum*** amount of *intermolecular forces* and a ***higher melting point***.

Animal fats, therefore, tend to be ***solids*** at ***room temperature***.

Vegetable oils and ***marine oils*** contain *more* ***unsaturated fatty acids*** in their *glyceride* molecules.



The presence of the C = C ***double bond*** makes the ***carbon*** *chain* ***non-linear*** or *'bent'*.

This prevents the *glyceride* molecules ***packing*** so close together, so ***fewer*** *intermolecular forces* can be established, and the ***melting point*** is ***lower***.

Vegetable oils and ***marine oils*** tend to be ***liquids*** at *room temperature*.

Sample	*Melting Point*	*Drops of bromine solution decolourised*
lard	*'high'*	*10*
margarine	*medium*	*15*
corn oil	*low*	*20*

The more drops of ***bromine*** that can be ***decolourised***, the more C = C ***double bonds*** the molecules must contain, the ***more unsaturated*** they must be.

Conclusions:

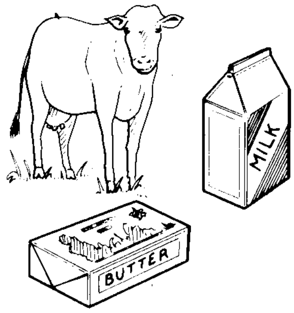
fats are more ***saturated*** *than oils and have* ***higher*** *melting points*

oils are more ***unsaturated*** *than fats and have* ***lower*** *melting points*

Hardening Oils

This activity deals with the way in which oils can be converted into solids by hardening

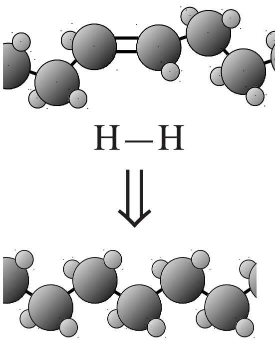
***Hardening** a fat or oil means **hydrogenating** it to increase its melting point.*



Foods that are high in ***animal fats***, such as *milk* and ***butter*** , pose ***health risks*** because of the ***saturated fatty acids*** they contain.

Vegetable oils are considered ***healthier*** because of the *higher level* of ***unsaturated acids*** they contain. In many cases, e.g. *frying food*, oils can do the same job that fats such as ***lard*** and ***butter*** used to do.

Vegetable oils are ***runny liquids*** and unsuitable for ***spreading*** on bread. However, if some of the ***unsaturated acids*** are converted into ***saturated acids*** by reacting with ***hydrogen***, then the ***melting point*** of the oil will be ***increased*** and it will be ***more solid*** at *room temperature*.



This is the same ***addition reaction*** met earlier in the course that can be used to *convert* an ***alkane*** into an ***alkene*** and requires the same *catalyst*, ***nickel***

As more and more of the ***unsaturated acids*** are *converted*, the ***margarine*** becomes *more and more* ***solid***. However, it must not be allowed to become ***too saturated*** or it will be *too* ***solid*** and will loose it ability to '*spread straight from the fridge*'.

Even more importantly, if allowed to become *too* ***saturated*** the ***health advantages*** that ***unsaturated margarine*** enjoys over ***saturated butter*** will be lost. For both these reasons only ***partial hydrogenation*** takes place

Health and Diet

This activity looks at some of the benefits and some of the problems associated with fats and oils

We all need some fat in our diet. But too much of a particular kind of fat – ***saturated fat*** – can raise our ***cholesterol***, which ***increases*** the risk of ***heart disease***. It's important to cut down on fat and choose foods that contain ***unsaturated fat***.

Fats & Oils are ***high energy*** foods - ***twice*** as much as ***carbohydrate*** - and food high in fats & oils would be appropriate for people doing ***very active*** jobs, but for most people will be ***stored*** and can lead to ***obesity*** and the ***health problems*** associated with ***obesity***.

The four ***fat-soluble vitamins*** namely ***vitamin*** **A**, **D**, **E** and **K** are, in fact, require fats and oils in the food to be ***absorbed*** through the gut. Inadequate fats may results in the ***deficiency*** of these ***vitamins*** leading to serious ***health problems***. By law, ***vitamins*** are added to ***margerine***.

Eating ***unsaturated*** fats instead of ***saturated*** can help lower blood cholesterol. ***Unsaturated*** fat, such as *omega-3 essential fatty acids*, is found in: ***oily fish*** such as ***salmon*** and ***sardines***.

SELF CHECK 6.4

Q1. Which of the following is not a source of fats and oils for direct consumption?

- **A** animal
- **B** mineral
- **C** vegetable
- **D** marine

Q2. Which of the following will provide a fat with a high melting point?

- **A** olives
- **B** lamb
- **C** sunflower seed
- **D** sardines

Q3. Fats and oils are both examples of

- **A** carboxylic acids
- **B** hydrocarbons
- **C** alcohols
- **D** esters

Q4. The most unsaturated fats or oils are those which decolourise

- **A** bromine solution the most quickly
- **B** the least bromine solution
- **C** bromine solution the most slowly
- **D** the most bromine solution

Q5. When comparing a fat and an oil of equal molecular size

- **A** the more saturated one will have the higher melting point
- **B** the more unsaturated one will have the higher melting point
- **C** the less saturated one will have the higher melting point
- **D** the two will have exactly the same melting point

Q6. In comparison to oils, fats are generally

- **A** more unsaturated
- **B** equally unsaturated
- **C** more saturated
- **D** equally saturated

Q7. Compared with carbohydrates fats provide

- **A** slightly less energy per gram
- **B** slightly more energy per gram
- **C** more than double the energy per gram
- **D** less than half the energy per gram

Q8. Compared with vegetable oils, butter in the human diet can

- **A** provide important vitamins
- **B** cause less heart disease
- **C** keep the arteries clear
- **D** cause less obesity

Q9. Fats have higher melting points than oils because comparing fats and oils

- **A** fats have more hydrogen bonds
- **B** fat molecules are more saturated
- **C** fat molecules are more loosely packed
- **D** fats have more cross-links between molecules.

Q10. Oils are generally

- **A** solid at room temperature and contain a high proportion of unsaturated molecules
- **B** solid at room temperature and contain a high proportion of saturated molecules
- **C** liquid at room temperature and contain a high proportion of unsaturated molecules
- **D** liquid at room temperature and contain a high proportion of saturated molecules

SELF CHECK 6.4

Q11. Which statement is ***not*** true of fats?

A the parent acid molecule has three carboxyl groups.

B there are three fatty acid chains in the fat molecule.

C the parent alcohol molecule has three hydroxyl groups.

D there are three ester links in the fat molecule

Q12. Hydrolysis of an oil is likely to produce

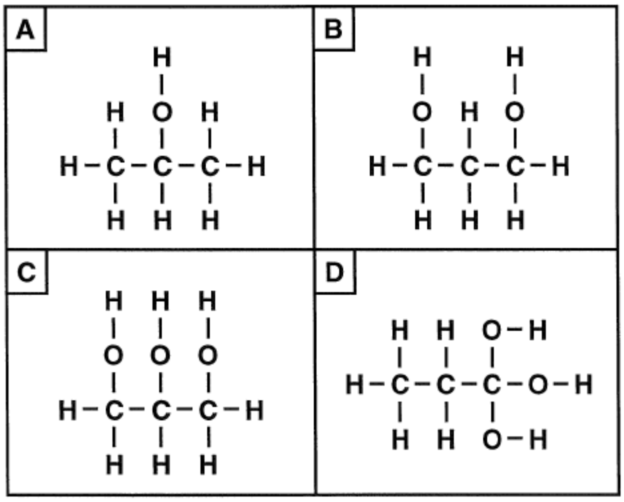
A methanol

B glycerol

C ethanoic acid

D methanoic acid

Q13. What is the structural formula of glycerol?



Q14. What is the ratio of alcohol to acid in the products from a hydrolysed fat?

A 3 moles acid to 2 moles alcohol

B 3 moles acid to 1 moles alcohol

C 1 moles acid to 2 moles alcohol

D 1 moles acid to 3 moles alcohol

Q15. Which of the following is a saturated fatty acid?

A $C_{18}H_{33}COOH$

B $C_{18}H_{35}COOH$

C $C_{17}H_{33}COOH$

D $C_{17}H_{35}COOH$

Q16. The conversion of an oil into a fat involves the removal of

A single bonds

B double bonds

C hydrogen atoms

D hydroxyl groups

Q17. Hardening of a fat or oil is done by

A hydrolysis

B dehydration

C catalytic hydrogenation

D fractional distillation

Q18. In the manufacture of margarine, why is only partial hydrogenation carried out?

A to retain as much unsaturation as possible

B to avoid destroying natural vitamins

C to avoid losing the natural flavours

D to keep the molecular size as large as possible

Q19. Which line in the table shows correct functional groups for aldehydes and ketones and fats and oils?

	Aldehydes and ketones	Fats and oils
A	carbonyl	hydroxyl
B	carboxyl	hydroxyl
C	carboxyl	ester link
D	carbonyl	ester link

HOME PRACTICE 6.4

Q1. Olive oil and bacon fat are chemically related.

a) To which class of organic compound do both belong? **1**

b) Which of these two substances has the lower melting point? **1**

c) Which of them is likely to be more unsaturated? **1**

d) What test could you do to compare the degree of unsaturation in these two substances and what result would you expect? **2**

Q2. Carbohydrates, fats and oils are all regarded as energy foods.

a) How would you expect equal masses of olive oil and sugar to compare in energy content? **1**

b) In what way can some fatty foods claim to be healthier than oils in the human diet? **1**

c) In what way can unsaturated fats claim to be healthier than saturated fats in the human diet? **1**

d) Explain what obesity is and how eating fats and oils can cause this. **1**

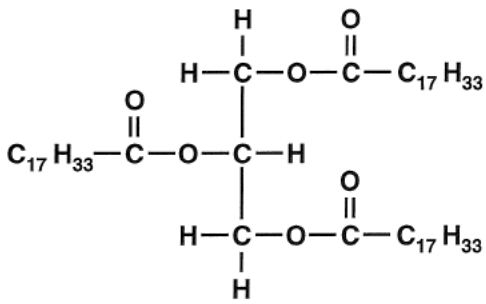
Q3. Animal fats and vegetable oils are examples of esters.

a) How many ester links are present in a single fat molecule? **1**

b) Name the alcohol which is produced by the hydrolysis of any animal fat. **1**

c) Draw the full structural formula for this alcohol. **1**

Q4. The diagram shows a structural formula of an ester oil.



a) Write the functional molecular formula of the parent fatty acid. **1**

b) Is this particular fatty acid saturated or unsaturated? Explain your answer. **2**

c) What will be the ratio of acid molecules to alcohol molecules in the products of hydrolysis of this oil? **1**

d) What type of reaction can be used to 'harden' this oil? **1**

e) What effect does hardening have on

i) the degree of saturation in the molecule,

and ***ii)*** the melting point? **2**

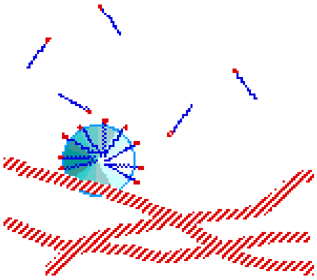
Total ***(19)***

6.5 Soaps, Detergents & Emulsions

This lesson topic introduces other aspects of fats & oils including derivatives and special mixtures.

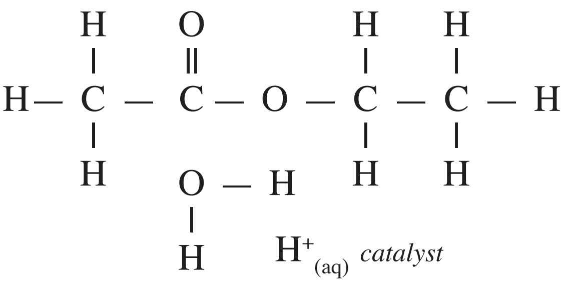
Soaps & Cleansing Action

This activity considers how soaps are made and how the structure of the soap molecule allows it to act as a cleansing agent



Soaps are molecules that help ***water*** cope with awkward '*greasy*' molecules, such as ***fats*** & ***oils***, that would be difficult for ***water*** *alone* to wash away.

The names of some ***soaps***, e.g *Palmolive*, betray the fact that ***soaps*** themselves are made from ***fats*** and ***oils*** - *palm oil* and *olive oil*.

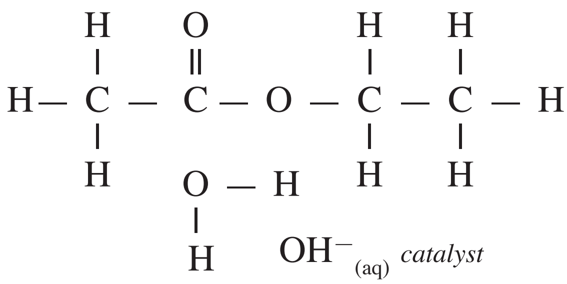


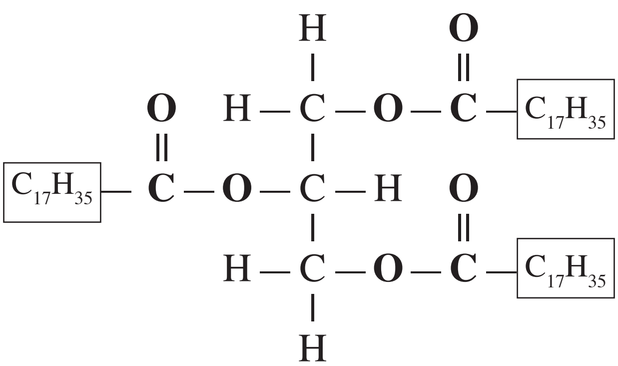
Earlier in this section you learnt that ***water*** can be used to *break an **ester** apart* to reform the *parent **acid*** and *parent **alcohol***.

