Unit 2 | Carbon Compounds | Intermediate 2

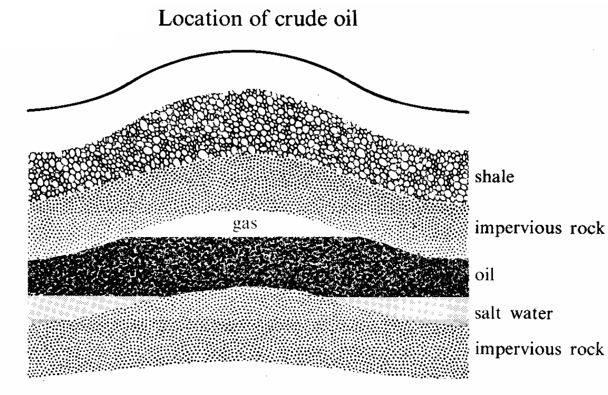
1. A **fuel** is a chemical which burns to release energy, mainly as heat.

2. When a substance burns it reacts with **oxygen**.

3. **Combustion** is another name for burning and can be described as exothermic since energy is released.

4. The main fuels presently in use are **fossil fuels** – coal, oil, natural gas and peat.

5. Fossil fuels were formed over millions of years from decaying plant and animal remains. The action of high temperature and pressure induced chemical change.



6. Fossil fuels are finite resources, i.e., they are limited in supply and cannot be replaced. Over-use will lead to a world fuel crisis where demand exceeds supply.

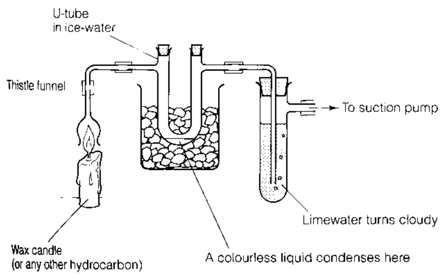
7. The chemical compounds which are found in oil and natural gas are mainly hydrocarbons.

8. **Hydrocarbons** are compounds which contain carbon and hydrogen only.

9. Hydrocarbons burn in a plentiful supply of air to produce carbon dioxide and water as the only products. This is called **complete combustion**:

hydrocarbon + oxygen → carbon dioxide + water

10. Hydrocarbons can be burnt in the laboratory and the products identified:

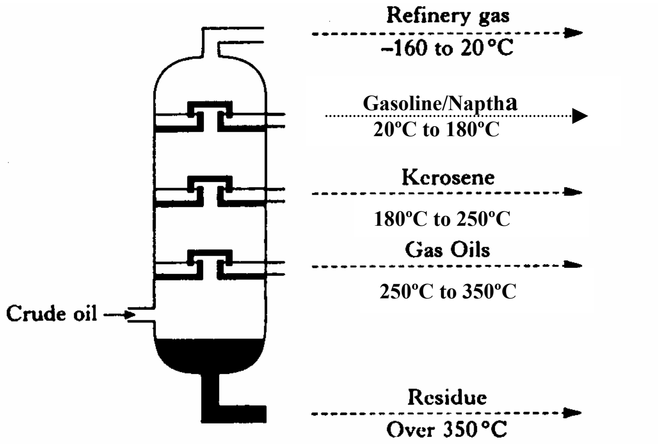


Collecting the combustion products of a hydrocarbon

If the lime-water (tube B) turns milky, CO_2 has been produced and the fuel must contain carbon.
If the colourless liquid collected in tube A boils at 100ºC and freezes at 0ºC, then H_2O has been produced and the fuel must contain hydrogen.

11. Crude oil is a complex mixture of chemical compounds, mainly hydrocarbons.

12. Fractional distillation is the process used to separate the different hydrocarbons in crude oil according to their boiling points.



Separation takes place in a tall, heated tower called a fractionating column where the various oil fractions are colleted at different levels from pipes on the side of the tower.

13. A group of hydrocarbons with similar boiling points within a given range is called a **fraction.**

	Petroleum Gas	Gasoline	Naptha	Kerosene	Gas Oils	Residue
Number of C atoms	1-4	5-10	6-11	9-15	15-25	25+
Boiling Point Range (°C)	-160 to 20	20 to 65	65 to 180	180 to 250	250 to 350	>350
Ease of evaporation	← Easier to evaporate					
Viscosity	Becoming thicker →					
Flammability	← Easier to ignite					
Examples of Use	Calor gas fuel	Petrol fuel for cars and chemicals		Jet aircraft fuel	Diesel fuel	Road tar & waxes

14. As molecular size increases the boiling point increases due to stronger intermolecular forces between different molecules.

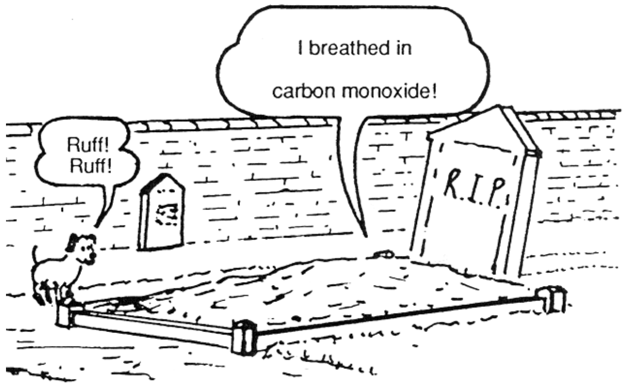
15. As molecular size increases flammability decreases as there is less tendency for the molecule to exist as a vapour.

16. As molecular size increases viscosity increases due to the longer molecules becoming tangled up.

17. Most of our modern plastics, fibres, paints, dyes, drugs and medicines are made from the raw materials obtained from coal, crude oil and natural gas.

