THE BRITISH SCHOOL OF KUWAIT

Organic Chemistry

The total number of compounds known to man is just over 5 million. Of these, about 4.5 million contain carbon! Carbon forms more compounds than all the other elements put together.

Organic chemistry is the study of the chemistry of covalently bonded **carbon compounds** (excluding carbon as an element, the carbonates, carbon dioxide & carbon monoxide).

The reason why carbon is such a very special element, being able to form a huge number of different compounds is because of its ability to: -
a) Bond to four other atoms
b) Join up to form chains and rings.

Long-chained carbon compounds are found in all living organisms, both animals and plants, and because most of the molecules within our bodies contain carbon, we are known as carbon based life forms. For example, a haemoglobin molecule, found in red blood cells, contains a chain of 5000 carbon atoms.

A major source of carbon for chains is atmospheric carbon dioxide. During **photosynthesis**, plants use the sun's energy to combine carbon dioxide and water and make glucose. The glucose molecules are then joined together to make long-chained carbohydrates such as starch or cellulose.
When animals eat plants the carbohydrate chains are used by the animal to make new cells and tissues such as muscle.
When plants and animals die, their remains slowly decay either releasing the carbon back into the atmosphere or, under certain conditions, forming oil and coal.

To help organise the millions of organic compounds, chemists place similar compounds in families called **homologous series'**.

Homologous Series

Compounds in a homologous series have the following properties: -
1. They have the same general formula
2. They undergo the same chemical reactions
3. They have the same functional group
4. Their physical properties gradually change as you go down a series (increase the number of carbon atoms)

Each different homologous series is given is own name. For IGCSE you need to know about six homologous series'
a) Alkanes
b) Alkenes
c) Haloalkanes
d) Alcohols
e) Carboxylic acids
f) Esters

Formulae in organic chemistry

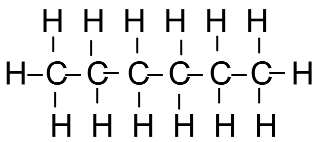
Chemists generally use 3 different types of formulae

- Empirical formula – The simplest ratio formula of a substance
- Molecular formula – The true formula showing the exact number of atoms in the substance.
- Structural formula – The formula that shows how the atoms are joined together in the substance.

For example, hexane has the following formulae

a) Empirical formula = C_3H_7 (C : H are in a 3 : 7 ratio)

b) Molecular formula = C_6H_{14}

c) Structural formula = 

Functional groups

A functional group is any atom or group of atoms that when substituted into an alkane molecule changes its chemistry. (The double bond is also a functional group)

Homologous series	**Functional group**
Alkanes	none
Alkenes	C=C
Haloalkanes	-X (where X = any halogen atom)
Alcohols	-OH
Carboxylic acids	-COOH $-\overset{O}{\overset{\Vert}{C}}-OH$
Esters	-OCO- $-\overset{O}{\overset{\Vert}{C}}-O-$

Basic Nomenclature

Nomenclature means, the naming of compounds

Organic compounds are named using a number of simple rules.

Rule 1: - The root of the name of a compound depends on the number of carbon atoms in the chain.

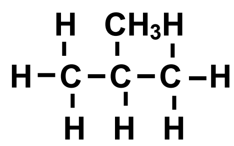
Rule 2: - The ending of the name normally depends on the type of homologous series

No of C's	Root	Alkanes (-ane)	Alkenes (-ene)	Alcohols (-anol)	Carboxylic acids (-anoic acid)
1	Meth-	Methane	—	Methanol	Methanoic acid
2	Eth-	Ethane	Ethene	Ethanol	Ethanoic acid
3	Prop-	Propane	Propene	Propanol	Propanoic acid
4	But-	Butane	Butene	Butanol	Butanoic acid
5	Pent-	Pentane	Pentene	Pentanol	Pentanoic acid
6	Hex-	Hexane	Hexene	Hexanol	Hexanoic acid
7	Hept-	Heptane	Heptene	Heptanol	Heptanoic acid
8	Oct-	Octane	Octene	Octanol	Octanoic acid
9	Non-	Nonane	Nonene	Nonanol	Nonanoic acid
10	Dec-	Decane	Decene	Decanol	Decanoic acid

As well as the carbon atoms in the main chain, carbons can be placed in the middle of the chain to form branched molecules. The branches (called alkyls) on a molecule generally only contain 1 or 2 carbons.

Rule 3: - Hydrocarbon branches are named by placing –yl after the root name.

No of C's in the branch	Root	Alkyls (-yl)
1	Meth-	Methyl
2	Eth-	Ethyl

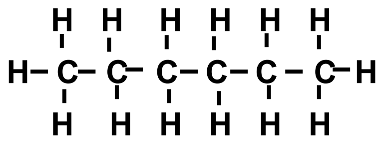
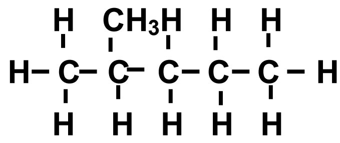
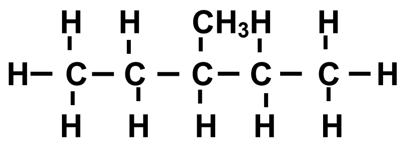
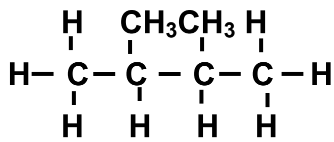
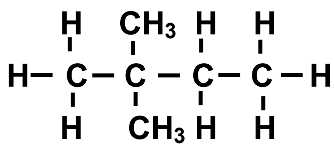


Methylpropane

Isomerism

Isomers are molecules that have the same molecular formula, but different structural formulae. All organic molecules with 4 or more carbon atoms have isomers.

For example, molecules whose molecular formula is C_6H_{14} have the following isomers: -

 Hexane	 2-Methylpentane
 3-Methylpentane	 2,3-Dimethylbutane
 2,2-Dimethylbutane	

ALKANES - C_nH_{2n+2}

The alkanes is a family of **saturated hydrocarbons**, this means that they are compounds made of carbon and hydrogen only, and that all the covalent bonds are single bonds.

Petroleum (also called crude oil) is composed almost entirely of alkanes, and substances such as petrol, kerosene and bitumen are alkanes.