The reaction benefits from the presence of $H^+_{(aq)}$ ions provided by ***dilute sulphuric acid*** $H_2SO_{4(l)}$. This is often called ***acid hydrolysis***.

Alkaline hydrolysis, heating the ***ester*** with *sodium hydroxide solution*, will also *break apart an **ester*** to reform the *parent **alcohol***,

The ***acid***, however, goes on to ***react*** with the ***alkali*** so the *salt of the acid* is formed instead. In this case ***sodium*** *ethanoate* ($CH_3COO^- \ Na^+$) would be made.

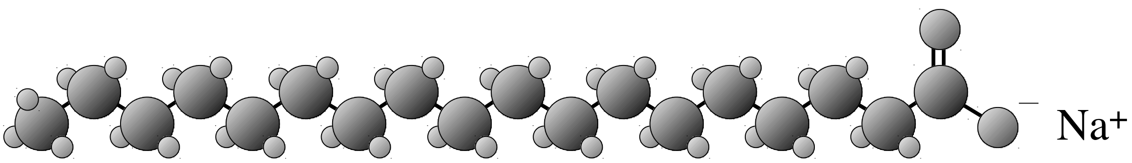




Alkaline hydrolysis of a ***glyceride*** molecule will yield ***glycerol*** and the ***sodium salts*** of its ***fatty acids***.

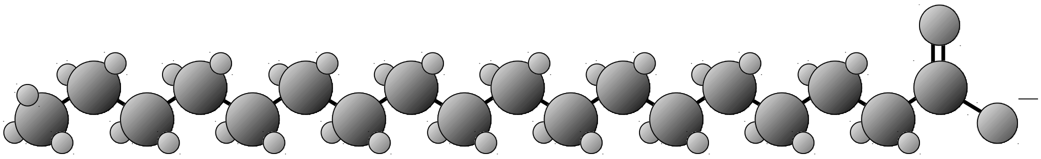
Glyceryl tristearate (found in most animal fats) will produce ***sodium stearate*** which was one of the earliest and most common ***soaps*** ever made.

Thousands of years ago, probably by accident, people discovered that boiling animal fat with alkali rocks produced a scum that, when cooled and solidified, could be used as a cleansing agent



Structurally, what makes these molecules capable of acting as a ***cleansing agent*** is their *'ionic head'* - COO^- , and long *'covalent tail'* - $C_{17}H_{35}$.

Covalent Tail - most of the ***hydrocarbon tail*** is far enough away from the ***ionic** head* that it maintains the ***properties*** of a typical ***covalent*** molecule - namely, *weak London Dispersion forces* between neighbouring molecules.



Ionic Head - the ***ionic** heads* can set up *strong attractions* - of similar strength to the ***hydrogen bonding*** between ***water*** molecules - allowing the *heads to dissolve in **water*** .

Water, particularly ***hot water***, is a very effective ***cleansing agent***. The strength of the ***hydrogen bonding*** between its ***polar molecules*** is *similar* to the strength of ***attractions*** in many *ionic substances*, which allows ***water*** to *dissolve* them.

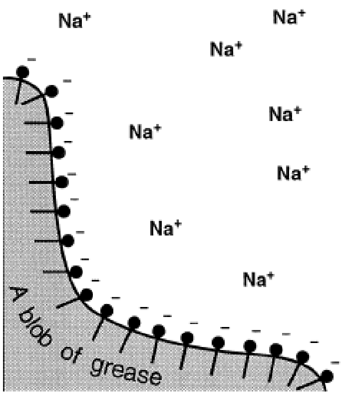
Many ***covalent** substances* are *polar enough* to also dissolve in water. The main problem is with ***covalent** substances* with *very weak **polar attractions*** or only *Van der Waals attractions*

When *mixed* with ***water***, these ***pure** covalent liquids* form ***separate*** *layers* as the *difference in intermolecular forces* is too ***great*** to allow *mixing*.

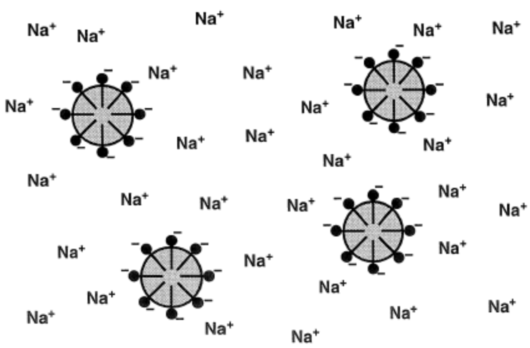
Shaking can form a *temporary **emulsion*** as small drops of 'oil' float in the water.

On standing, the two liquids will ***separate*** out again.

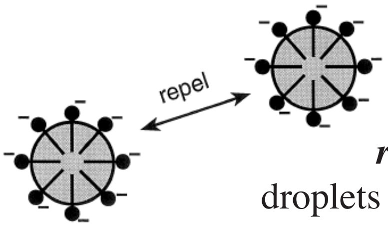
This makes it very difficult for water to remove *greasy* or oily *stains* from *clothes*, *plates* or even *people*.



Soap** molecules* cannot make grease ***'dissolve' in water, but they can prevent the tiny *droplets* of ***grease*** from *reforming* into large *blobs* which would stick to the surface of the ***clothes***, ***plates*** or *skin of a person*.



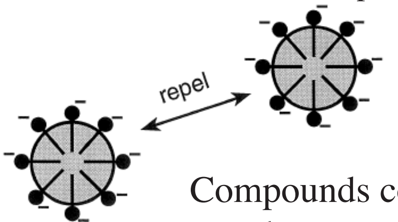
Instead they keep the tiny *globules **suspended*** in the water so that they can be ***rinsed*** away with the water.



The ***negatively*** charged ***ionic*** heads set up *strong* ***repulsions*** which prevent the droplets reforming into large blobs.

Detergents

This activity considers the problems caused by 'hard' water and the need for soapless detergents



To be *effective*, it is important that the ***soap*** molecule is able to ***dissolve*** and ***dissociate*** - that the ***Na⁺*** ion detaches to leave a ***negatively*** charged head.

Compounds containing ***Group I*** metals (The ***Alkali*** metals) are always ***soluble*** but water can also contain ***Group II*** metals (The ***Alkali Earth*** metals). Scotland gets its water from '*above ground*' - water flows over hard ***igneous*** rocks to collect in *lochs* and ***reservoirs***. There are very few ***Ca^{2+}*** and ***Mg^{2+}*** ions and the water is described as '*soft*'.

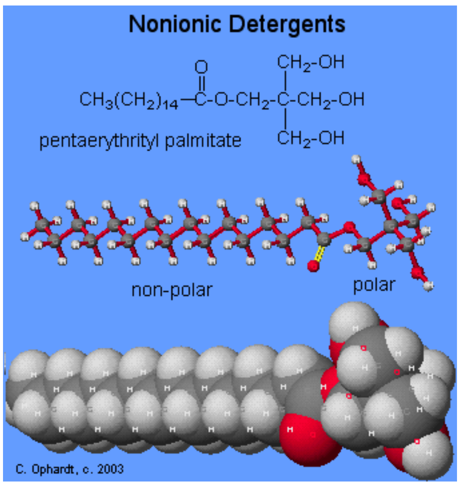
In much of England, particularly the ***South***, water *percolates* through rocks such as ***limestone*** and collects below ground from where it is ***pumped*** to the surface or flows out into rivers and lakes. The water has *higher* levels of ***Ca^{2+}*** and ***Mg^{2+}*** ions and is described as '*hard*'.

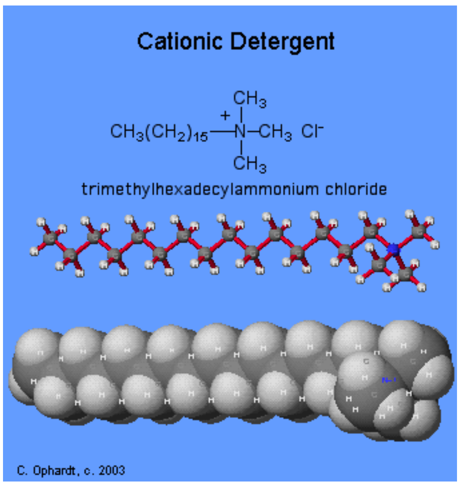
This causes a number of problems such as ***limescale*** build up in *water pipes*, *kettles* and *water heaters*. In addition, normal soaps struggle to work as they form an ***insoluble scum*** with ***Ca^{2+}*** and ***Mg^{2+}*** ions.

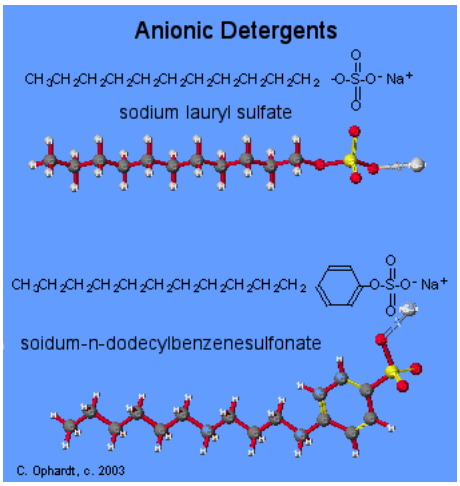
One solution is to *treat* the water by passing it through '*filters*' that absorb the ***Ca^{2+}*** and ***Mg^{2+}*** ions and replace them with ***Na^+*** and ***K^+*** ions which '*softens*' the water.

The alternative was to redesign the ***soap*** molecule to create a molecule that did not form an ***insoluble scum*** with Ca^{2+} and Mg^{2+} ions. These '*man made*' ***soaps*** are usually referred to as ***detergents***.

There are many variations but they all have the '***covalent tail***' with '***polar/ionic head***' required.

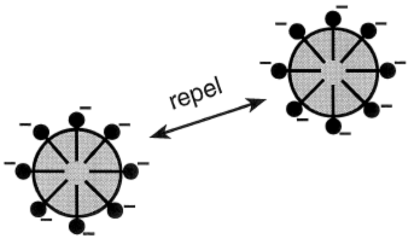


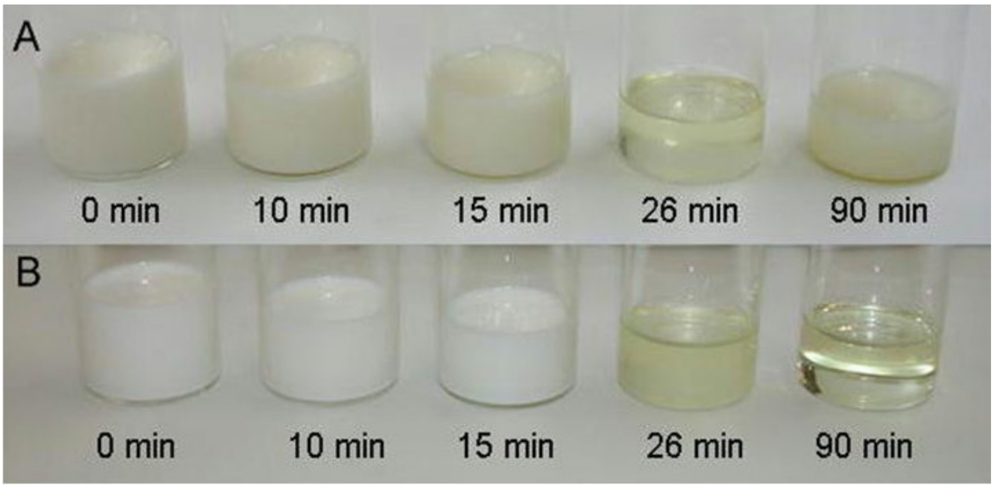




Emulsions

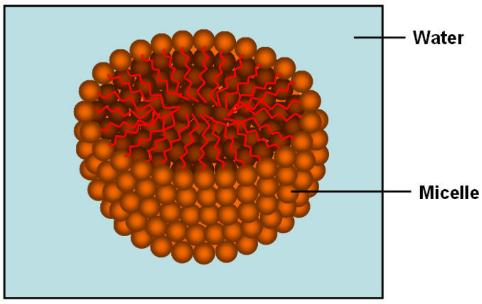
This activity considers the use of emulsifying agents to form stable emulsions.

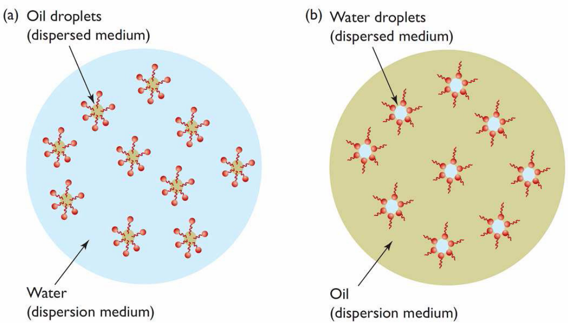




Oil and ***water*** will *mix*, but they form an ***emulsion*** with droplets ***suspended***. This is ***unstable*** and the liquids will ***separate*** (as shown in **B**).

Soap molecules can be very effective at ***stabilising emulsions*** (*as shown in* **A**), by positioning themselves at the ***surface*** of a *droplet* of *oil* with ***covalent tails*** in the *oil* and ***ionic heads*** in the *water*. These *droplets* are referred to as ***micelles*** and molecules like ***soap*** are described as ***surfactants***. The ***negative charges*** on the ***surface*** prevent/slow down the ***separation*** of the liquids and help form a ***stable emulsion***. *Emulsion paints* are good examples of ***stable*** oil/water mixtures.