18. When a hydrocarbon burns in air with insufficient oxygen for complete combustion, carbon (soot) and carbon monoxide can be produced. This is called **incomplete combustion**.

19. Carbon monoxide is an odourless and colourless poisonous gas which combines with haemoglobin in blood.

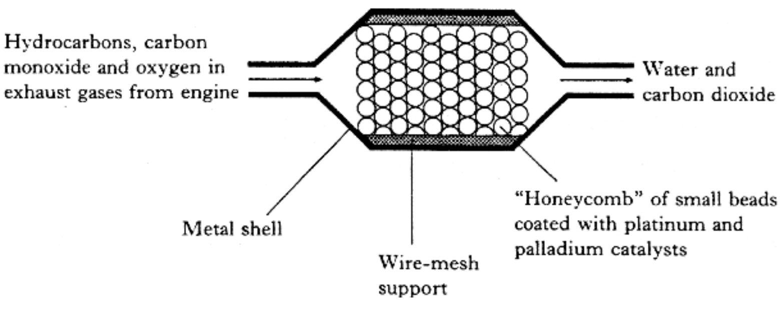


20. The incomplete combustion of diesel fuel can produce soot particles which are harmful.

21. Coals and oils may contain sulphur compounds which burn to produce the toxic gas SO_2 which contributes to 'acid rain'.

22. In petrol engines the electrical spark provides sufficient energy to cause N_2 to react with O_2 to form oxides of nitrogen (NO_x). These poisonous gases also contribute to acid rain.

23. Catalytic converters fitted to most car exhaust systems convert the poisonous gases NO_x and CO into the harmless gases N_2 and CO_2.



24. A **homologous series** is a family of compounds which can be represented by a general formula and share similar chemical properties.

25. **Alkanes** are an example of a homologous series and are a subset of the set of hydrocarbons.

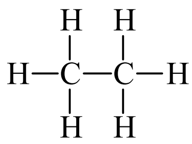
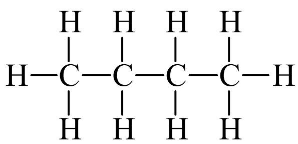
26. Each member of the alkane series has a name which ends in **–ane** and a prefix which indicates the number of carbon atoms in the molecule.

Prefix	**Number of C atoms**
meth-	1
eth-	2
prop-	3
but-	4

Prefix	**Number of C atoms**
pent-	5
hex-	6
hept-	7
oct-	8

27. All alkanes are **saturated** hydrocarbons. All the carbon to carbon bonds are single covalent bonds.

28. Alkanes can be represented using **molecular formula, full structural formula** or **shortened structural formula**:

Name	**Molecular Formula**	**Full Structural Formula**	**Shortened Structural Formula**
Ethane	C_2H_6		CH_3CH_3
Butane	C_4H_{10}		$CH_3CH_2CH_2CH_3$

29. The general formula for the alkanes is $\mathbf{C_nH_{2n+2}}$ where n is the number of carbon atoms.

30. Straight-chain alkanes have a continuous single line of bonded carbon atoms.

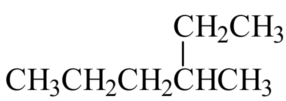
$CH_3CH_2CH_3$
Propane

31. In a **branched-chain alkane** carbon atoms are bonded to the main continuous carbon chain as 'side-chains'.

32. The branches are named after the corresponding alkanes with the –ane ending changing to **–yl**.

$CH_3CH(CH_3)CH_2CH_3$

a methyl branch



an ethyl branch

33. Alkanes are named using the following internationally accepted convention:

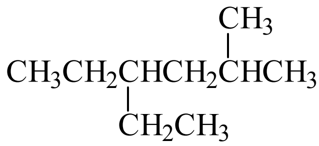
(i) select the longest continuous chain of carbon atoms and name it after the appropriate straight-chain alkane.

(ii) number the carbon atoms from the end of the chain nearest the branch

(iii) name the branch(es) and indicate the position(s) of the branch(es) on the chain.

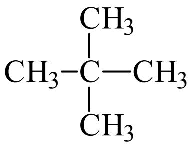
$CH_3CH(CH_3)CH_2CH(CH_3)CH_3$

2, 4-dimethylpentane

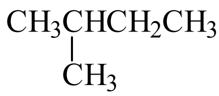


4-ethyl-2-methylhexane

34. Isomers are compounds with the same molecular formula but different structural formula.



2,2-dimethylpropane
C_5H_{12}

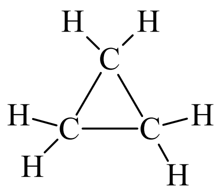


2-methylbutane
C_5H_{12}

35. Cycloalkanes are alkanes where the carbon atoms are arranged in a ring.

36. Each member of the cycloalkane homologous series has a name which ends in **–ane** and a prefix which starts with **cyclo** and indicates the number of carbon atoms in the ring.

37. The simplest cycloalkane is **cyclopropane**:



Cyclopropane

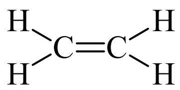
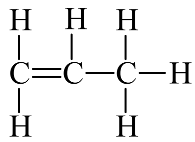
38. The general formula for the cycloalkanes is $\mathbf{C_nH_{2n}}$.

39. Alkenes are hydrocarbons which contain a carbon to carbon double covalent bond (C=C).

40. Each member of the alkene homologous series has a name which ends in –ene and a prefix which indicates the number of carbon atoms in the molecule.

41. The carbon to carbon double bond is an example of a **functional group**, i.e. a group of atoms with characteristic properties.