General properties of alkanes

1. Very unreactive molecules (apart from combustion and reaction with halogens)
2. Flammable, burning with a yellow orange flame (they make good fuels)
3. Immiscible with water (oil and water don't mix)
4. Smell like petrol

The reactions of alkanes

- **Burning with oxygen**

Type: - Combustion
Reagent: - Oxygen gas
Conditions: - Room temperature and pressure, source of ignition
Products: - Carbon dioxide + water (complete combustion)

General word equation – Alkane + Oxygen → Carbon dioxide + water

Example: - Ethane + oxygen → Carbon dioxide + water

$$C_2H_{6(g)} + 3\frac{1}{2}O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$

As well as complete combustion, alkanes will burn in a limited supply of oxygen by incomplete combustion, in which the products are carbon monoxide and water.

Incomplete combustion - $C_2H_{6(g)} + 2\frac{1}{2}O_{2(g)} \rightarrow 2CO_{(g)} + 3H_2O_{(l)}$

N.B. Combustion is always exothermic

- **With halogen**

Type: - Photochemical substitution reaction (Halogenation)
Reagent: - Chlorine gas or bromine liquid
Conditions: - Room temperature and pressure, sunlight
Products: - Haloalkane + Hydrogen halide

General word equation – Alkane + Halogen → Haloalkane + Hydrogen halide

Example: - Methane + Chlorine → Chloromethane + Hydrogen chloride

$$CH_{4(g)} + Cl_{2(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)}$$

A substitution reaction is one in which an atom from the reagent replaces one from the main molecule. In this case a chlorine atom from the chlorine molecule replaces a hydrogen atom from the methane.

The uses of alkanes

Alkanes are used as: - Fuels, waxes, lubricating oils, surface of roads and in the manufacture of alkenes.

<u>ALKENES</u> - C_nH_{2n}

The alkenes is a family of **unsaturated hydrocarbons**, this means that they are compounds made of carbon and hydrogen only, and that they contain at least 1 covalent carbon to carbon double bond.

Alkenes are more reactive than alkanes since they contain a double bond. One of the bonds of the double bond is quite easy to break and this "weakness" in the molecule increases its reactivity.

Alkenes are very useful molecules and many common polymers (plastics) are made from alkene molecules.

General properties of alkenes

1. Reactive molecules
2. Undergo addition reactions
3. Flammable, burning with a slightly sooty yellow orange flame
4. Immiscible with water

The production of alkenes

- **Catalytic cracking**

This is a method of making alkenes and hydrogen by taking long-chained alkanes and breaking them up into smaller pieces.

Type: - Catalytic cracking
Reagent: - none
Conditions: - Aluminium and chromium oxides, 500°C
Products: - Short-chained alkane, alkene and hydrogen

Two reactions will be occurring: -

Reaction one
General word equation – Long-chained Alkane → Short-chained alkane + Alkene

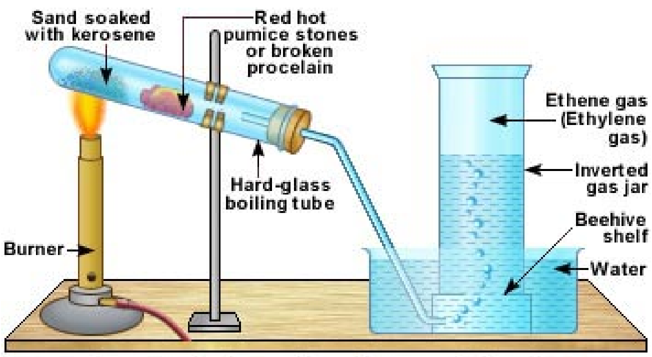
Example: - Dodecane → Decane + Ethene

$$C_{12}H_{26(g)} \rightarrow C_{10}H_{22(g)} + C_2H_4$$

Reaction two
General word equation – Long-chained Alkane → Alkenes + Hydrogen

Example: - Dodecane → Octene + Butene + Hydrogen

$$C_{12}H_{26(g)} \rightarrow C_8H_{16(g)} + C_4H_{8(g)} + H_{2(g)}$$



Apparatus for the cracking of kerosene hydrocarbon to prepare ethene gas.

The reactions of alkenes

- **With hydrogen**

Type: - Addition (Catalytic hydrogenation)
Reagent: - Hydrogen gas
Conditions: - Nickel catalyst, 200°C
Products: - Alkane

General word equation – Alkene + Hydrogen → Alkane

Example: - Ethene + Hydrogen → Ethane

$$CH_2CH_{2(g)} + H_{2(g)} \rightarrow CH_3CH_{3(g)}$$

- **With halogens**

Type: - Addition (Halogenation)
Reagents: - Halogen
Conditions: - Room temperature
Products: - Dihaloalkane

General word equation – Alkene + Halogen → Dihaloalkane

Example: - Ethene + Bromine → 1,2-Dibromoethane

$$CH_2CH_{2(g)} + Br_{2(l)} \rightarrow CH_2BrCH_2Br_{(g)}$$

- **With water (Steam)**

Type: - Addition (Hydrolysis)
Reagents: - Steam
Conditions: - Phosphoric acid catalyst, 300°C, 60atm
Products: - Alcohol

General word equation – Alkene + Steam → Alcohol

Example: - Ethene + Steam → Ethanol

$$CH_2CH_{2(g)} + H_2O_{(g)} \rightarrow CH_3CH_2OH_{(g)}$$

Tests for alkenes (unsaturation)

- **Test for an alkene (1)**

Reagents: - Bromine solution (Bromine water)
Conditions: - Room temperature
Test result: - Decolouration of bromine solution from brown to colourless.

- **Test for an alkene (2)**

Reagents: - Alkaline potassium manganate (VII) solution
Conditions: - Ice cold
Test result: - Colour change from purple to green

ALCOHOLS - $C_nH_{2n+1}OH$

Alcohols are the simplest family of organic molecules to contain an oxygen atom. Economically, ethanol is the most important member of the series being found in alcoholic drinks.

General properties of alcohols

1. Reactive molecules
2. Undergo substitution reactions
3. Flammable, burning with a clear blue flame
4. Soluble in water

The production of ethanol (1 member of the alcohol family).