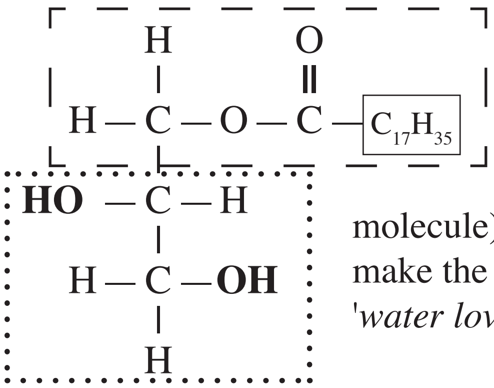
Cream: Oil-in-Water **Butter: Water-in-Oil**

Oil in Water	***Water in Oil***
egg yolk	*margarine*
milk	*butter*
ice cream	*skin cream*
salad cream	*moisturiser*
mayonnaise	

There are very few foods that do not contain both *oils/fats* and *water*. Therefore ***emulsifying agents*** are widely used in the food industry.

Traditional ***soap molecules*** can have a negative impact on ***taste*** so other, very similar, molecules have been developed.

A convenient way to make an ***emulsifying agent*** is to react a ***glycerol*** molecule with a ***single fatty acid*** (instead of the 'normal' 3 used to make an edible fat or oil).



Though ***not*** *ionic* (like the head of a ***soap*** molecule) the ***hydroxyl*** groups make the head ***hydroscopic*** - '*water loving*' - ***water soluble***.

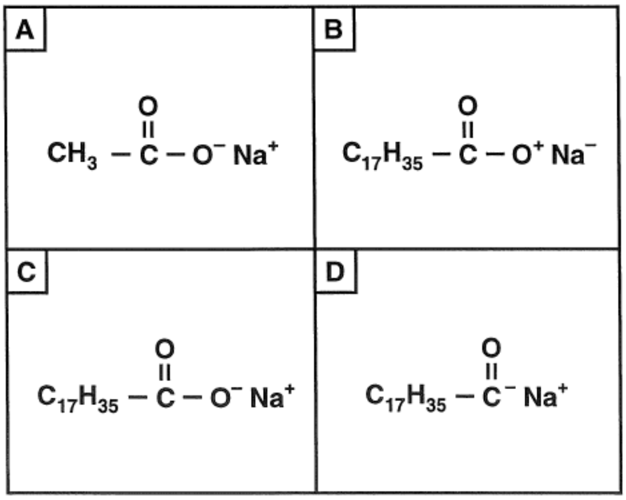
The ***largely hydrocarbon fatty acid***, as well as the ***ester link***, make the tail ***hydrophobic*** - '*water hating*' - ***oil soluble***.

SELF CHECK 6.5

Q1. Soaps are produced from fats and oils by

A alkaline hydrolysis
B catalytic cracking
C acidic condensation
D dehydrogenation

Q2. Which of the following is a typical soap molecule?

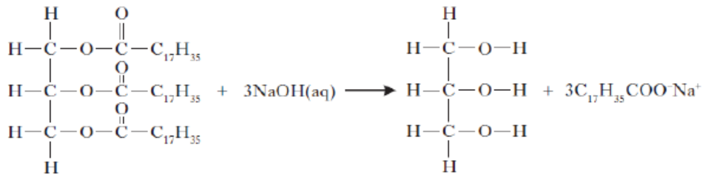


Q3. Soap molecules are effective cleansing agents because they have

A grease-soluble hydrocarbon chains joined to water-soluble ionic ends
B water-soluble hydrocarbon chains joined to grease-soluble ionic ends
C grease-soluble acidic parts joined to water-soluble alkaline ends
D water-soluble acidic parts joined to grease-soluble alkaline ends

Q4. Which of following statements about detergents is ***incorrect*** ?

A soap detergents can be manufactured from fat
B soapless detergents do not form foam in water
C the hydrophilic 'head' of a detergent can be anionic or cationic
D the hydrophilic 'head' of a detergent can be polar



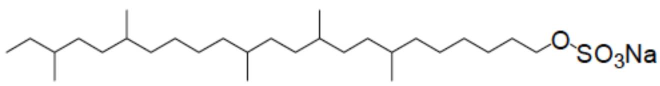
Q5. Soaps are produced by the above reaction. This reaction is an example of

A condensation
B esterification
C hydrolysis
D oxidation

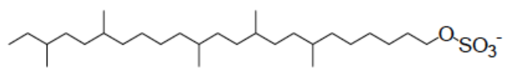
Q6. When a detergent is added to a beaker of oil and water and then the solution is shaken, an emulsion is formed. The emulsion consists of

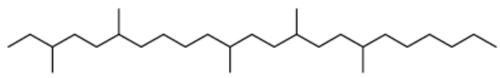
A oil and detergent
B oil droplets and water
C water, oil and oil droplets
D water , oil, detergent and oil droplets

Q7. Consider the following detergent particle



Which part of this structure makes the detergent particle hydrophilic?

A 

B 

C — OSO_3^-

D Na^+

Q8. Shaking a soap with grease produces tiny globules which cannot rejoin because

A they are no longer soluble in water
B the grease molecules have hydrolysed
C the molecules in them have changed shape
D charges on their surfaces make them repel

HOME PRACTICE 6.5

Q1. The structure of a soap molecule can be used to explain its cleansing action with grease.

a) Draw the full structural formula for an example of a soap molecule. **1**

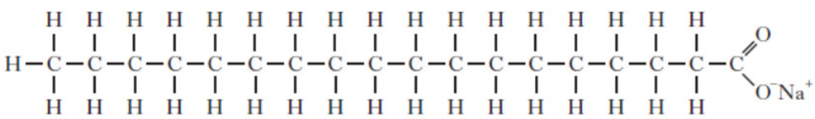
b) Which part of this molecule is soluble in grease and which part is soluble in water? **1**

Q2. A fatty acid is a long chain carboxylic acid. Examples of fatty acids are shown in the table below.

Common name	Systematic name	Structure
stearic acid	octadecanoic acid	$CH_3(CH_2)_{16}COOH$
oleic acid	octadec-9-enoic acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
linoleic acid	octadec-9,12-dienoic acid	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$
linolenic acid		$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$

a) What is the systematic name for linolenic acid? **1**

b) Stearic acid reacts with sodium hydroxide solution to form sodium stearate.

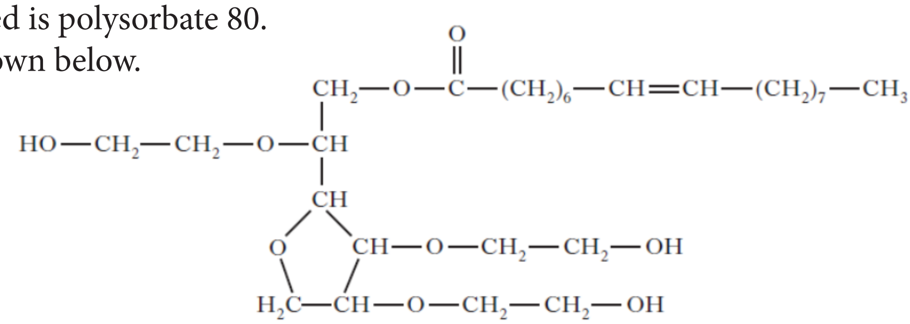


Name the type of reaction taking place when stearic acid reacts with sodium hydroxide. **1**

c) Explain fully how sodium stearate acts to keep grease and non-polar substances suspended in water during cleaning. **3**

Q3. Small children can find it difficult to swallow tablets or pills so ibuprofen is supplied as an "infant formula" emulsion.

a) The emulsifier used is polysorbate 80.
Its structure is shown below.



Explain why this molecule acts as an emulsifier. **2**

b) The emulsion contains 2 g of ibuprofen in every 100 cm^3 of emulsion. The recommended dose for treating a 6 month old baby is 0·050 g. Calculate the volume, in cm^3, of "infant formula" needed to treat a 6 month old baby. **1**

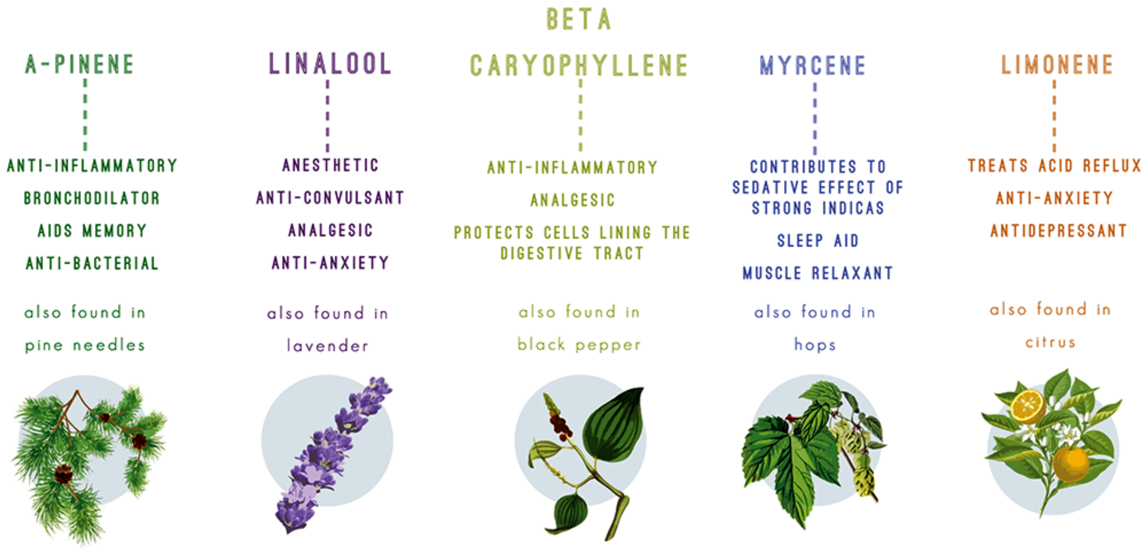
Total ***(10)***

6.6 Terpenes - Fragrance Molecules

This lesson topic introduces terpenes which are a major component of essential oils.

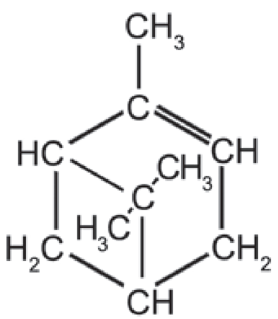
Essential Oils

This activity considers the role of essential oils.

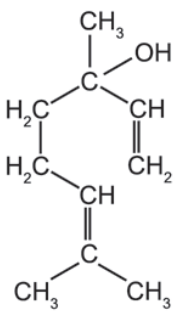


Essential oils are the ***concentrated*** extracts of ***volatile***, *non-water-soluble* ***aroma*** compounds from plants. '*Essential*' refers to the fact that the oil carries the ***distinctive essence*** (*scent*) of the plant. ***Essential oils*** are mixtures of organic compound, though ***Terpenes*** are the key components in most essential oils.

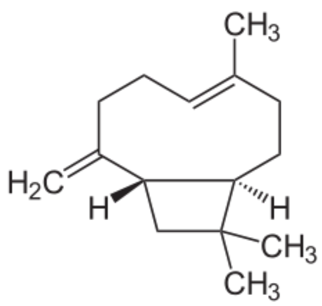
The ***distinctive*** character of an essential oil can be attributed to the ***functional group*** present in its key molecule. ***Esters***, ***aldehydes***, ***ketones*** and ***alcohols*** are all found in ***essential oils*** but many are ***terpenes***.



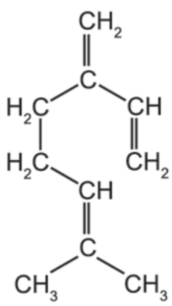
a-pinene



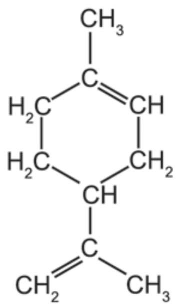
linalool



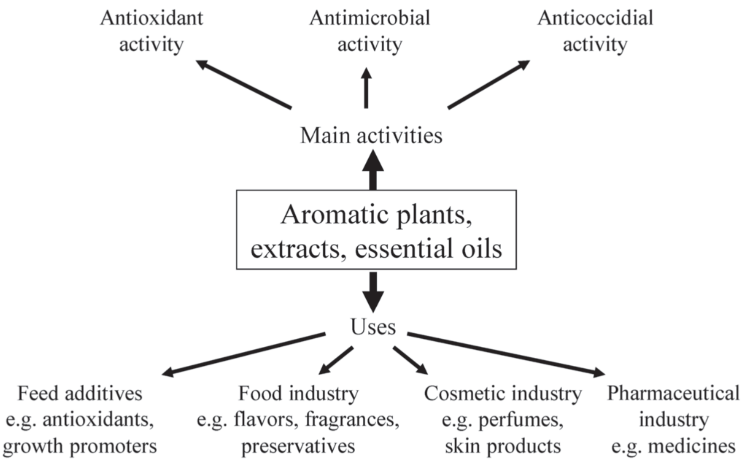
beta carophyllene



myrcene



limonene



As well as their role as ***fragrance*** *molecules*, there are 3 other reasons why essential oils might be used:

antioxidant activity

antimicrobial activity

anticoccidial activity

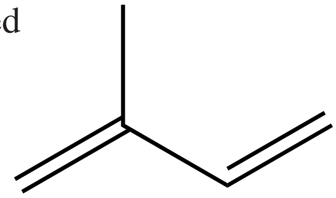
Coccidia are tiny single-celled ***parasites*** that live in the wall of an animal's intestine.