42. Alkenes can be represented using molecular or structural formula:

Name	Molecular Formula	Full Structural Formula	Shortened Structural Formula
Ethene	C_2H_4		$CH_2{=}CH_2$
Propene	C_3H_6		$CH_2{=}CHCH_3$

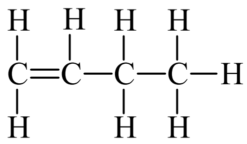
43. All alkenes are **unsaturated** hydrocarbons - there is at least one carbon to carbon double bond.

44. The general formula for the alkenes is $\mathbf{C_nH_{2n}}$.

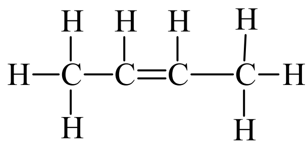
45. Alkenes may be named by:

(i) selecting the longest continuous chain of carbon atoms containing the double bond and naming it after the appropriate straight-chain alkene.

(ii) numbering the C atoms from the end of the chain nearest the double bond and indicating the position of the double bond



but-1-ene

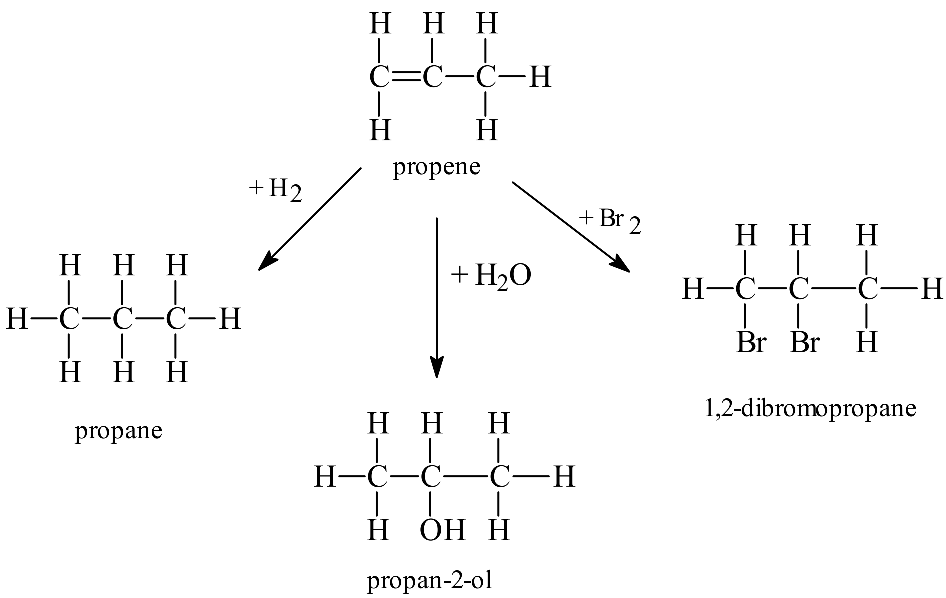


but-2-ene

46. The presence of the C=C in alkenes makes them much more chemically reactive than alkanes or cycloalkanes.

47. Bromine solution rapidly decolourises upon reaction with alkenes and this is used as a chemical test to distinguish between saturated and unsaturated hydrocarbons**.**

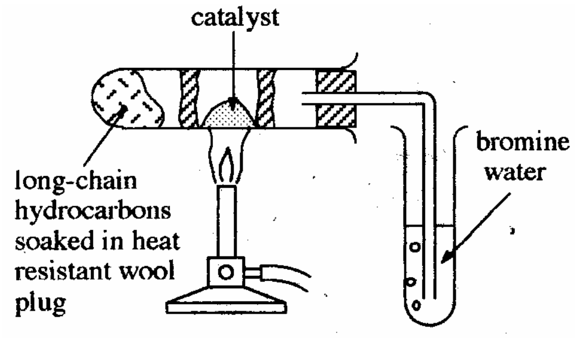
48. Alkenes undergo **addition** reactions with small molecules to form saturated products.



49. Fractional distillation of crude oil yields more long chain hydrocarbons than are useful for present day industrial purposes.

50. Cracking is a process where the fractions containing long chain hydrocarbons are broken down into a mixture of smaller, more useful molecules.

51. The use of a catalyst (aluminium oxide or silicate) allows cracking to be carried out at a lower temperature. This is referred to as **catalytic cracking.**



52. Cracking produces a mixture of products, some of which are saturated and some of which are unsaturated.

$$C_{24}H_{50} \rightarrow C_{12}H_{24} + C_{12}H_{26}$$

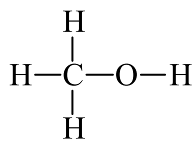
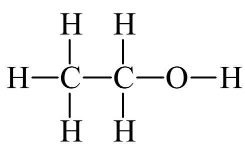
$$C_{24}H_{50} \rightarrow C_6H_{12} + C_{18}H_{38}$$

$$C_{24}H_{50} \rightarrow C_4H_8 + C_6H_{12} + C_{14}H_{30}$$

53. The **alkanols** are a homologous series with general formula $\mathbf{C_nH_{2n+1}OH}$.

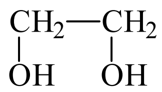
54. Alkanols are characterised by the **hydroxyl (-OH)** functional group and have names ending in **–ol.**

55. Alkanols may be represented by molecular or structural formula:

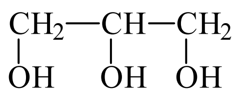
Name	**Molecular Formula**	**Full Structural Formula**	**Shortened Structural Formula**
Methanol	CH_3OH		CH_3OH
Ethanol	C_2H_5OH		CH_3CH_2OH

56. Alkanols may be named by:

(i) selecting the longest continuous chain of carbon atoms containing the hydroxyl group and naming it after the appropriate alkanol;
(ii) numbering the C atoms from the end of the chain nearest the functional group, indicating the position of the functional group;
(iii) some alkanols can have more than one hydroxyl group.



ethane-1,2-diol
(ethylene glycol)