- **Fermentation**

This is a method of making ethanol by using a microorganism called yeast. The yeast uses sugar for energy during anaerobic respiration (respiration without oxygen)

Type: - Fermentation
Reagents: - Yeast
Conditions: - 37°C
Products: - Ethanol

General word equation – Glucose $\xrightarrow{\text{Yeast}}$ Ethanol + Carbon dioxide

$$C_6H_{12}O_{6(aq)} \xrightarrow{\text{Yeast}} 2CH_3CH_2OH_{(l)} + 2CO_{2(g)}$$

- **Alkene with steam**

See reactions of alkenes for conditions

Example: - Ethene + Steam → Ethanol

$$CH_2CH_{2(g)} + H_2O_{(g)} \rightarrow CH_3CH_2OH_{(g)}$$

The reactions of alcohol

- **Burning with oxygen**

Type: - Combustion
Reagent: - Oxygen gas
Conditions: - Room temperature and pressure, source of ignition
Products: - Carbon dioxide + water (complete combustion)

General word equation – Alcohol + oxygen → Carbon dioxide + water

Example: - Ethanol + oxygen → Carbon dioxide + water

$$C_2H_5OH_{(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$

- **With oxygen from the air without burning**

Type: - Oxidation
Reagent: - Atmospheric oxygen gas
Conditions: - Room temperature and pressure
Products: - Carboxylic acid and water

General word equation – Alcohol + oxygen → Carboxylic acid + water

Example: - Ethanol + oxygen → Ethanoic acid + water

$$CH_3CH_2OH_{(l)} + O_{2(g)} \rightarrow CH_3COOH_{(aq)} + H_2O_{(l)}$$

- **with acidified potassium dichromate (VI) solution**

Type: - Oxidation
Reagents: - Potassium dichromate (VI) solution acidified with dilute sulphuric acid
Conditions: - boil
Products: - Carboxylic acid

General word equation – Alcohol + acidified potassium dichromate (VI) → Carboxylic acid + water

Example: - Ethanol + acidified potassium dichromate (VI) → Ethanoic acid + water

$$CH_3CH_2OH_{(aq)} + 2[O]_{(aq)} \rightarrow CH_3COOH_{(aq)} + H_2O_{(l)}$$

Oxygen from acidified potassium dichromate (VI)

The uses of alcohols

As well as being found in alcoholic drinks, alcohols are used as: - Fuel when added to petrol, antifreeze, solvents, and in the manufacture of vinegar.

CARBOXYLIC ACIDS - $C_nH_{2n+1}COOH$

These are very common organic compounds in nature. The first food you ever had may well have been a type of carboxylic acid called lactic acid, which is found in milk. Ethanoic acid is more commonly called vinegar an everyday ingredient in cooking.
Methanoic acid (also called formic acid) causes the sting in both stinging nettles and ant bites.

General properties of carboxylic acids

1. Reactive molecules
2. Soluble in water
3. Smell like vinegar

The reactions of carboxylic acids

- **with alcohol**

Type: - Esterification
Reagent: - alcohol
Conditions: - A few drops of concentrated sulphuric acid
Products: - Ester and water

General word equation – Alcohol + carboxylic acid → Ester + water

Example: - Ethanol + ethanoic acid → Ethyl ethanoate + water

$$CH_3CH_2OH_{(l)} + CH_3COOH_{(aq)} \rightarrow CH_3CH_2OOCCH_{3(aq)} + H_2O_{(l)}$$

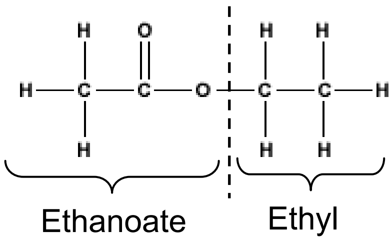
ESTERS

These are sweet smelling molecules that occur naturally and are responsible for the flavours and smells of many fruits and flowers. For example, butyl butanoate is the smell of pineapples.

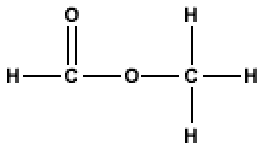
Naming esters

The name of an ester is made up of two parts, an alkyl group and the anion of a carboxylic acid

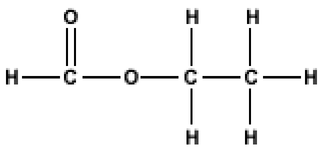
ethyl ethanoate is $CH_3COOCH_2CH_3$



methyl methanoate is $HCOOCH_3$



ethyl methanoate IS $HCOOC_2H_5$



Topic 14.8 Macromolecules

Synthetic polymers

You should be able to –

1. Describe macromolecules in terms of large molecules built up from small units (monomers)
2. Describe different macromolecules as having different units and/or different linkages.
3. Work out the structure of the polymer product from a given alkene and vice versa.
4. Describe the formation of nylon (a polyamide) and *Terylene* (a polyester) by condensation polymerisation.
5. Name some typical uses of plastics and of man-made fibres
6. Describe the pollution problems caused by non-biodegradable plastics

Natural macromolecules

You should be able to –

1. Name proteins, fats and carbohydrates as the main constituents of food.
2. Describe proteins as possessing the same (amide) linkages as nylon but with different units.
3. Describe the hydrolysis of proteins to amino acids.
4. Describe fats as esters possessing the same linkage as Terylene but with different units.
5. Describe complex carbohydrates in terms of a large number of sugar units, joined together by condensation polymerisation.
6. Describe soap as a product of hydrolysis of fats.
7. Describe the acid hydrolysis of complex carbohydrates (e.g. starch) to give simple sugars.
8. Describe the fermentation of simple sugars to produce ethanol (and carbon dioxide).
9. Describe, in outline, the usefulness of chromatography in separating and identifying the product of hydrolysis of carbohydrates and proteins

Introduction

The manufacture of synthetic macromolecules (known as **plastics**) began in 1860. The idea was to find a suitable alternative to ivory, which at the time was the material of choice for pool balls.

However, macromolecules are extremely common in nature, for example in proteins, fats, carbohydrates, and DNA

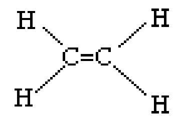
The distinction between ‘natural’ and ‘synthetic’ macromolecules does not exist when we look in detail at these substances. In fact, people who make plastics are often using chemistry that nature perfected millions of years ago.

Synthetic polymers

Two types of synthetic polymers are of interest namely **addition** and **condensation** polymers. These differ in two key ways

- The molecules of which they are made.
- The way in which the molecules join.