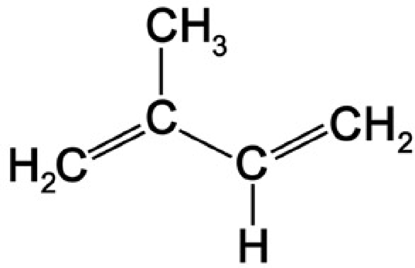
Terpenes

This activity considers the structure of terpenes

Terpenes are ***unsaturated*** compounds formed by joining together ***isoprene*** units.

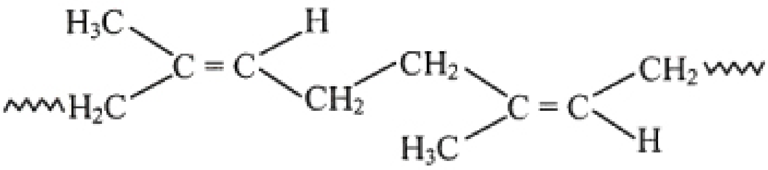
Isoprene is the common name for
2-methylbuta-1,3-diene





Isoprene is made in the chloroplasts of plants.

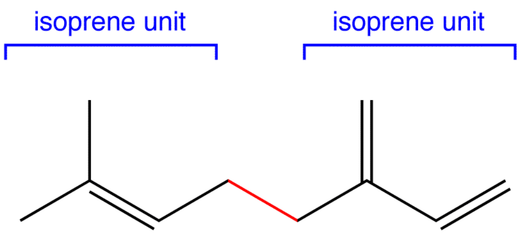
Isoprene is produced and ***emitted*** by many species of trees into the ***atmosphere***, where they can be converted by ***free radicals*** (like the ***hydroxyl*** (OH) radical) into various species, such as ***aldehydes***, *hydroperoxides*, *organic nitrates*, and *epoxides*.



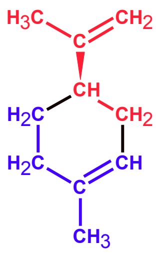
cis-Polyisoprene
(Natural rubber)

It has been proposed that ***isoprene*** emission is specifically used by plants to protect against large fluctuations in leaf ***temperature***. ***Isoprene*** also confers ***resistance*** to *reactive oxygen species*.

The ***isoprene*** skeleton can be found in naturally occurring compounds called ***terpenes***. They can join '*head to tail*' to form ***linear terpenes***. An example is *myrcene*, a component of plants, including bay, ylang-ylang and thyme

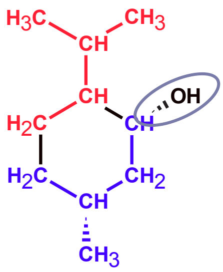


Other ***terpenes*** are ***cyclic***, whilst other have been ***oxidised*** to form ***hydroxyl*** or ***carbonyl*** groups:



Limonene

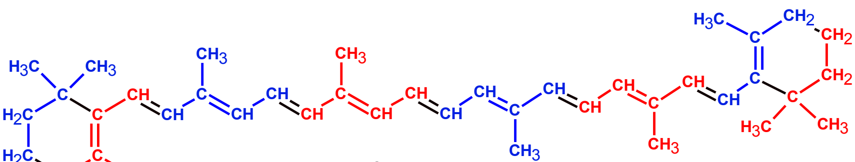
(skin of citrus fruits)



This terpene has been oxidised to a terpenoid

Menthol

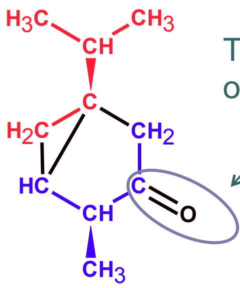
(peppermint)



β-carotene

8 isoprene units

40 carbon atoms



This terpene has been oxidised to a terpenoid

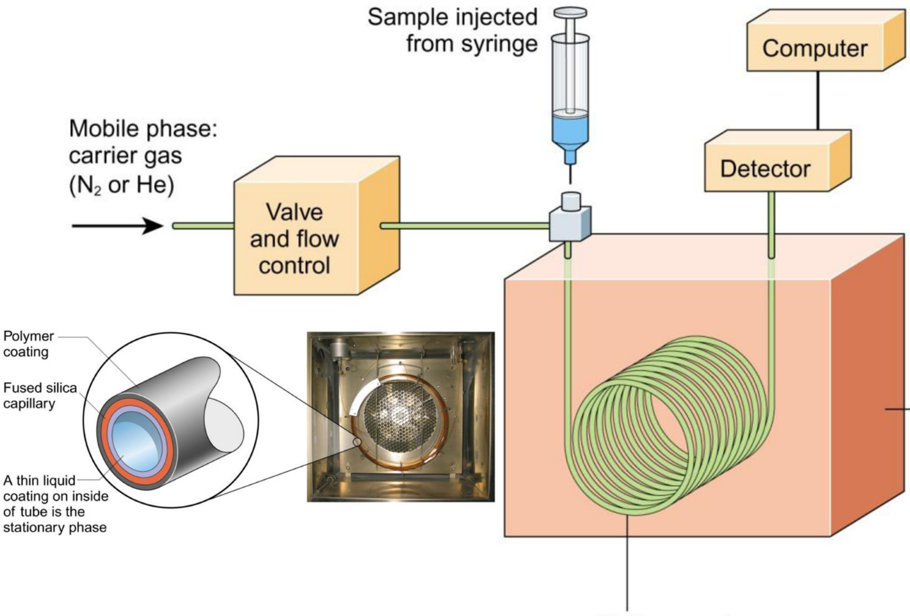
Thujone

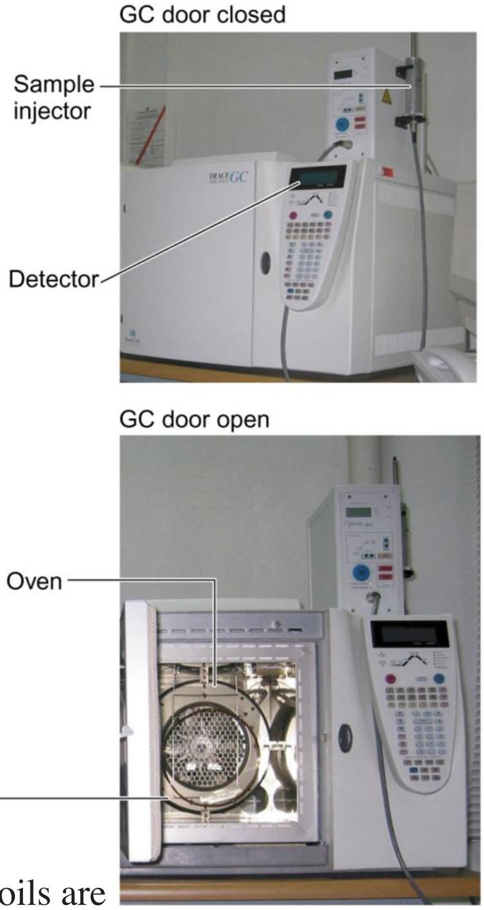
(Absinthe)

Gas Chromatography

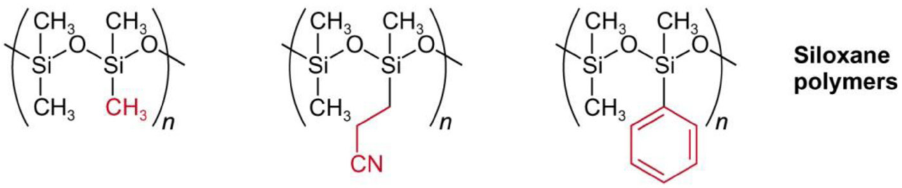
This activity considers the technique of gas chromatography as a means of separating and identifying volatile molecules.

As with ***Paper Chromatography***, met in an earlier topic, ***molecules*** move in a ***mobile phase*** but can also spend some of their time '*trapped*' in a ***stationary phase***.

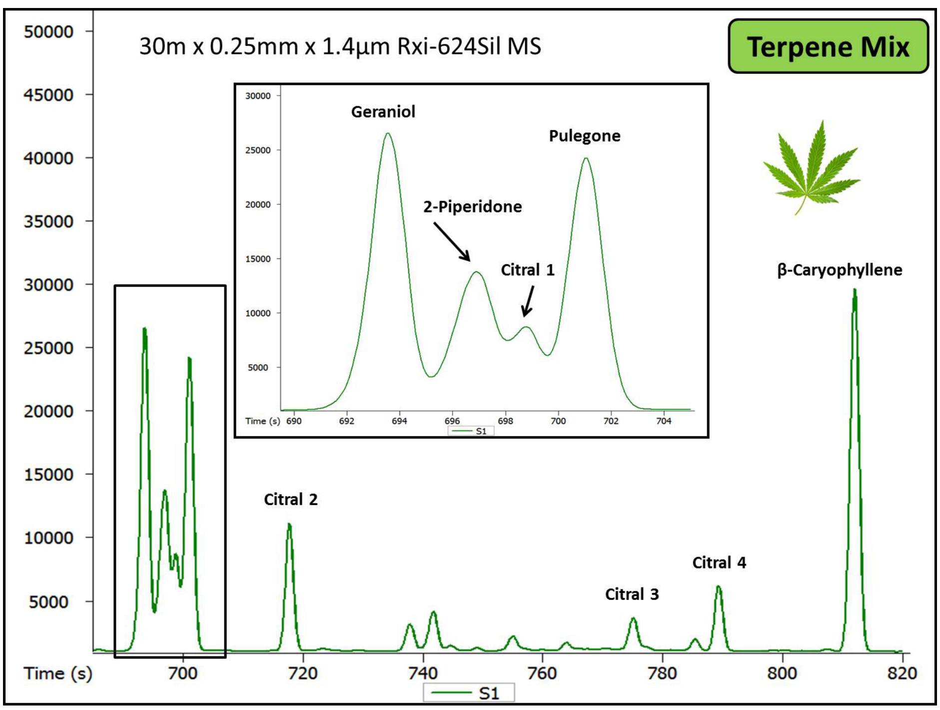


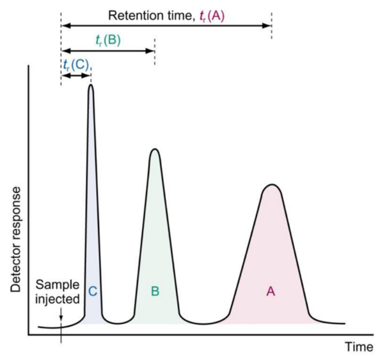


Given the ***volatile*** nature of many of the molecules studied in this topic, an ***inert carrier gas*** is chosen to be the ***mobile phase***. Thin metal coils are either packed with suitable solid *powders* (*Gas Solid Chromatography* (***GSC***)) or *liquids* are ***absorbed*** onto a polymer coating (*Gas Liquid Chromatography* (***CLC***)).



Polar or ***non-polar*** materials can be used depending on the molecules being identified.



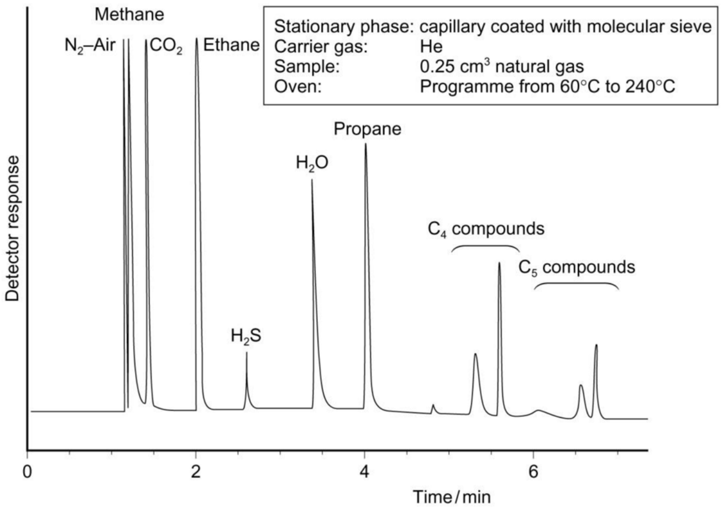


Different molecules take ***different*** times to move through the coil depending on factors such as ***mass***, ***shape*** and ***polarity***.

The ***area*** under each signal represents the ***amount*** present.