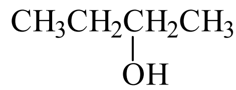


propane-1,2,3-triol
(glycerol)

57. Isomerism can occur from propanol upwards due to the different positions of the hydroxyl group.

$CH_3CH_2CH_2CH_2{-}OH$

butan-1-ol



butan-2-ol

58. Ethanol, for alcoholic drinks, can be made by **fermentation** of glucose derived from any fruit or vegetable.

59. An enzyme in yeast acts as a catalyst in the fermentation process which breaks down glucose to form ethanol and carbon dioxide:

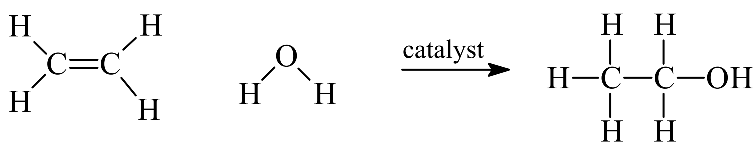
$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

60. At concentrations above 15%, the alcohol poisons the living organisms in the yeast thus limiting the alcohol concentration that can be produced from fermentation.

61. **Distillation** is a method of increasing the alcohol concentration of fermentation products in the manufacture of 'spirit' drinks, e.g. gin, vodka.

62. Alcoholic drinks, if taken in excess, can have damaging effects to health and mind.

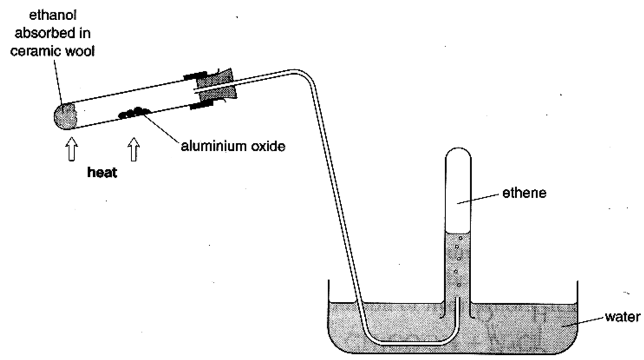
63. To meet market demand, ethanol is made by methods other than fermentation. Ethanol is produced industrially by the **catalytic hydration** of ethene using steam.



ethene water ethanol

64. Dehydration of ethanol produces ethene. This reaction is the reverse of hydration and can be carried out in the laboratory:

$$C_2H_5OH \longrightarrow CH_2{=}CH_2 + H_2O$$

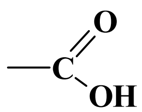


65. Ethanol is being mixed with petrol for use as an engine fuel in countries where it can be economically produced in sufficient quantities.

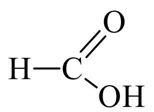
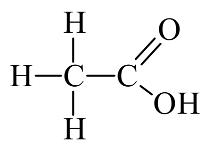
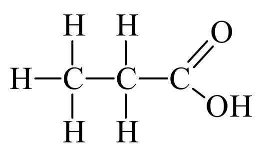
66. The ethanol can be obtained by the fermentation of sugar cane which is a renewable energy resource.

67. Alkanoic acids are a homologous series and are a subset of the **carboxylic acids.**

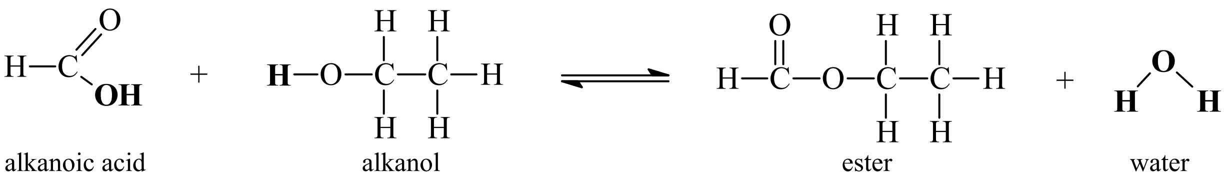
68. Alkanoic acids are characterised by the **carboxyl** functional group and have names ending in **–oic acid.**



69. Alkanols may be represented by molecular or structural formula:

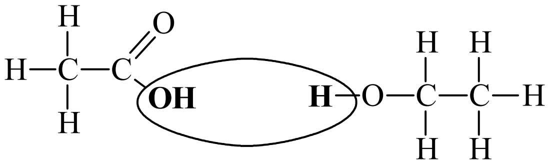
Name	Molecular Formula	Full Structural Formula	Shortened Structural Formula
Methanoic Acid	CH_2O_2		HCOOH
Ethanoic Acid	$C_2H_4O_2$		CH_3COOH
Propanoic Acid	$C_3H_6O_2$		CH_3CH_2COOH

70. Esters are formed by a **condensation** reaction between alkanoic acids and alkanols.

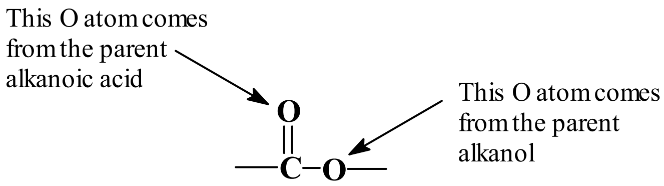


71. A **condensation** reaction occurs when two reactants join up with the elimination of water.

72. The **ester link** is formed from the reaction of a hydroxyl group with a carboxyl group:



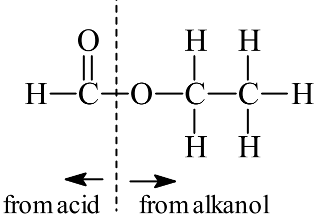
73. Esters can be identified by the **–COO-** functional group . This is referred to as the ester link:



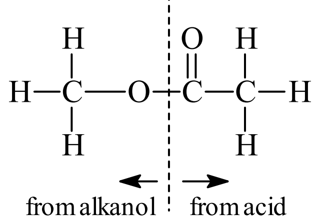
74. An ester takes its name from the alkanol and alkanoic acid from which it is made. It can be recognised by the **–oate** ending.