Addition polymers

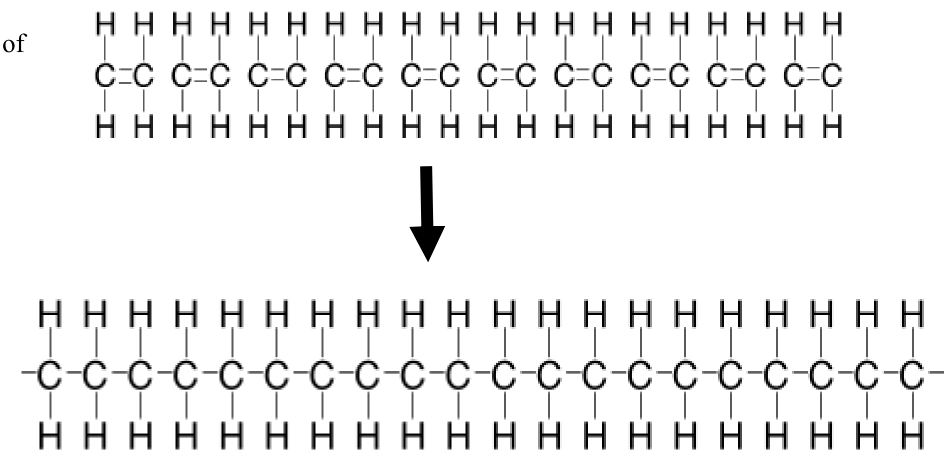


Ethene is an **unsaturated** hydrocarbon with molecular formula C_2H_4 and structural formula

The fact that ethene molecules are unsaturated is the reason for their reactivity. You have already seen how bromine can **add** to ethene making the molecule saturated. The new idea in this topic is that ethene molecules can join to other ethene molecules in almost the same way.

To make a polymer from ethene we need thousands of ethene molecules to make just one polymer chain. High temperatures and pressures are needed and to control the reaction a catalyst is required.

Thousands of ethene molecules

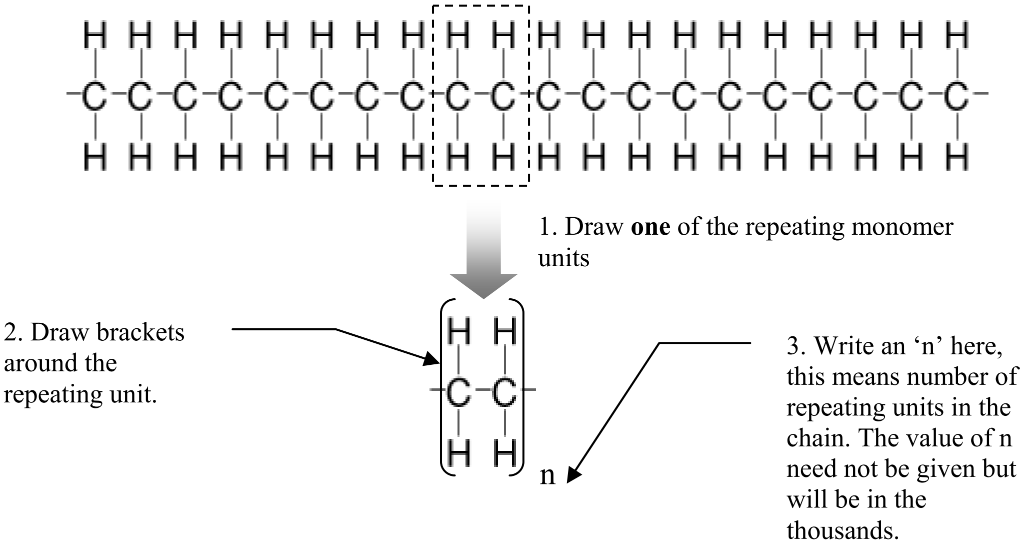


One chain of poly (ethene)

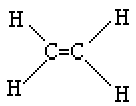
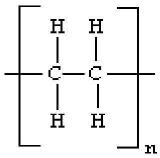
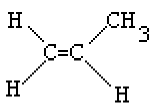
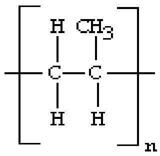
The following point should be noted about the poly (ethene) chain.

- The polymer is **named for the original monomer** (ethene), so although it is now saturated (no double bonds present) it is still called poly (eth**ene**)

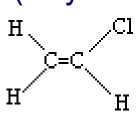
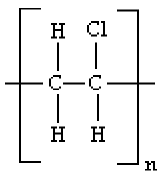
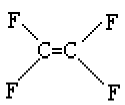
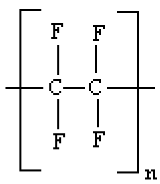
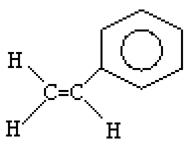
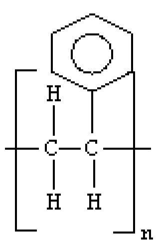
The chain is too long to draw so a shortened formula is used to describe the structure…



This shorthand applies to all addition polymers as can be seen from the table below.

Name	Monomer	Repeating unit in polymer chain	Nature, properties and uses
Polyethene	ethene 		Easy to colour, mould and roll into thin films, good insulator, chemically inert. Used for household articles and packaging
Polypropene	propene 		Stronger, less dense than polyethene. Used for making wrapping films, ropes, plastic pipework.

Polymers are not limited to simple hydrocarbons other common polymers include…

Polychloro-ethene (PVC)	chloroethene (vinyl chloride) 		Very tough, easy to colour, chemically inert, good insulator. Used for electrical insulation, upholstery, floor coverings etc.
Polytetra-fluoroethene (PTFE) (Teflon)	tetrafluoroethene 		Very hard, heat resistant, chemically inert, has anti-stick properties. Used for plastic seals, bearings and non-stick coatings.
Polyphenyl-ethene (Polystyrene)	phenylethene (styrene) 		Low density, good insulator. Used for lightweight packaging. Expanded to form polystyrene foams.

You should be able to draw the shorthand formula of a given polymer chain and draw a polymer chain from a given shorthand formula.

You need to know the names and uses of some common polymers,
learn the uses and names in the table.

Because addition polymers are made of lots of the same monomer unit they are called **homopolymers** (homo meaning ‘one’)

Other polymers are more complicated being made of two different monomers and as such are called **copolymers**.

Condensation polymers

As the name suggests these are not formed by a simple addition reaction as seen with poly (ethene).

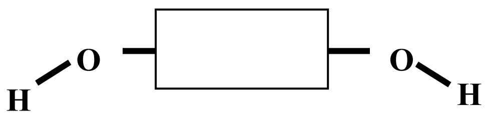
Condensation polymers are examples of **copolymers** because they are made of two different repeating monomer units.