Mineral Oils

This activity examines the chromatograms of natural gas and unleaded petrol and establishes some of the factors that effect retention times.



molecule	*mass*	*polar*	*time/min*
methane	**16**	***no***	***1.25***
water	**18**	***yes***	***3.5***
ethane	**30**	***no***	***2.0***
hydrogen sulphide	**34**	***yes***	***2.6***
propane	**44**	***no***	***4.0***
carbon dioxide	**44**	***no***	***1.5***

Whilst ***methane*** is the main component (*off the scale*) in ***natural gas***, there are many other molecules present.

molecule	*mass*	*time/min*
methane	16	1.5
ethane	30	2.0
propane	44	4.0

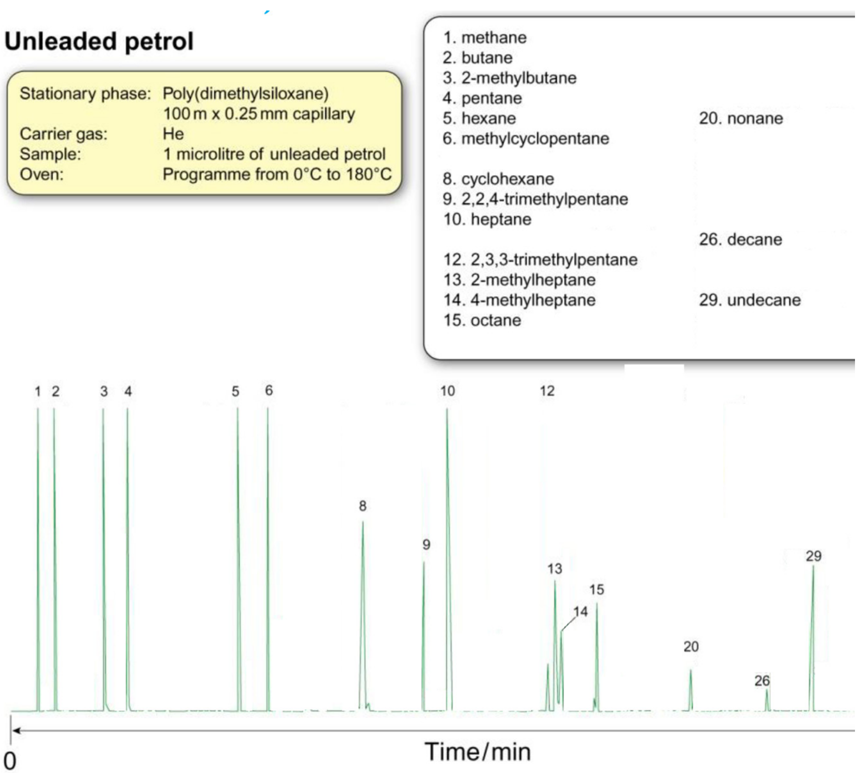
Since these molecules should have the ***same polarity*** we see that:

as mass increases, the time increases

Comparing molecules of ***similar mass*** like *methane* with *water* and *ethane* with *hydrogen sulphide* shows the effect of ***polarity***:

as polaity increases, the time increases

Propane and *carbon dioxide* have ***similar mass*** and ***similar polarity***. *Carbon dioxide* is, however, a more ***compact*** molecule and moves through the coil ***more quickly***.



Examination of the simplified ***chromatogram*** of ***unleaded petrol*** confirms that:

as mass ↗, the time ↗

Comparing ***branched isomers*** with the *equivalent* ***chain*** molecule:

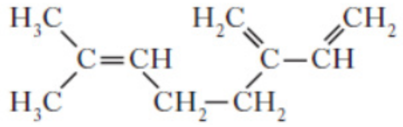
as no. of branches ↗, the time ↙

and looking at the *positions* of ***branches***, *2-methyl* to *4-methyl*:

branch position ↗, the time ↗

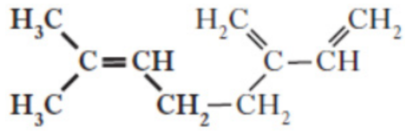
Self Check 6.6

Q1. Myrcene is a simple terpene.

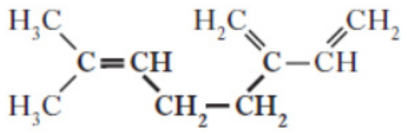


Terpenes contain at least one isoprene unit. Which of the following shows a correctly highlighted isoprene unit?

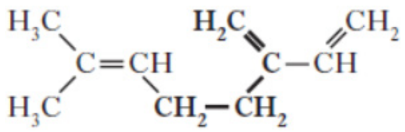
A



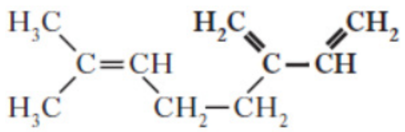
B



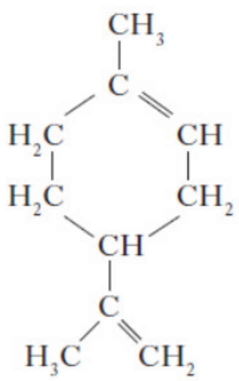
C



D



Q2. Limonene is one of the terpene molecules responsible for the flavour of lemons.



How many isoprene molecules are used in the production of one limonene molecule?

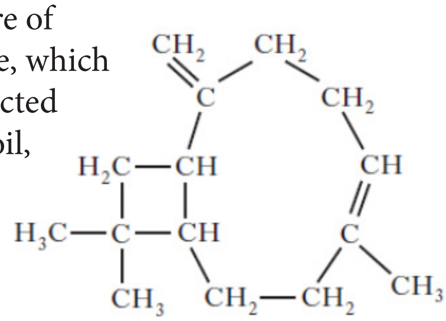
A 1

B 2

C 3

D 4

Q3. The structure of carophyllene, which can be extracted from clove oil, is



Which of the following would be the best solvent for extracting carophyllene?

A hexane

B hexanol

C hexanal

D hexanone

Q4. Which of the following is the most suitable gas to use as a carrier gas in a gas chromatogram?

A oxygen

B carbon dioxide

C helium

D methane

Q5. Acetone is an organic molecule with a formula of CH_3COCH_3. A student runs a sample of acetone through a GLC at 50°C.

The acetone produces a peak after 4.2 mins.

The student then injects a mixture of unknown organic substances into the same column at the same temperature.

There are peaks after 3.1, 4.2 and 7.4 mins. From this information, it can be concluded that ...

A the mixture has 3 components, but acetone is not one of them.

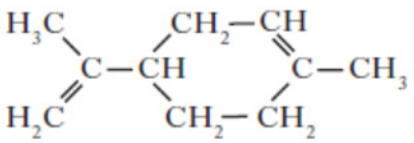
B the mixture has at least 3 components, one of which might be acetone.

C the mixture has 3 components, one of which must be acetone.

D the mixture has at least 3 components, one of which must be acetone

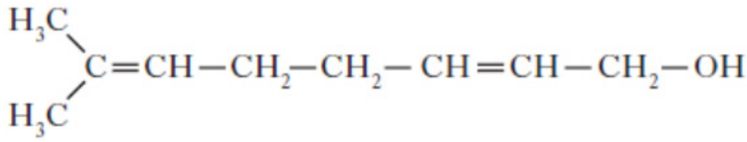
Home Practice 6.6

Q1. Two typical compounds that are present in many perfumes are shown.



$C_{10}H_{16}$

limonene

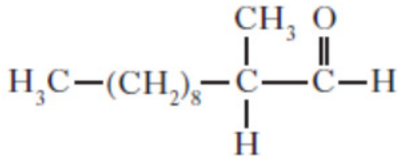


$C_9H_{16}O$

geraniol

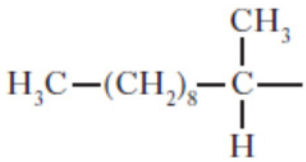
a) Why does geraniol evaporate more slowly than limonene? **1**

The structure of one of the first synthetic scents used in perfume is shown opposite.



b) Name the family of carbonyl compounds to which this synthetic scent belongs. **1**

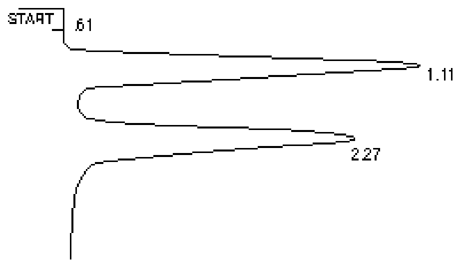
c) Copy and complete the structure opposite to show the product formed when this scent is oxidised.



1

d) Suggest what effect the oxidation would have on the fragrance of the molecule. **1**

Q2. Study the chromatograph of a mixture of hydrocarbons A and B. Compound A has the shorter retention time.



RT	AREA	TYPE	AR/HT	AREA%
0.61	XXXX	XX	XX	0.009
1.11	XXXX	XX	XX	55.874
2.27	XXXX	XX	XX	44.117

a) What is the retention time of compound A? Compound B? **1**

b) Which compound is present in a larger amount? **1**

c) Which compound has the lower boiling point? **1**

d) You suspect that compound B is octane. What can you do to provide supporting evidence for this hypothesis? **1**

Q3. Traces of a liquid were discovered in a bottle believed to contain perfume belonging to Queen Hatshepsut, ruler of Egypt over 3500 years ago. Perfumes were made by dissolving plant extracts containing pleasant smelling terpenes and esters in an edible oil. A little ethanol and water may also have been added.

Using your knowledge of chemistry, comment on the possible smell(s) when such a bottle is opened after being stored for thousands of years. **3**

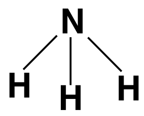
Total ***(11)***

6.7 Amines, Amides & Amino Acids

This topic introduces the amine functional groups and, in particular, its ability to form a link with other groups - the amide or peptide link.

Amines & Amides

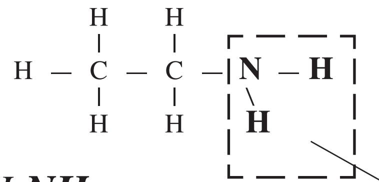
This activity deals with how to recognise and identify amines and introduces a few of their properties.



$N^{\delta-} — H^{\delta+}$

Amines are the ***organic*** relatives of ***ammonia***, NH_3, and like ***ammonia***, their properties are mainly due to the small, highly ***electronegative*** Nitrogen atom.

The simplest amines are called ***primary*** *amines* and will have a ***carbon*** chain (*alkyl group*, R—) in place of *one* of the ***hydrogen*** atoms, $R—NH_2$

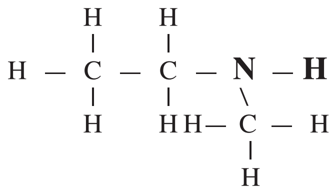


$C_2H_5NH_2$

This amine is usually called simply *ethylamine*, though its more formal name is *aminoethane*.

You do not need to learn the formal systematic naming of amines.

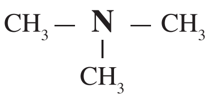
This is the ***amino functional group***



$C_2H_5NHCH_3$

Replacing *two* of the ***hydrogens*** with carbon chains produces what is called a ***secondary*** *amine*.

Simple naming is used whenever possible, so this molecule is called *ethylmethylamine*.



$CH_3\ N(CH_3)\ CH_3$

Replacing *all* of the ***hydrogens*** with three carbon chains produces what is called a ***tertiary*** *amine*.

Simple naming is used whenever possible, so this molecule is called *trimethylamine*.

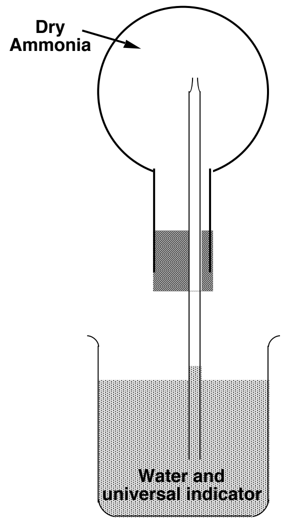
We will concentrate mainly on ***primary*** *amines* and molecules containing the ***amino*** *group*, —NH_2 , though you are expected to at least recognise other amines when you meet them.

Properties of Amines

This activity will remind you of some of the properties that ammonia has and which are shared by the amines

Ammonia is a *gas* with a very *pungent* smell. Similarly the smaller amines are *gases* or ***volatile*** *liquids* with very *unpleasant* smells similar to rotten fish or.......

~~F~~ P



Last year you were shown that ***ammonia*** is an *extremely soluble* gas - *the **fountain** experiment*.

This is due to the fact that ***ammonia*** molecules are like ***water*** molecules and have *very strong **hydrogen** bonding* between them. *Small **primary** amines* will also have *strong **hydrogen** bonding* and will also be *very soluble*. ***Secondary*** *amines* are *less soluble* and ***tertiary*** *amines* even *less soluble*.

Ammonia was the *only **alkali*** gas met during Standard grade. *Amines* are *organic alkalis* and will ***dissolve*** in water to produce ***hydroxide*** ions, OH^-.