Alkanol	Alkanoic Acid	Ester
methanol	ethanoic acid	methyl ethanoate
propan-1-ol	methanoic acid	propyl methanoate
ethanol	ethanoic acid	ethyl ethanoate

75. Esters can be named from their structure:

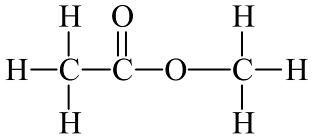
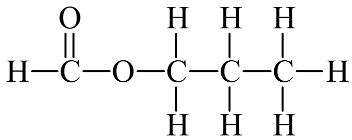
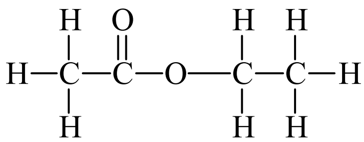


ethyl methanoate



methyl ethanoate

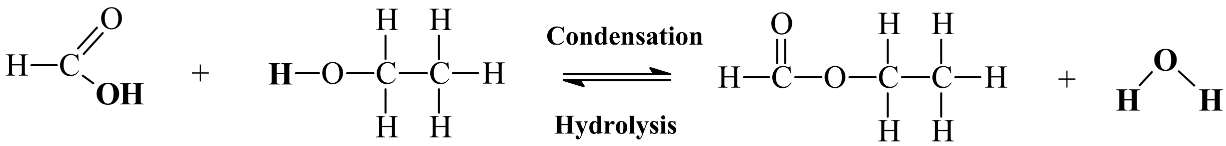
76. Esters may be represented by full or shortened structural formula:

Name	Full Structural Formula	Shortened Structural Formula
Methyl ethanoate		CH_3COOCH_3
Propyl methanoate		$HCOOCH_2CH_2CH_3$
Ethyl ethanoate		$CH_3COOCH_2CH_3$

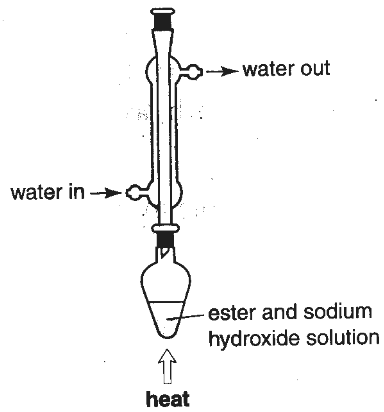
77. Esters can be broken down to the parent alkanol and alkanoic acid by heating with an acid or an alkali.

78. Since the breakdown of an ester occurs due to the addition of the elements of water, this is an example of a **hydrolysis** reaction**.**

79. The formation and hydrolysis of an ester is a reversible reaction which can eventually reach equilibrium as indicated by the $\rightleftharpoons$ sign.



80. An alkali is normally used to break down an ester in the laboratory.



81. Synthetic materials are made by the chemical industry, i.e. they are not natural.

82. Most plastics and synthetic fibres are made from chemicals obtained from crude oil.

83. Examples of plastics include polythene, PVC, polystyrene, perspex and bakelite

84. Examples of synthetic fibres include nylon and polyesters.

85. The uses of plastics are related to their properties:

Plastic	Property	Use
PVC	flexible, non-conductor of electricity	insulating electrical cable
Polystyrene	light, poor conductor of heat	packaging, ceiling tiles, drinking cups
Poly(ethene)	light, durable, unreactive	washing-up bottles, kitchen bowls
Kevlar	very strong	bullet-proof vests, replace steel in car tyres, protective suits for racing motorcyclists
Poly(ethenol)	readily dissolves in water	stitches in surgery, laundry bags in hospitals

86. Natural fibres come from plants and animals, e.g. *wool, cotton, silk and linen*

87. Synthetic materials often have advantages over natural materials, e.g. *nylon wears better than wool in carpets*.

88. For some uses, natural materials have advantages over synthetic materials, e.g. *wool is warmer than synthetic fibres*.

89. The low density and durability of plastics can cause environmental problems, e.g. *unsightly litter and disposal of plastic waste.*

90. Options for disposal include incineration, landfill or recycling

91. Some plastics burn giving off toxic fumes including carbon monoxide; the fumes are related to the elements present in the plastics.

92. Biopol is a recently developed biodegradable plastic, i.e. it can be broken down by bacteria in the soil.

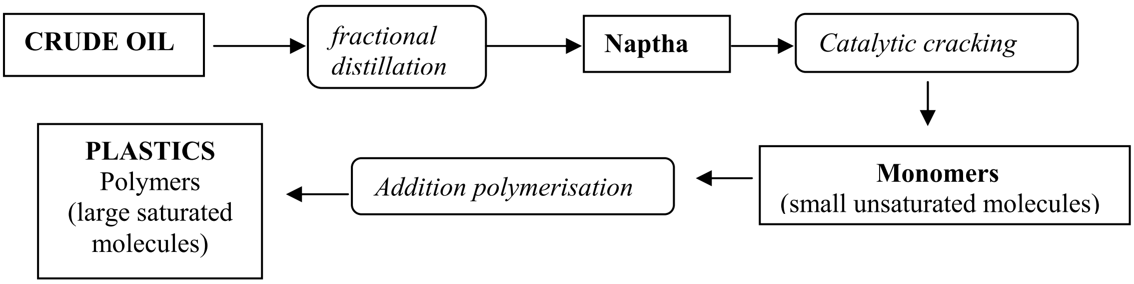
93. Thermoplastics soften on heating and can be reshaped over and over again, e.g. *nylon and polythene.*