There are two kinds of condensation polymers of interest to us these are
1. Polyesters
2. Polyamides

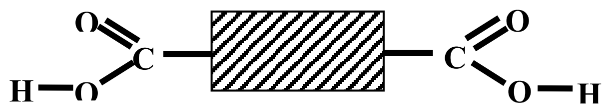
They differ from each other in two important ways namely
1. The types of monomer
2. The types of **linkage**

Polyesters

The two kinds of monomer required to make a polyester are…

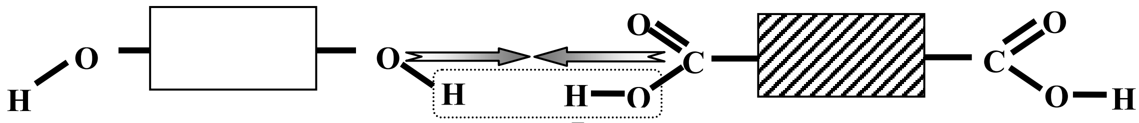


A diol, a molecule with two alcohol groups.

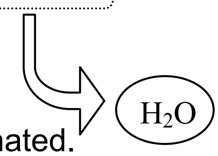


A dicarboxylic acid, a molecule with two carboxylic acids.

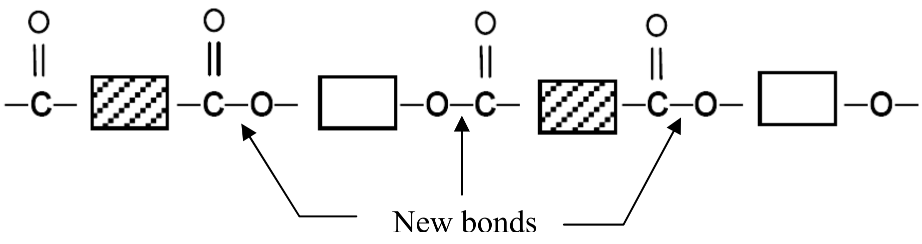
Formation of an ester linkage

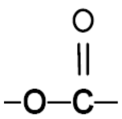


The two monomers approach and a new bond forms between the oxygen and carbon. While this happens a water molecule is eliminated.



Each molecule can join to more monomers forming a chain.





The ester linkage

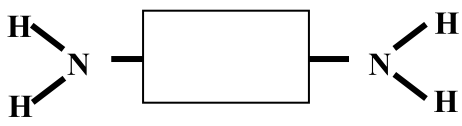
This is the kind of linkage that joins the monomers together in a polyester.

You should be able to identify and draw an ester linkage.

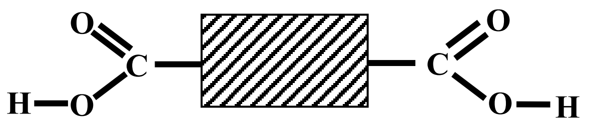
The example of polyesters you need to know is **Terylene**.

Polyamides

The two kinds of monomer required to make a polyamide are…

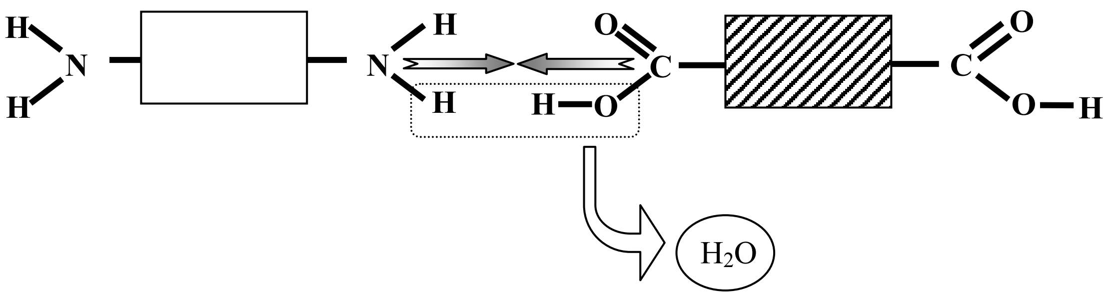


A diamine, a molecule with two amine groups.

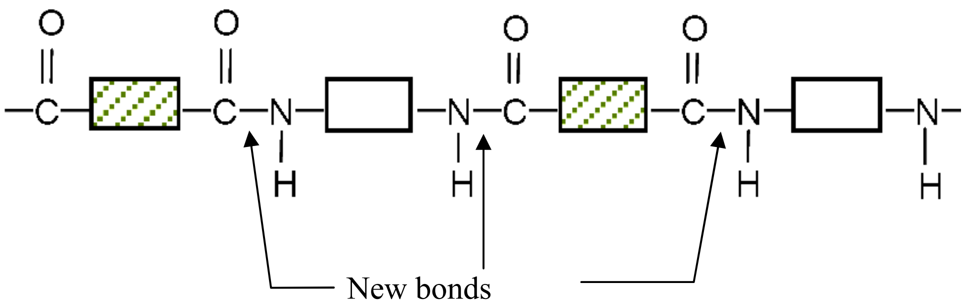


A dicarboxylic acid, a molecule with two carboxylic acids.

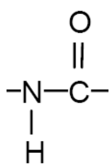
Formation of an amide linkage



The process is almost identical except the new bond is formed between the **nitrogen** and **carbon**.



The amide linkage



This is the kind of linkage that joins the monomers together in a polyamide.

You should be able to identify and draw an amide linkage.

The example of a polyamide you need to know is **Nylon**.

Uses of Nylon and Terylene

Both can be woven into fibres to make clothing and nylon is also used to make precision parts for machines e.g. gear wheels.

Disposal of plastics

Many plastics are chemically inert and have been used because of this property. However whilst this may be useful when the plastic is doing its' job, what about when it is thrown away.

Many plastics are non-biodegradable which means that they are not broken down by the action of bacteria and fungi. This results in huge amounts of waste building up.

The possible options to deal with this problem include

- Burial in a landfill site
- Burning
- Recycling

Burial has the following problems

- Creates and eyesore (looks ugly compared with the natural environment)
- The breakdown takes 100's of years so huge amounts of land is needed.

Burning (pyrolysis) is also not desirable because

- Releases large amounts of toxic substances into the environment e.g. PCB's.