Many ions of ***Transition*** *metals* are ***coloured*** but only when *hydrated* - surrounded by ***water*** molecules. Cu^{2+} ions - or more acuurately $[Cu(H_2O)_4]^{2=}$ ions - are ***blue*** in colour. ***Ammonia*** and the smaller ***amines*** can replace these ***water*** molecules but this will change the ***colour*** of these ions:

$$\underset{\text{BLUE}}{[Cu(H_2O)_4]^{2+}} \rightarrow \underset{\text{VIOLET}}{[Cu(NH_3)_4]^{2+}}$$

These colour changes are sometimes used as a *'Test'* for ammonia/amines

Reactions of Amines

This activity introduce you to the reactions of ammonial/ amines

① *Dissolve in water to produce Alkalis*- solutions containing the ***hydroxide*** ion.

$$\underset{\textit{ammonia}}{NH_3} + H^{\delta+}—O^{\delta-}—H \rightarrow \underset{\textit{ammonium ion}}{NH_4^+} + OH^-$$

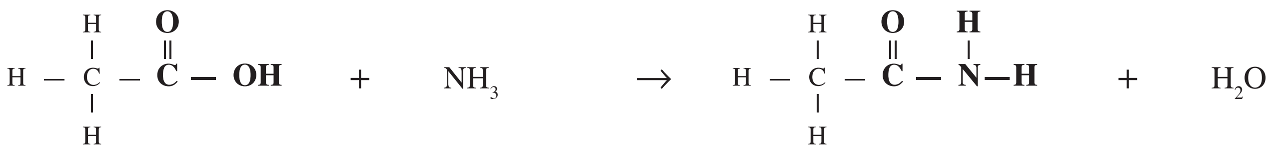
$$\underset{\textit{ethylamine}}{C_2H_5NH_2} + H^{\delta+}—O^{\delta-}—H \rightarrow \underset{\textit{ethylammonium ion}}{C_2H_5NH_3^+} + OH^-$$

② *React with acids to produce Salts*-

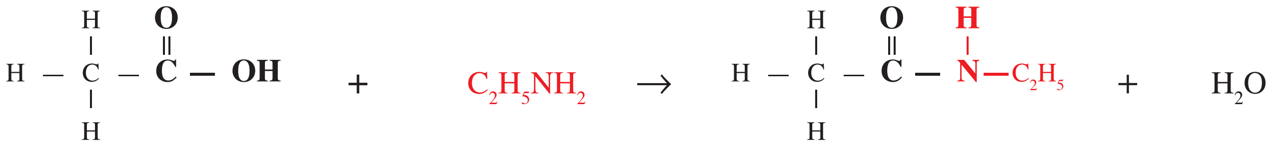
$$\underset{\textit{ammonia}}{NH_3} + H^+ \ Cl^- \rightarrow \underset{\textit{ammonium chloride}}{NH_4^+ \ Cl^-}$$

$$\underset{\textit{ethylamine}}{C_2H_5NH_2} + H^+ \ Cl^- \rightarrow \underset{\textit{ethylammonium chloride}}{C_2H_5NHCl^-}$$

③ *React with organic acids to produce Amides-*



ammonia *a primary amide*

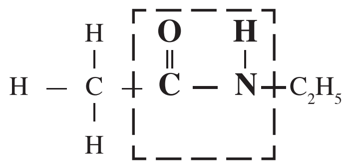


ethylamine *a secondary amide*

Amides are not an 'important' family and you are not required to learn how to name them.

The reactions above are very similar to *esterification* - ***acid*** groups can react with ***amine*** groups in a ***condensation*** reaction that allows the two molecules to *join together*.

This is an important reaction in nature, and you will need to learn to recognise the ***amide link*** (the ***peptide link***)



Proteins

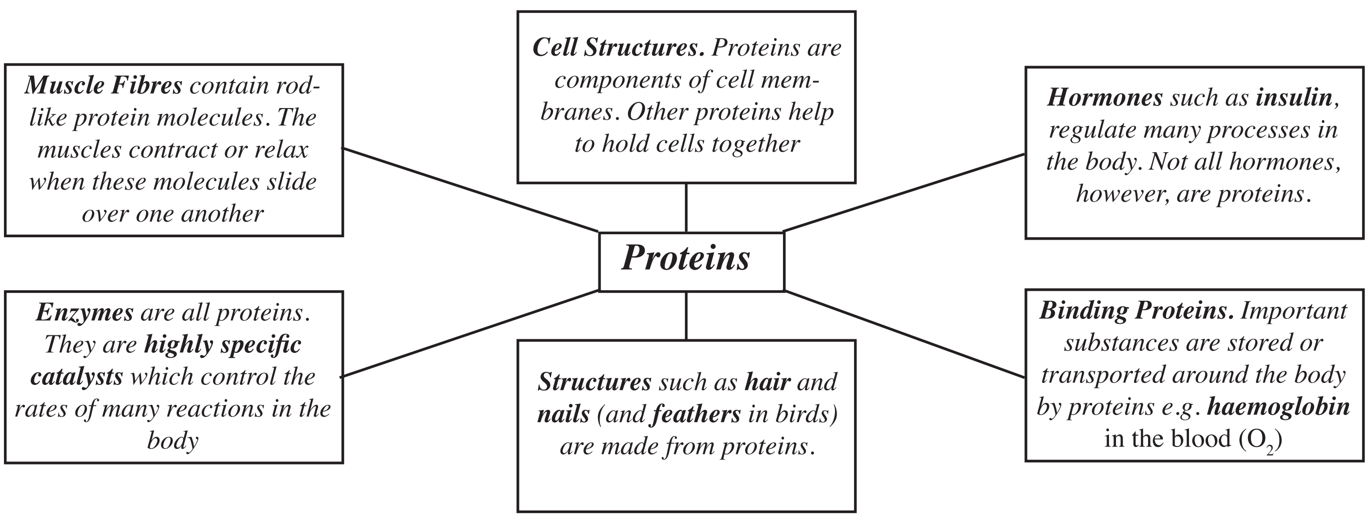
- *peas and **beans***
- ***meat***
- ***fish***
- ***cheese***
- ***eggs***
- *hide & **skin***
- *wool & **silk***

This activity will introduce you to some proteins and the roles played by proteins in living organisms

When ***protein*** is mentioned, most people will think of *foodstuffs* that contain ***protein*** and make up a very important part of our *diet*.

When we eat ***proteins*** they are ***digested*** (*broken down*) into simpler molecules called ***amino acids***.

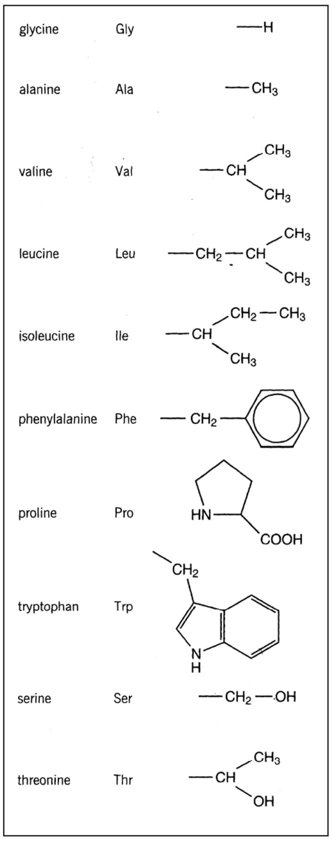
These ***amino acids*** are then reconstituted as ***proteins*** that fulfil a large number of important roles in living organisms.



Amino Acids

This activity will introduce you to the structure of amino acids and explains why some are labelled as essential amino acids

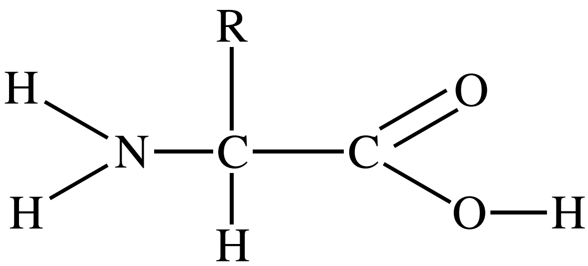
All the ***proteins*** in the world are made from *about* 20 ***amino acids***.

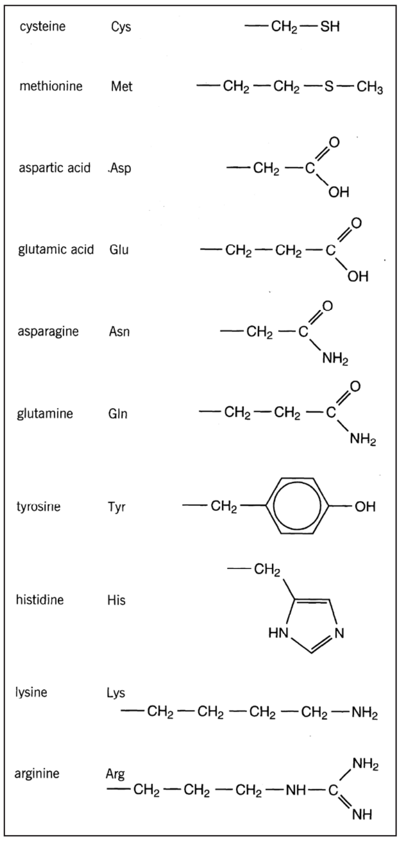


These 20 ***amino acids*** have a common structure. (one exception)

A central ***carbon*** atom has an acid group (***carboxyl***), an ***amino*** group and a ***hydrogen*** atom attached .

The final group attached to the carbon is *different* for each ***amino acid*** and is usually represented by —R.





When we ***digest proteins*** we break them down into ***amino acids*** which we then use to build new ***proteins***. Most ***amino acids*** (12) can be made from *carbohydrates* and other *amino acids* so it is not crucial that we eat ***foods*** containing these amino acids.

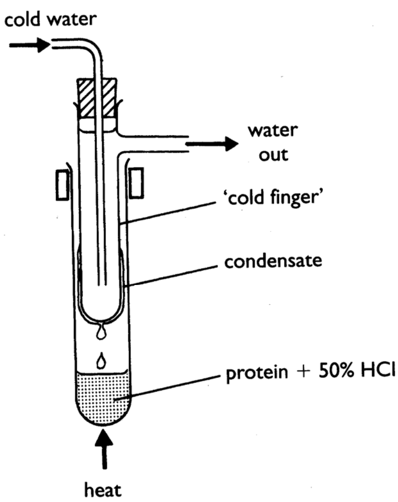
The remaining amino acids (8), however, *cannot be made* and therefore must be part of our food intake. These are classified as ***essential amino acids*** (though we need all 20 to remain healthy).

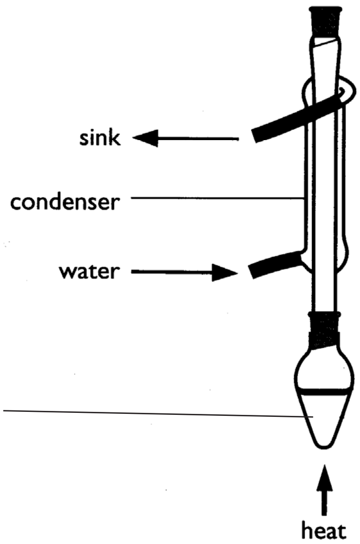
Proteins can be broken down in the lab by ***heating*** them for several hours with dilute acid.

This reaction is called *hydrolysis*,

hydro = ***water***
lysis = ***splitting apart***

To prevent the water ***evaporating*** away before the ***reaction*** has finished we can use apparatus like these.





a reflux condenser

Having *hydrolysed* a ***protein***, we will often attempt to ***identify*** the ***amino acids*** that made up the ***protein*** using ***paper chromatography***. They all have the ***amine group*** and ***carboxyl group*** but differences in the ***polarity*** of their ***side-groups*** will effect their ***retention*** in the ***stationary phase***.

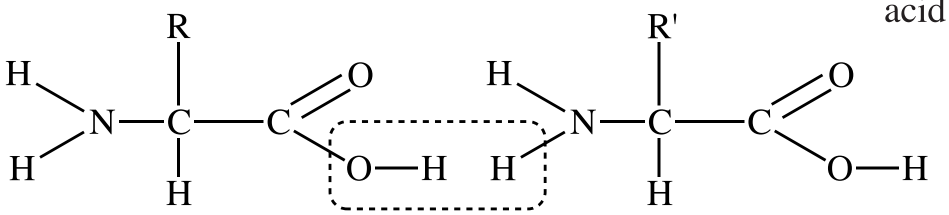
Making Peptides

This activity looks at how amino acids can link together to form peptides.

Most ***proteins*** contain more than 40 ***amino acids*** joined together. Firstly, however, the ***amino acids*** tend to join together in twos or threes to make *peptides*.

two ***amino acids***
(R and R' represent different side chains)
link together to form a
dipeptide

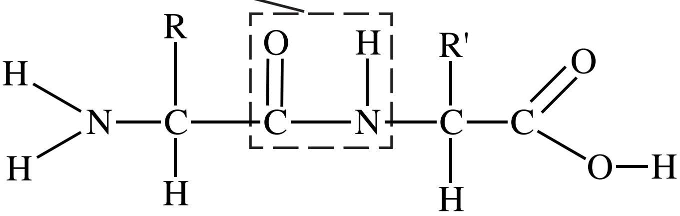
The ***carboxylic*** group from one amino acid links with the ***amino*** group of another amino acid



Water is also produced and this is a ***condensation*** reaction

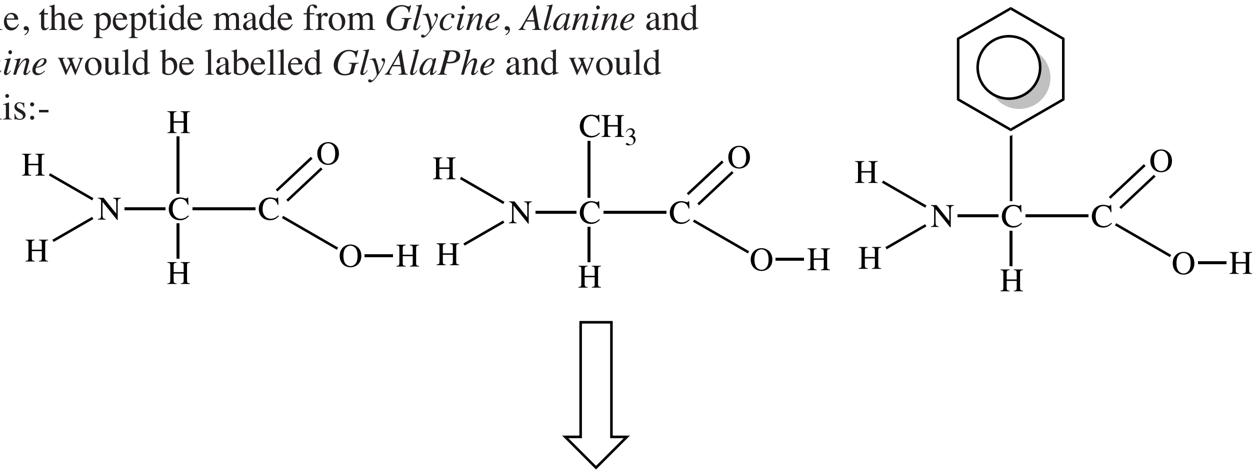
This is known as the ***peptide link*** (or ***amide link***)

H_2O



Tripeptides are made by joining ***three*** amino acids together. ***Peptides*** are *'named'* using the accepted ***abbreviations*** of the ***amino acids*** they contain.