94. Thermosetting plastics harden upon heating and do not melt on reheating, e.g. *bakelite used for plugs and sockets.*

95. Plastics are made up of very long chain molecules called **polymers.**

96. Polymer molecules are made by the joining together of small molecules called **monomers.**

97. Most plastics are made from ethene and other alkenes obtained from the catalytic cracking of oil fractions.



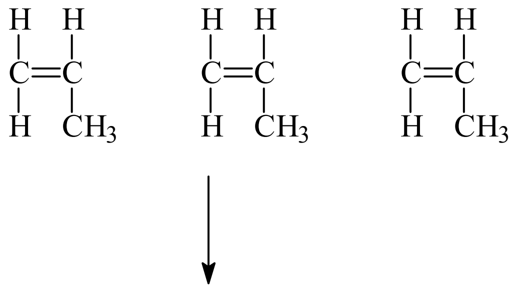
98. Addition polymers are formed when the carbon to carbon double bond of unsaturated monomer units opens up and allows the molecules to 'add' together; this is called **addition polymerisation.**

99. The name of any addition polymer is clearly associated with the name of the monomer:

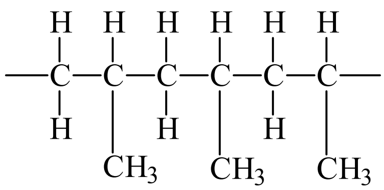
Monomer	Polymer
Ethene	Poly(ethene)
Propene	Poly(propene)
Styrene	Polystyrene
Vinyl chloride	Polyvinylchloride (PVC)

100. The polymerisation of propene can be represented by:

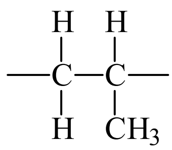
Propene monomers



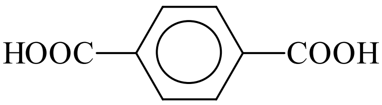
Poly(propene) polymer



Repeating Unit



101. **Condensation polymers** are made from monomers with two functional groups.



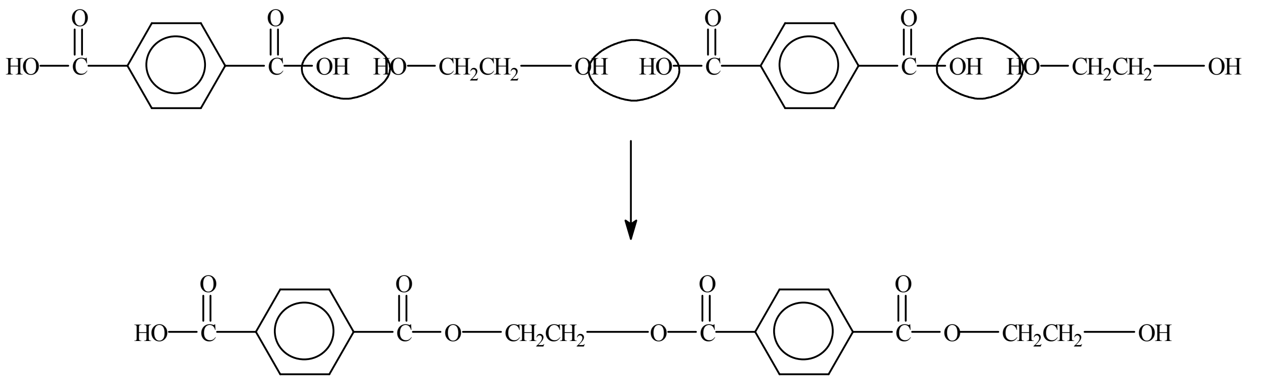
diacid monomer

$$HO-CH_2CH_2-OH$$

diol monomer

102. Condensation polymers usually link together by a loss of elements to produce water.

103. **Polyesters** are long chain molecules with many ester links. Polyesters such as terylene are formed from a reaction between alcohols with two hydroxyl functional groups (a diol) e.g. *ethane-1,2-diol* and carboxylic acids with two carboxyl functional groups (a diacid) e.g. *benzene-1,4-dicarboxylic acid.*

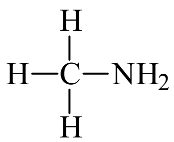


+ $3H_2O$

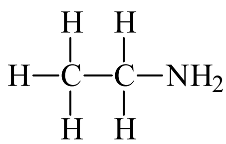
Terylene

104. **Amines** are a homologous series of carbon compounds which contain nitrogen atoms.

105. The functional group of the amines is $-NH_2$, otherwise known as the **amino** group.



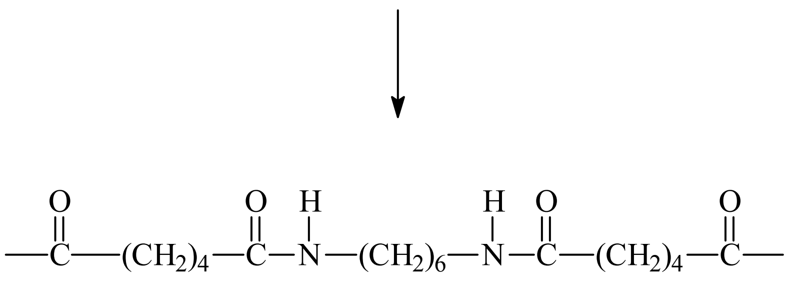
methylamine



ethylamine

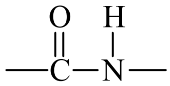
106. **Polyamides** are examples of condensation polymers which are formed from monomers which contain amino and carboxyl functional groups.