Recycling

Plastics that melt (called thermoplastics) can be collected and made into 'new' products. This has then advantage of reducing pollution and saves crude oil as less has to be made into new plastic.

Natural macromolecules

The major constituents of our diet include

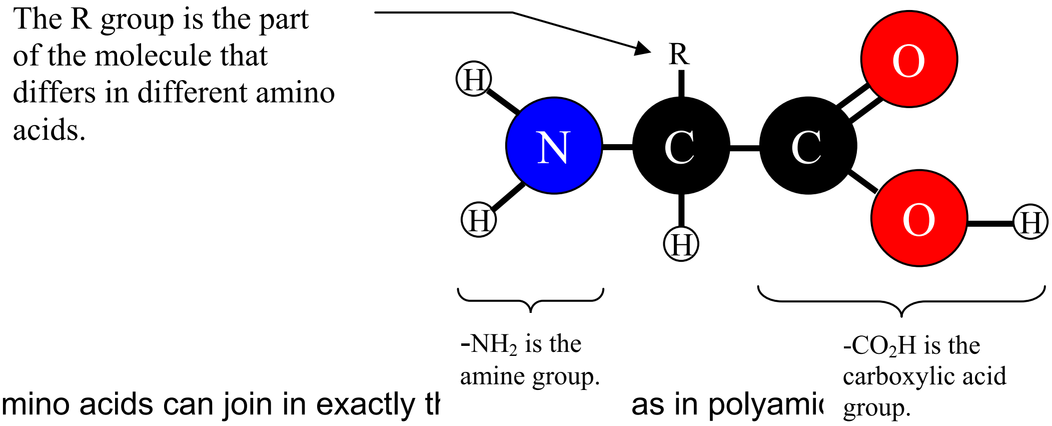
- Proteins
- Carbohydrates
- Lipids

The structures of proteins and lipids have much in common with the condensation polymers we have already seen.

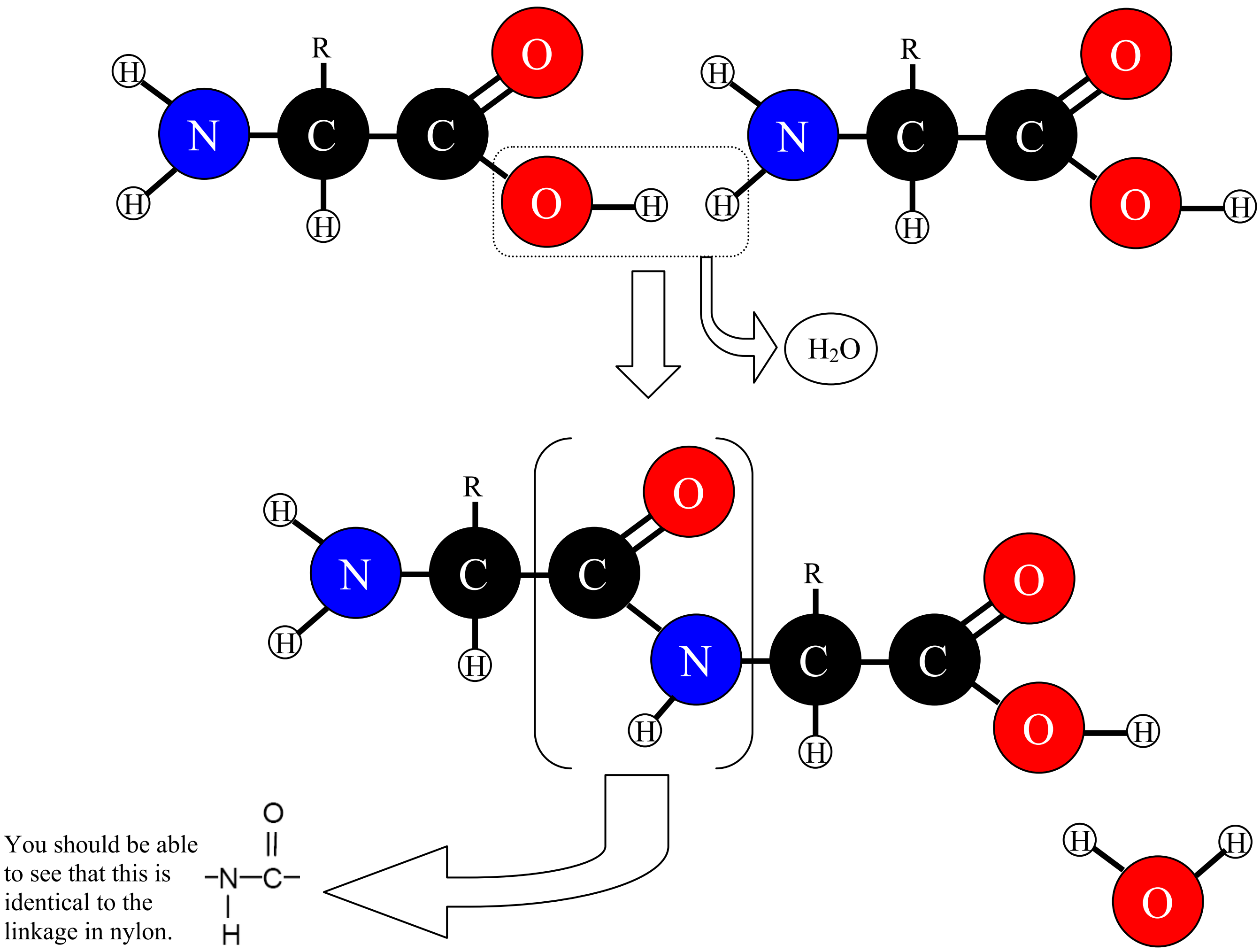
Proteins

Proteins are macromolecules made up from many different amino acids joined together. Only 20 different kinds of amino acids are required to make all of the 1000's of different proteins found in living organisms on earth.