For example, the peptide made from *Glycine*, *Alanine* and *Phenylalanine* would be labelled *GlyAlaPhe* and would look like this:-

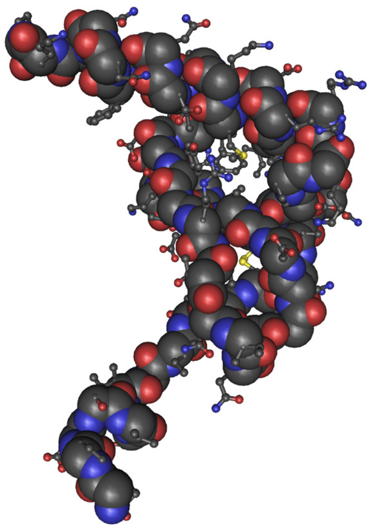


By convention, the ***amino acids*** are always drawn with their ***amino*** *groups* to the left, in the order they appear in the ***peptide*** name - a different ***peptide*** would be formed if we'd lined the 3 ***amino acids*** up facing the 'wrong way'.

Polypeptides can contain *up to about* 40 ***amino acids***; more than 40 and we tend to call it a ***protein***, though the distinction between a ***polypeptide*** and a ***protein*** is an *arbitrary* one.

Making Proteins

This activity looks at how proteins are made



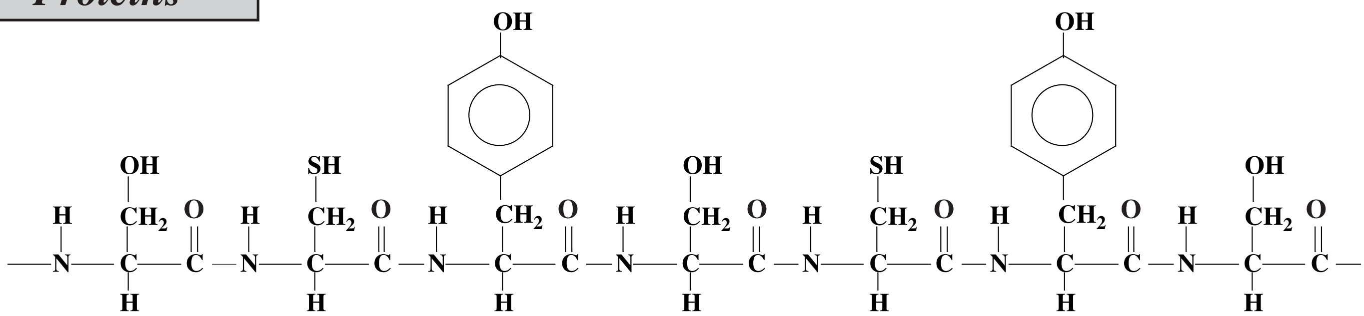
Proteins are ***condensation polymers*** which can contain *several thousand* amino acids. A massive *variety* of ***proteins*** can be made by *arranging* up to 26 ***amino acids*** in *varying numbers* and *varying orders*.

Proteins comprise a large part of an animal's *diet*. During ***digestion*** the ***animal*** and ***vegetable*** *proteins* are ***hydrolysed*** into their component ***amino acids***. Some *amino acids* can be *synthesised* in the body, but others (*the **essential amino acids***) have to be present in the diet.

Proteins required for the body's *specific* needs are built up from ***amino acids*** in the body cells according to information supplied by DNA in the cell ***nuclei***.

Breakdown of Proteins

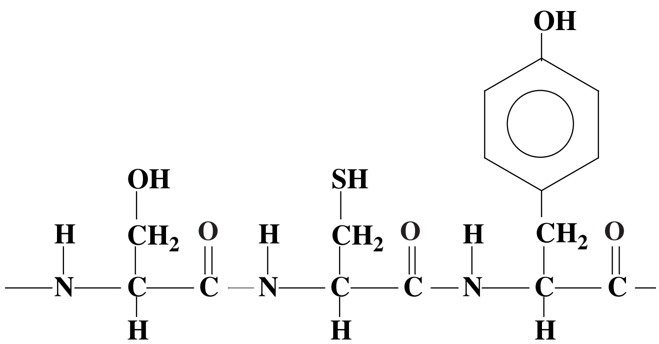
This activity looks at the hydrolysis of proteins to recreate the original amino acids used to form them.



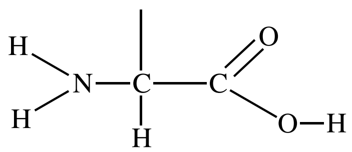
You will only ever see a *fragment* of a ***protein chain*** but it will be enough to allow you to recognise the *"repeating pattern"* and identify how many ***different amino acids*** are being used to make this protein.

In this case there are ***three*** amino acids in the *"repeating pattern"*.

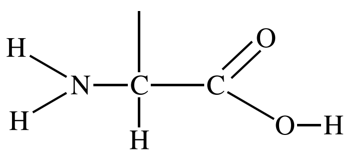
The recognisable ***peptide link*** is used to show where one amino acid ends and the next one begins.



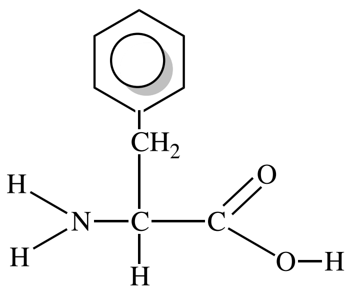
The *original amino acids* can then be drawn - remembering to replace the —H atoms and —OH groups lost when they joined together. In other words, the original ***carboxyl*** and ***amino groups*** are reformed.



serine



cysteine



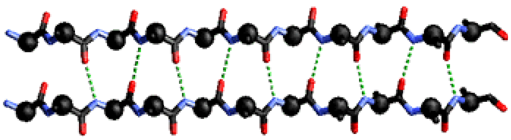
tyrosine

Structure of Proteins

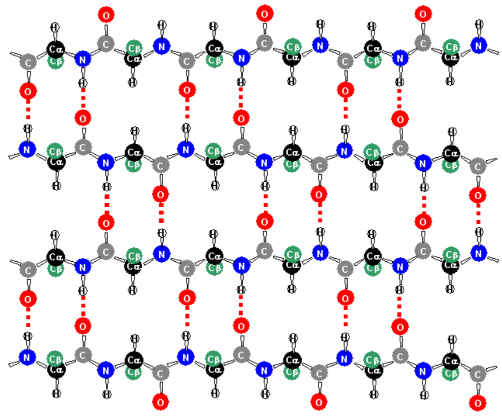
This activity looks at how different structures for proteins depend on their constituent amino acids and affect their role

The *primary structure* of all ***proteins*** is *long chains* of ***amino acids***. However, all along these chains are ***polar*** *groups* such as $—N^{\delta-}—H^{\delta+}$ and $—C = O^{\delta-}$ as well as ***polar*** and ***non-polar*** groups (—R) on each amino acid. A lot of ***attractions*** (and ***repulsions***) are set up *within* and *between* chains, plus some reactions that lead to *permanent* bonds.

As a result of these extra bonds, *secondary structures* will be formed.

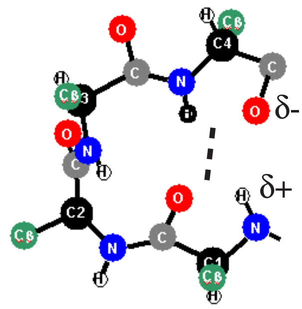


Chains can become linked together by ***strong hydrogen bonds*** *between* the chains.

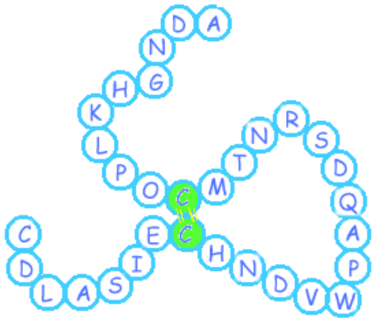


Many *chains* can link in this way to form a ***sheet***.

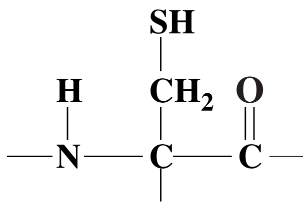
Often the *chains* will ***twist*** around to form ***strong hydrogen bonds*** *within* the chain. The length of 4 ***amino acids*** is usually enough to allow this to happen



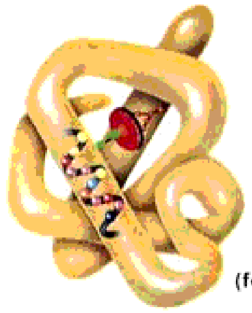
As a result of this *twisting* a ***helix*** chain will form.


Note: two cysteines form a disulphide bridge.

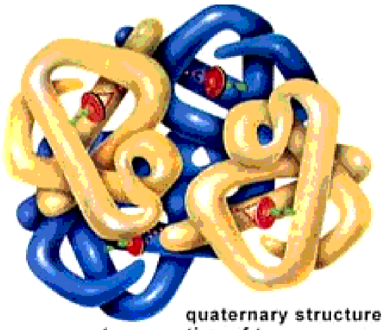
More ***permanent bonds*** can also be formed. For example,two *cysteine* side groups can be oxidised and lose hydrogen atoms to form a *'disulphide bridge'*



The ***folding*** of *chains* and *helixes* is what gives ***proteins*** their individual ***shapes***.


tertiary structure
(folded individual peptide)

Proteins which remain more elongated are referred to as ***FIBROUS*** proteins. These make up most *animal tissue* such as *muscles*. Other examples include *Keratin* found in *horns*,*hoof* and *hair*, and *Collagen* found in *tendons*.



quaternary structure
(aggregation of two or more peptides)

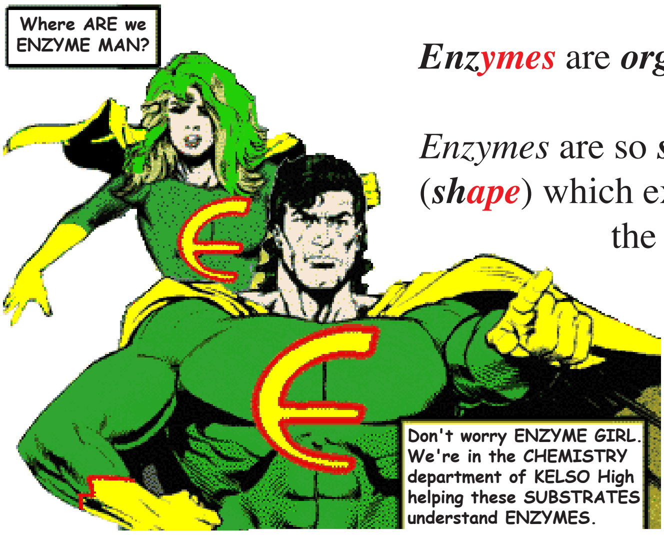
Even more complicated structures called ***GLOBULAR*** proteins can result when a number of ***peptide chains*** join together. These ***Globular*** proteins are involved in the *maintenance and regulation of life processes*.

Examples include ***hormones*** e.g insulin, and ***enzymes***.

Shape*, and their ability to form various types of bonds to bind to other substances, are crucial to a proteins role.*

Enzyme Shape

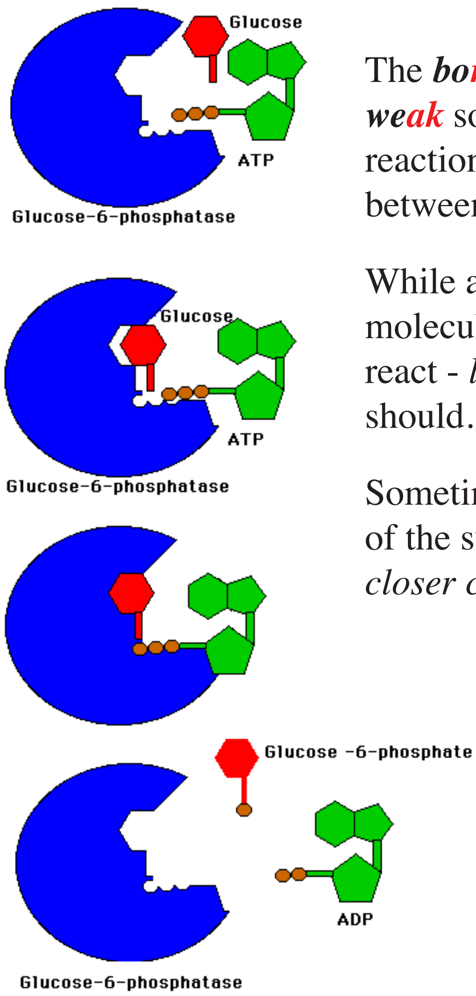
This activity looks at the importance of molecular shape to the way an enzyme functions



Enzymes are ***organic catalysts*** and all contain ***protein.***

Enzymes are so ***specific*** because they have a precise structure (***shape***) which exactly matches the structure of the ***substrate*** - the molecule(s) which is/are reacting.

Enzymes will have an *active site* where reaction takes place. Within the ***active site*** chemical groups (some of the side chains on the ***amino acids***) will form *bonds* with the ***substrate*** molecule



The ***bonds*** which bind the ***substrate*** to the ***active site*** have to be ***weak*** so that the products can easily leave the ***active site*** after the reaction. The bonds are usually ***hydrogen bonds*** or *interactions* between ***ionic*** groups.