$HOOC-(CH_2)_4-COOH$ $H_2N-(CH_2)_6-NH_2$ $HOOC-(CH_2)_4-COOH$



part of nylon-6,6

107. The joining together of a carboxyl and amino group produces an **amide** link. Polyamides contain many amide links.



108. **Carbohydrates** are produced by plants during photosynthesis.

$$6CO_2 + 6H_2O \longrightarrow \underset{\text{glucose}}{C_6H_{12}O_6} + 6O_2$$

109. **Respiration** is the process where animals and plants break down carbohydrates to obtain energy.

$$\underset{\text{glucose}}{C_6H_{12}O_6} + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

110. Carbohydrates contain the elements carbon, hydrogen and oxygen with the hydrogen and oxygen in the ratio of 2:1.

Carbohydrate	**Molecular Formula**
Glucose	$C_6H_{12}O_6$
Fructose	$C_6H_{12}O_6$
Maltose	$C_{12}H_{22}O_{11}$
Sucrose	$C_{12}H_{22}O_{11}$
Starch	$(C_6H_{10}O_5)_n$

111. Glucose, fructose, maltose and sucrose are examples of simple carbohydrates or simple **sugars**. Starch is an example of a complex carbohydrate.

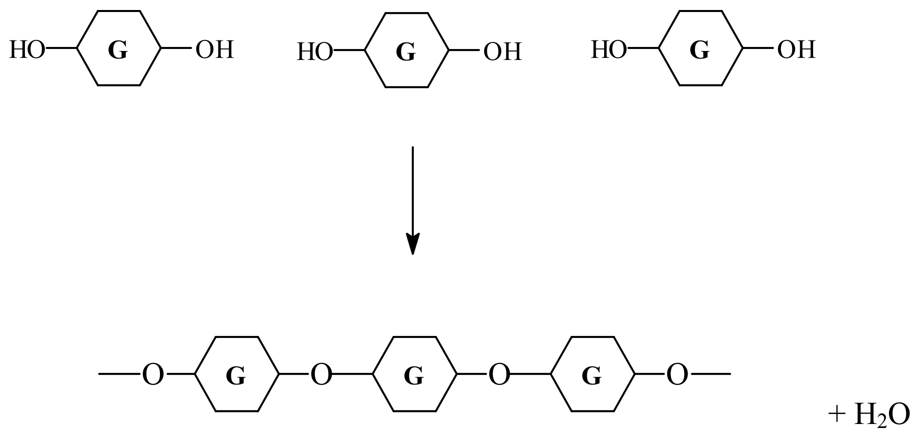
112. **Monosaccharides** have only one carbon ring e.g. *glucose and fructose*; **disaccharides** have two carbon rings, e.g. *maltose and sucrose*; **polysaccharides** contain many carbon rings, e.g. *starch and cellulose*.

113. **Iodine solution** can be used as a test for starch. A positive result generates a blue-black colour.

114. **Benedict's solution** can be used to test for sugars. A colour change from blue to orange-red is observed when a simple sugar is heated with Benedict's solution in a water bath. Sucrose is an exception, it is a sugar which DOES NOT react with Benedict's solution.

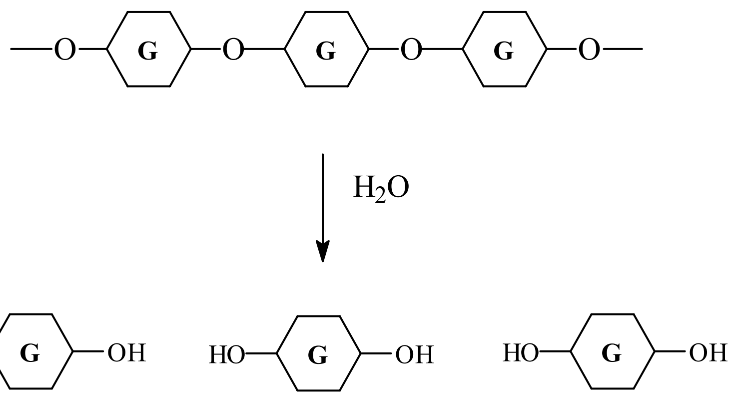
115. Sugars are carbohydrates with small molecules which can dissolve in water.

116. Starch is a natural condensation polymer made by linking together many glucose molecules.

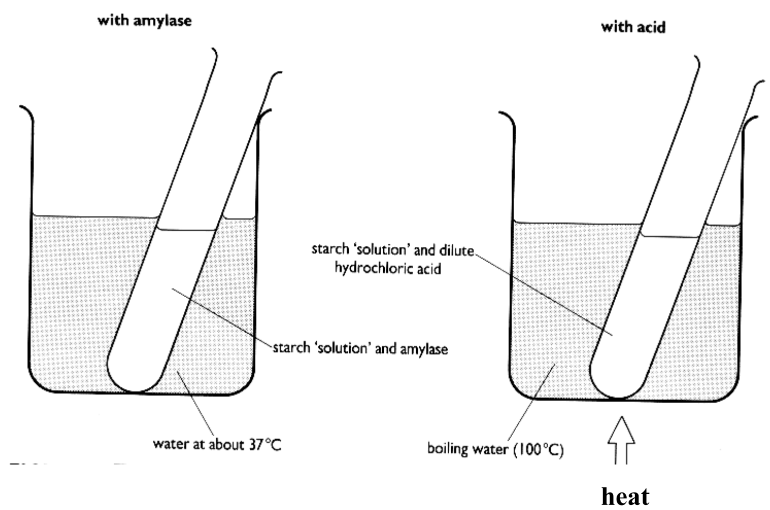


117. Plants convert the glucose into starch for storing energy.

118. During digestion, starch is broken down to glucose which is carried by the blood stream to the body cells. Since this involves the addition of water, this is an example of a **hydrolysis** reaction.