All amino acids share a common structure…



Two amino acids can join in exactly tl … as in polyamic



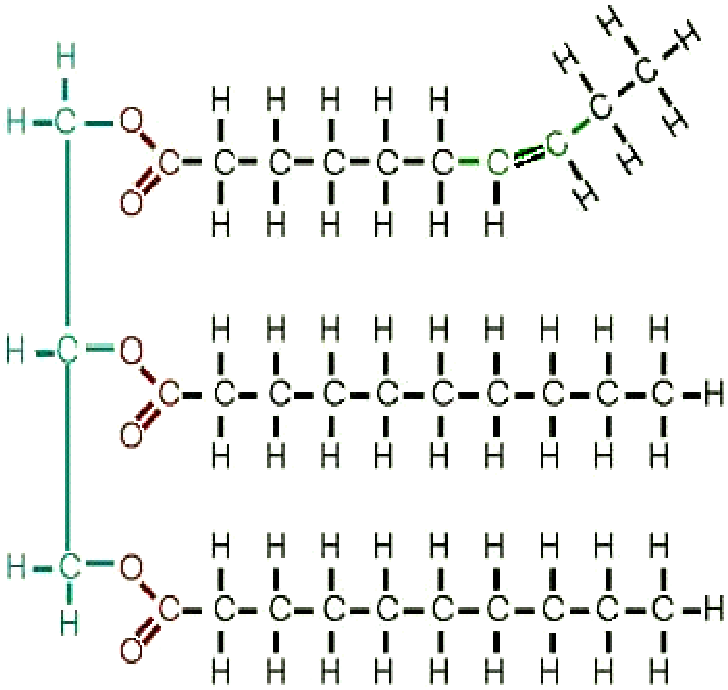
When two amino acids join, the result is a **dipeptide**. Up to 100 amino acids in a chain are a **polypeptide** and more than this is a **protein.**

You should know that the linkages in proteins are identical to polyamides; the difference is the units in each.

Lipids

Fats and oils are known collectively as lipids, fats have melting points above RTP and lipids melt below RTP.

All lipids have the common structure shown below.

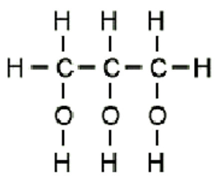


A lipid molecule

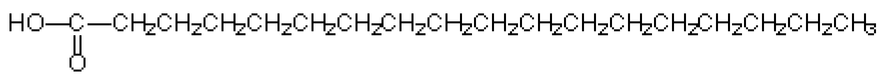
Lipids are composed of a molecule of **glycerol** and three **fatty acid molecules**. The different types of fatty acids give rise to the different types of lipid that exist.
The two main variations are

- Length of the chain e.g. stearic acid has 17 carbons in its chain (and the carboxylic acid carbon) and has the formula $HO_2C(CH_2)_{16}CH_3$

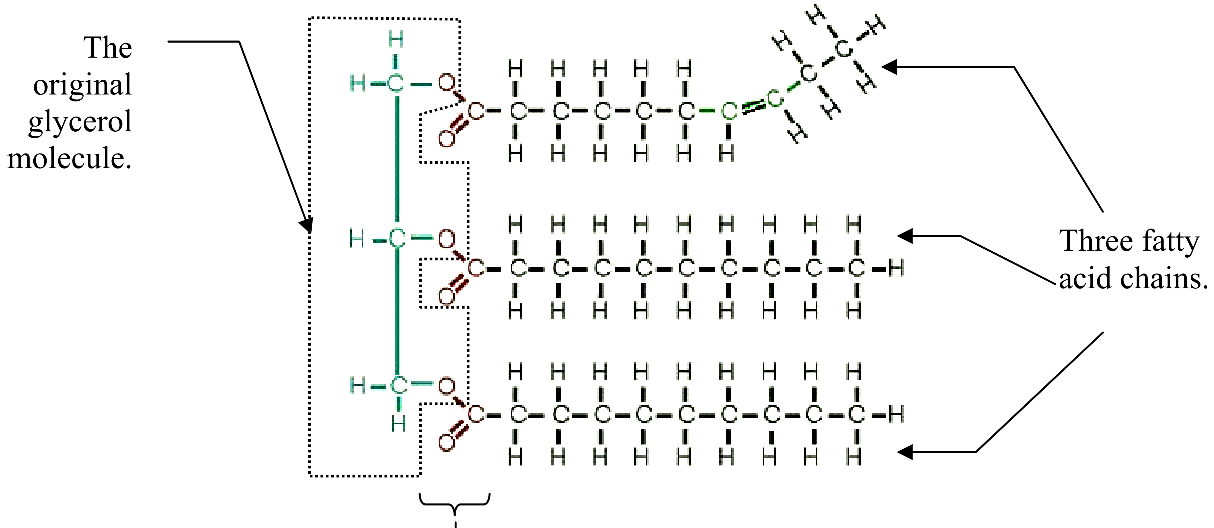
- The existence of double bonds in the chain (see diagram) and their position.

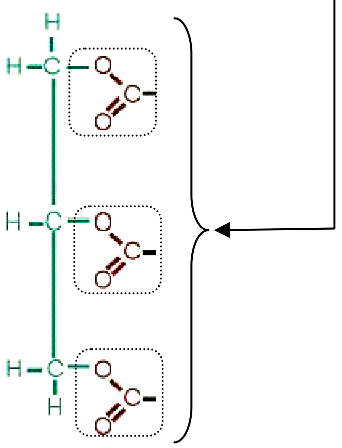


Glycerol



Stearic acid





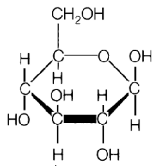
You should be able to see that the linkage between the fatty acid molecules and the glycerol is in fact an **ester linkage** and identical to the one found in polyesters.

You should be able to describe fats as **esters** possessing the same linkage as Terylene but with different units.

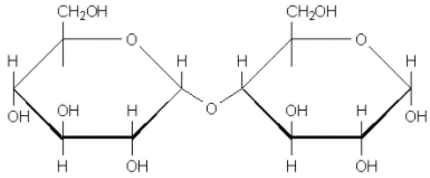
Complex carbohydrates

Carbohydrates are categorised according to the number of units in their structure

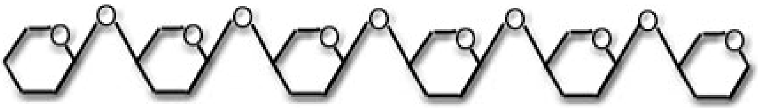
1. Monosaccharides – e.g. glucose
2. Disaccharides e.g. maltose
3. Polysaccharides e.g. cellulose



Glucose

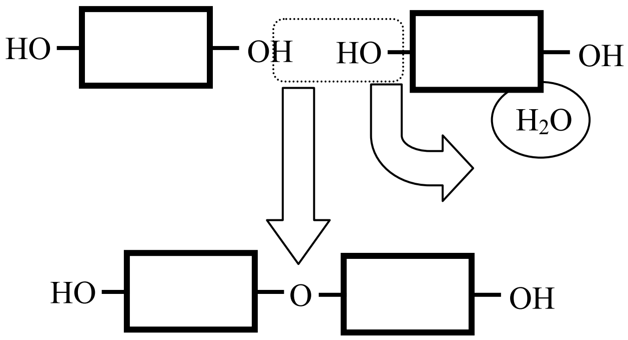


Maltose

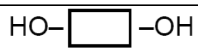


Part of a cellulose molecule

Formation of complex carbohydrates



This is another example of condensation polymerisation. Two monosaccharides join to form a disaccharide and further polymerisations are possible to make polypeptides also known as complex carbohydrates.