While attached to the ***active site***, bonds *within* the ***substrate*** molecule(s) will be *weakened* making it ***easier*** for the ***substrate*** to react - *lowering the **activation** energy* of the reaction as a ***catalyst*** should.

Sometimes, being attached to the ***active site*** will change the ***shape*** of the substrate bringing atoms or groups that need to react into *closer contact*. This helps overcome awkward *'collision geometry'*.

When talking about ***enzymes*** we often use the phrase *'lock and key'* to cover the importance of *correct* ***shape*** and the fact that each enzyme is likely to only work with one ***specific*** substrate.

The example on the left is a good illustration of how an enzyme works.

Denaturing

This activity looks at the factors which can change the shape of an enzyme and prevent it functioning.

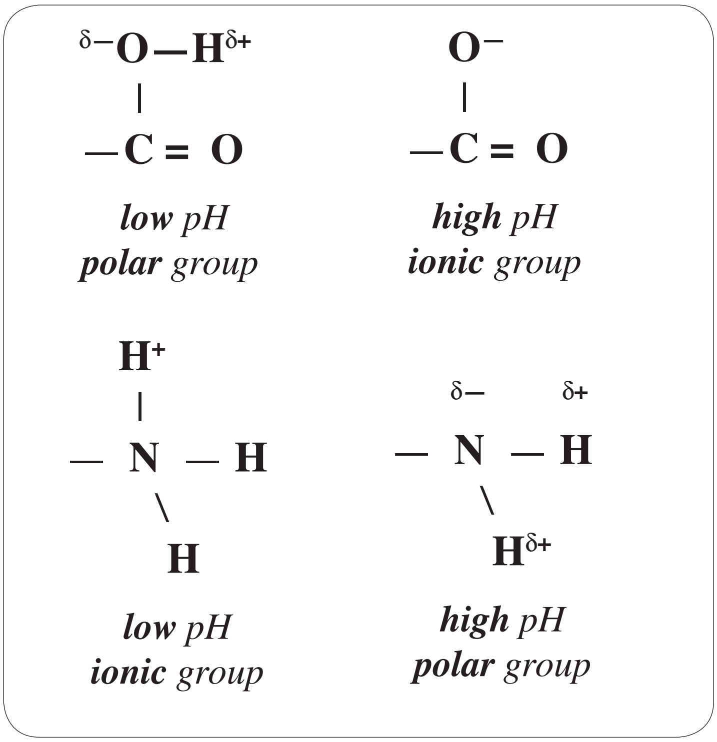
Many of the ***groups*** found on the ***side chains*** of ***amino acids*** (*see page 43*) are *ionisable* and will be affected by a change in ***pH***

Groups such as —COOH and —NH_2 are ***polar*** but can become ***ionic*** as the ***pH*** changes.

This can change the ***active site*** so that the ***substrate*** molecule will be unable to ***bond*** with the ***enzyme***.

Changing the nature of some of these ***groups*** can also change the ***shape*** of the ***enzyme***, as ***folding*** of the ***peptide chain*** may no longer happen at the same points.

If the ***active site*** is destroyed the enzyme is said to be ***DENATURED***.



The structure of an ***enzyme*** is often held together by *weak polar—polar bonds* and *hydrogen bonds*. These can easily be ***broken*** by raising the ***temperature***, which causes them to ***vibrate*** more vigorously. *So enzymes are sensitive to small changes in temperature or pH*.

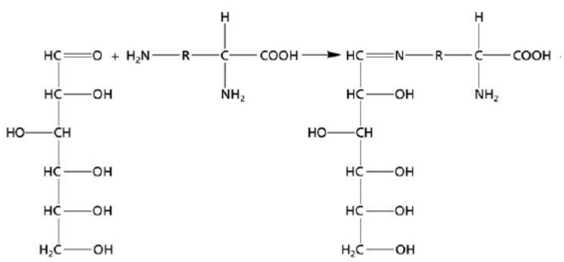
Cooking Meat

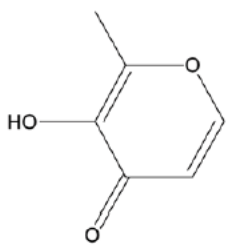
This activity looks at some of the reasons why we cookmeat and some of the chemical changes that take place.

Whilst killling bacteria and other microorganisms to make meat safe to eat is a major reason for cooking meat, most of the reasons are to do with increasing the acceptability of the food.

Texture - *tough meat can be softened* - *collagen* is a ***protein*** that forms the ***connective material*** in meat. Too much makes meat ***tough***. At ***temperatures*** above 60 °C, the ***spiral protein*** *unwinds* (***denatures***) and turns into *soft gelatine*.

Flavour- *browning improves appearance, flavour and aroma* - At ***temperatures*** above 140°C ***reactions*** between —NH_2 groups and ***carbohydrates*** produce ***polymers*** (*brown*) as well as ***volatile flavour*** and ***aroma*** molecules. ***Maillard Reactions***.





maltol - *a flavour molecule*

Other *less desirable* changes can happen during the ***cooking*** of meat - other ***protein*** molecules begin to change (denature) at about 40 °C and cause the meat to *harden*, for example. Chefs often ***brown*** meat with a blow torch and then cook at ***low temperatures***.

SELF CHECK 6.7

Q1. When a protein is denatured

A its overall shape is distorted

B its amide links are hydrolysed

C it is broken into separate peptide fragments

D it decomposes into amino acids

Q2. Which of the following compounds can be classified as proteins?

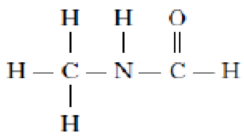
A fats

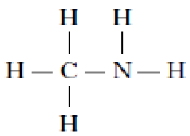
B oils

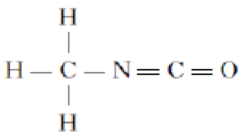
C enzymes

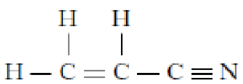
D amino acids

Q3. Which of the following is an amine?

A 

B 

C 

D 

Q4. The arrangement of amino acids in a peptide is Z-X-W-V-Y

where the letters V, W, X, Y and Z represent amino acids.

On partial hydrolysis of the peptide, which of the following sets of dipeptides is possible?

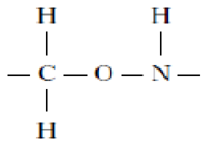
A V—Y, Z—X, W—Y, X—W

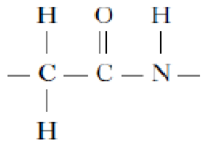
B Z—X, V—Y, W—V, X—W

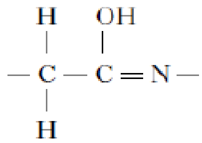
C Z—X, X—V, W—V, V—Y

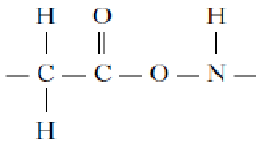
D X—W, X—Z, Z—W, Y—V

Q5. Which of the following arrangements of atoms shows a peptide link?

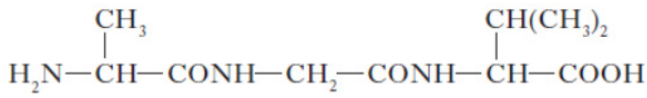
A 

B 

C 

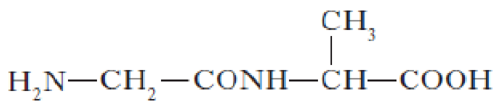
D 

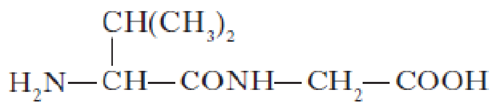
Q6. A tripeptide X has the structure

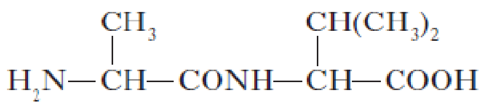


Partial hydrolysis of X yields a mixture of dipeptides.

Which of the following dipeptides could be produced on hydrolysing X?

A 

B 

C 

D 

HOME PRACTICE 6.7

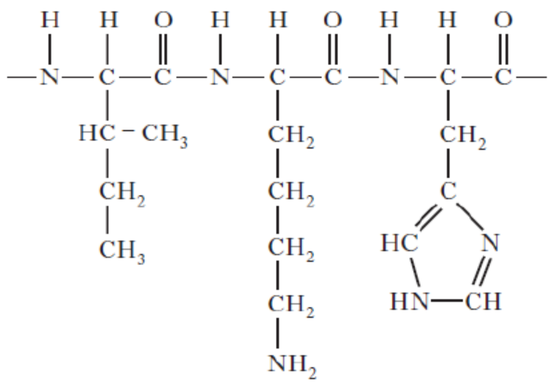
Q1. Chemists have developed cheeses specifically for use in cheeseburgers. When ordinary cheddar cheese is grilled the shapes of the protein molecules change and the proteins and fats separate leaving a chewy solid and an oily liquid.

a) What name is given to the change in protein structure which occurs when ordinary cheddar is grilled? **1**

To make cheese for burgers, grated cheddar cheese, soluble milk proteins and some water are mixed and heated to no more than 82 °C. As the cheese begins to melt an emulsifying agent is added and the mixture is stirred.

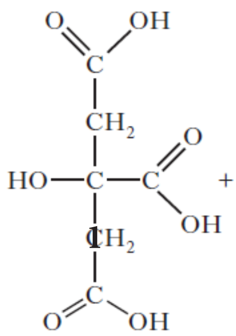
b) Why would a water bath be used to heat the mixture? **1**

c) A section of the structure of a soluble milk protein is shown.



Draw a structural formula for any one of the amino acids formed when this section of protein is hydrolysed. **1**

d) The emulsifier used is trisodium citrate, a salt formed when citric acid is neutralised using sodium hydroxide. Copy and complete the equation below showing a structural formula for the trisodium citrate formed.

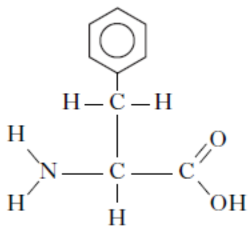


$+ \ 3NaOH \longrightarrow \qquad\qquad + \ 3H_2O$

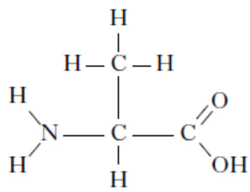
1

Q2. Phenylalanine and alanine are both amino acids.

Phenylalanine is an essential amino acid.



phenylalanine



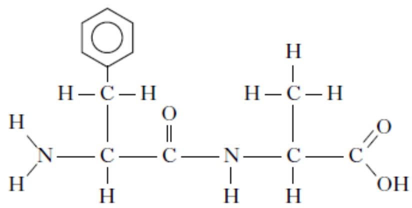
alanine

a) What is meant by an essential amino acid? **1**

b) How many hydrogen atoms are present in a molecule of phenylalanine? **1**

c) Phenylalanine and alanine can react to form the dipeptide shown.

Copy and circle the peptide link in this molecule.



1

d) Draw a structural formula for the other dipeptide that could be formed. **1**

Total **(8)**

Context - Kitchen Chemistry

This activity is to remind you how much of the Organic Chemistry met in this Unit has been taught within the context of Kitchen Chemistry

Flavour

Most of our 'tasting' is done through our noses, so most flavour molecules are *volatile* (*weak intermolecular forces*) such as

esters - many have sweet fruity smells - e.g. '*pear drops*' - *pentyl ethanoate*
aldehydes - can however be ***oxidised*** over time resulting in (sometimes unpleasant) changes in flavour
terpenes - '*essential oils*' are responsible for many distinctive flavours such as *cinnamon* and *ginger* as well as *oranges* and *lemons*.
acids - such as *vinegar*, *ethanoic acid* are used to introduce 'sour' flavours

Cooking

Cooking can *dissolve* out the flavour molecules so whilst many foods can be safely *cooked in water,* others are better *cooked in oil.*

Cooking also effects the structure of, in particular, ***proteins*** which can result in significant change in the *texture* of certain foods during cooking.

Texture

Protein *structure* has an important impact on the *texture* of food and can be effected by *changes in temperature* (*cooking*) and *changes in pH* (*marinading* in ***acids*** such as *vinegar*, *ethanoic acid*).

Foods, such as curries, often '*separate*' into '*water layer*' and '*oil layer*' as a result of *differences in solubility* (*different intermolecular forces*).

Colour

Colour can arise in many ways but larger ***terpenes*** are often responsible for the *yellow*, *orange* or *red* colour of so many foods - e.g. *carotene* in carrots.

Energy

Whilst ***carbohydrates,*** our main '*energy food*', are not covered in this course, ***proteins*** also contribute energy whilst *fats & oils* are our most concentrated source of energy.

Additives

antioxidants - can be added to food, though many foods already contain *Vitamin C* - a natural *antioxidant*

emulsifying agents - are used to prevent '*water layers*' and '*oily layers*' from separating. These molecules are often made from ***fats & oils*** and behave in exactly the same way as *soap molecules*. *Milk* contains natural ***emulsifiers***.

In addition, many reactions triggered by *UV light*, such as the ***substitution*** reaction between *alkanes* and *halogens*, involve the production of ***free radicals***. ***Free radicals*** start ***chain reactions*** which are responsible for the ageing of your skin. *Sun cream* contains chemicals designed to absorb UV before it reaches your skin.

Vitamin E and *melatonin* are natural ***free radical scavengers*** that can help counter the effect of free radicals. Many ***cosmetic*** products contain *free radical scavengers* which react with ***free radicals*** to form stable molecules and prevent ***chain-reactions*** starting.