119. The hydrolysis of starch can be carried out in the laboratory using acid or enzymes.



120. Body enzymes function best at body temperature (37°C) and are destroyed at higher temperatures.

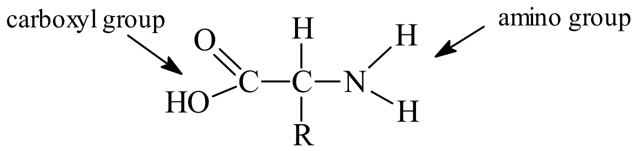
121. Proteins are made by plants from simple nitrogen compounds (nitrates) and are an essential part of a balanced diet of animals where they provide material for body growth and repair.

122. Proteins are the major structural materials of animal tissues, e.g. *hair, skin and nails*. Proteins are also involved in many human biological processes, e.g. *enzymes, hormones and haemoglobin.*

123. Proteins are natural condensation polymers made by the linking together of many amino acid monomers.

124. There are over 20 different amino acids found in proteins. The different possible sequences of these amino acids account for the wide variety of different protein molecules.

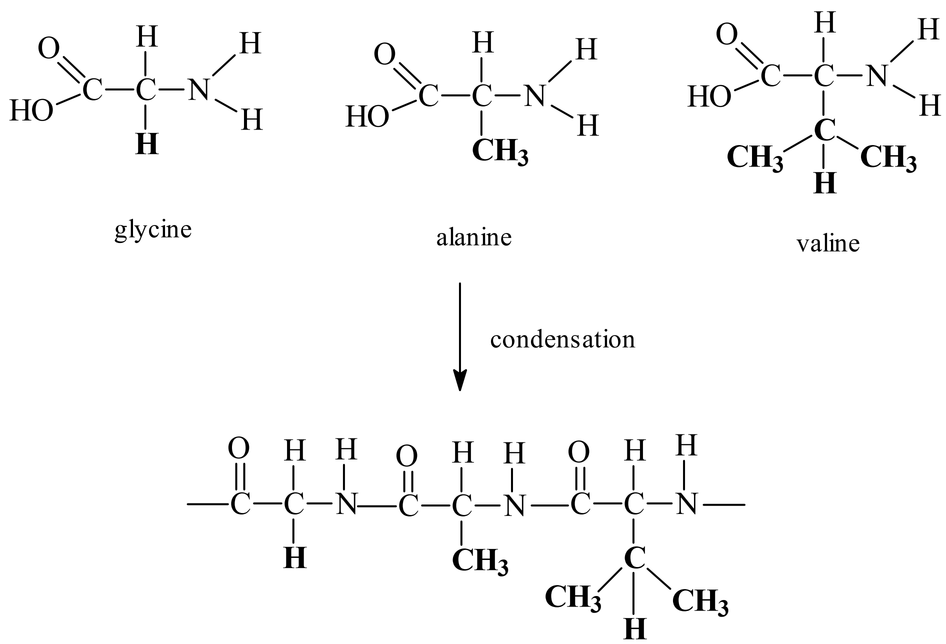
125. The structure of an **amino acid** can be represented as follows.



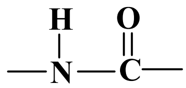
Where R = various side chains

126. The amino acids most commonly found in proteins have both functional groups attached to the same carbon.

127. The acidic group and the amino group of different amino acid molecules can join together with the loss of water.



128. A **peptide** link is formed by the reaction of an amino group with a carboxyl group.



129. Proteins may be hydrolysed to the constituent amino acids by the addition of the elements of water.

130. During digestion of our foods, body enzymes catalyse the hydrolysis of insoluble proteins into individual amino acids.

131. The smaller amino acids are then absorbed by the bloodstream and are circulated to various parts of the body.

132. Proteins specific to the body's needs are built up within the body cells from the amino acids released from digestion.

133. **Fats** and **oils** supply the body with energy and are a more concentrated source of energy than carbohydrates.

134. Fats and oils can be classified according to their origin

Animal	**Vegetable**	**Marine**
pork fat (dripping)	sunflower oil	cod liver oil
beef fat (lard)	rape seed oil	whale oil
	palm oil	
	olive oil	

135. Animals tend to produce fats which are mainly saturated solids, while plants and fish produce mainly liquid unsaturated oils.

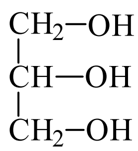
136. The saturated molecules of animal fats are more closely packed than the unsaturated oils. As a result, the forces of attraction between the molecules are strong and so fats have relatively high boiling points and hence exist as solids.

137. Oils can be **hardened** to make them suitable for use as margarine. The partial removal of the unsaturation by the addition of hydrogen (hydrogenation) raises the melting point.

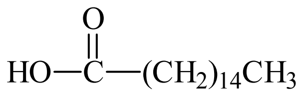
138. Fats and oils are examples of esters.

139. In fats and oils, **fatty acids** are always combined with propane-1,2,3-triol, more commonly known as **glycerol** in a 3:1 ratio of fatty acids: glycerol**.**

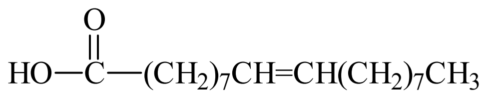
140. **Glycerol** is a trihydric alcohol, i.e., each molecule has three hydroxyl groups.



141. Fatty acids can be saturated or unsaturated straight chain carboxylic acids having even numbers of carbon atoms ranging from C_4 to C_{24}, but mainly C_{16} and C_{18}.



palmitic acid
- a *saturated* fatty acid



oleic acid
- an *unsaturated* fatty acid

142. The three fatty acid molecules combined with glycerol may or may not be identical.

143. Hydrolysis of fats and oils will always produce 3 moles of fatty acids to 1 of glycerol.