You should be able to draw monosaccharides as  and polysaccharides as 

Hydrolysis of macromolecules

Look again at the equations for the formation of the linkages discussed.

2 monosaccharides	⇌	1 disaccharide	+ water
2 amino acids	⇌	1 dipeptide	+ water
Glycerol + 3 fatty acids	⇌	1 lipid molecule	+ water

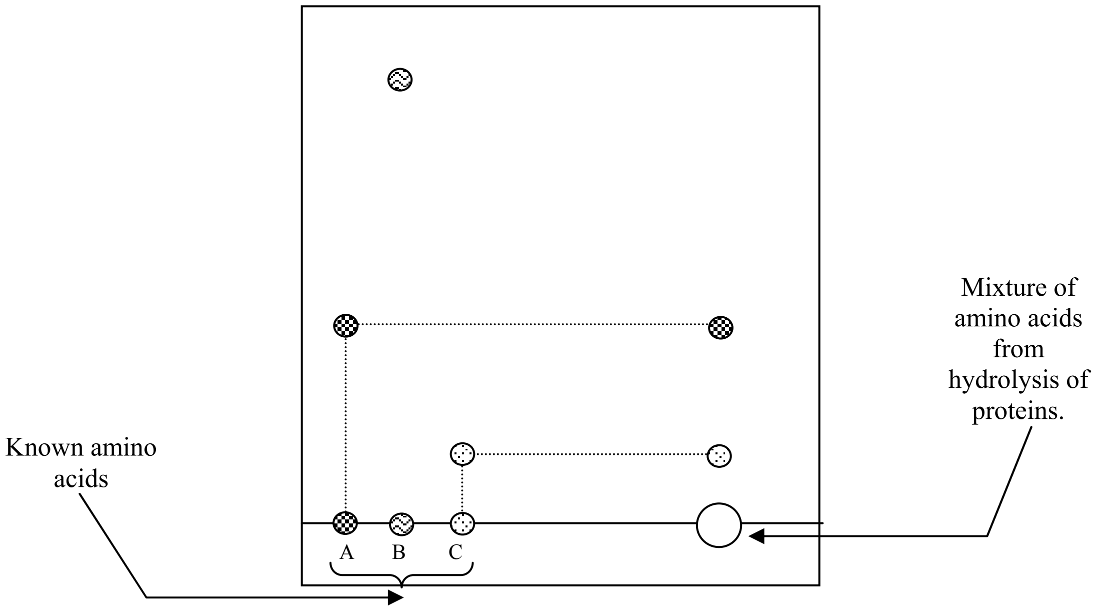
All three of the reactions shown are reversible. Therefore, water can breakdown a disaccharide/ dipeptide or lipid into simpler molecules.

However, the reverse reactions generally require an acid or base catalyst.

Complex carbohydrates and proteins are hydrolysed by heating in acidic solution for example concentrated $HCl_{(aq)}$. While lipids require heating in concentrated alkaline solution such as concentrated $NaOH_{(aq)}$.

Why do we hydrolyse large molecules?

Proteins are made up of many different amino acids and in order to understand their structure we need to know the identities of the amino acids. Hydrolysis of a protein leaves behind a mixture of amino acids.
These can be identified using **chromatography**. However, the amino acids are not coloured so the technique needs to be modified slightly.



The position of the amino acids after chromatography is shown by spraying a **locating agent**. This chemical reacts with the amino acids and changes colour.

The same technique can also be applied to identifying the monosaccharides that make up a complex carbohydrate. The hydrolysis of complex carbohydrates also has an industrial use in the production of sugars for the food industry.

Soap manufacture

The hydrolysis of fats and oils has great economic importance. One of the products of hydrolysis is **soap**. The process of soap manufacture is …

1. Mix fat or oil with concentrated sodium hydroxide solution
2. Heat and mix
3. Add sodium chloride – this is known as 'salting out'
4. Recover soap

The soap is actually the sodium salt of the fatty acids from the lipid. The salting out works by adding a very soluble substance to the mixture forcing the less soluble fatty acid salt to precipitate out.

Fermentation

Yeast is a fungus that has been used for thousands of years to make alcohol. Yeast feeds on sugars and respires anaerobicaly. The products of this anaerobic respiration are ethanol (C_2H_5OH) and carbon dioxide, which the yeast excretes.

$$C_6H_{12}O_{6\,(aq)} \rightarrow CO_{2\,(g)} + C_2H_5OH_{\,(l)}$$

Glucose → carbon dioxide + ethanol

Key terms	Meaning
Macromolecule	Large molecule
Monomers	A small molecule which can be polymerised to make a polymer; many polymers are joined together to make a polymer.
Linkages	The arrangement of atoms and bonds which hold the monomers in a polymer.
Amide linkage	The arrangement of atoms joining two amino acids together .
Pollution	The modification of the environment by human influence; often resulting in the environment being harmful or unpleasant to life.
Biodegradable	Able to be broken down into simpler substances by the action of decomposers e.g. bacteria
Polymer	A substance made of very large molecules which are made of a large number of repeating units (monomers) joined together.
Nylon	A synthetic polyamide
Polyamide	A polymer made of repeating diamine and dicarboxylic acid units joined together by amide linkages.
Terylene	A synthetic polyester
Polyester	A polymer made of repeating diols and dicarboxylic acid units joined together by ester linkages.
Amino acids	The repeating monomer units in a protein.
Esters linkage	The arrangement of atoms joining a glycerol molecule to a fatty acid.
Hydrolysis	A chemical reaction in which water breaks down a large molecule into smaller molecules.
Carbohydrates	Naturally occurring substances which contain only carbon, hydrogen and oxygen.
Fermentation	The action of yeast on glucose producing carbon dioxide and ethanol under anaerobic conditions.