Organic Chemistry

Introduction

Organic chemistry is the chemistry of carbon compounds, these compounds are numerous with over 5 million different carbon compounds currently identified, which is about 90% of all chemical compounds. But why carbon does carbon create so many compounds when there are over 100 other different elements in the periodic table. It is because carbon is tetravalent meaning it can form four bonds, it can form single double and triple bonds, and it can combine with other carbons to form chains of any length. All this allows carbon to combine with almost every other element on the periodic table.

Organic compounds have some properties in common. They are as follows:

- They all contain carbon and most commonly with hydrogen, oxygen and/or nitrogen.
- They are all covalent compounds and are therefore insoluble in water, low melting and boiling points and do not conduct heat and/or electricity
- They almost all burn

Systematic Nomenclature

With so many organic compounds and often with very small differences between compounds, we have to have a way of naming these compounds so we can easily tell them apart. Systematic nomenclature gives us a way to break down the structure of the organic compound into a clearly defined name. As the name suggests there is a certain way, a system, in which these are written so we must follow a set of rules.

Before we move onto the rules there are a set of prefixes we need to know

Naming Carbon Chains	
Prefix	**No of Carbons**
Meth	1
Eth	2
Prop	3
But	4
Pent	5
Hex	6
Hept	7
Oct	8
Non	9
Dec	10

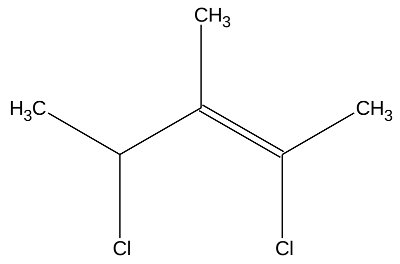
Naming Attached Carbon Groups	
Names of attached Carbon groups	**Formula**
Methyl	CH_3
Ethyl	C_2H_5
Propyl	C_3H_7
Butyl	C_4H_9
Pentyl	C_5H_{11}
Hexyl	C_6H_{13}
Heptyl	C_7H_{15}
Octyl	C_8H_{17}
Nonyl	C_9H_{19}
Decyl	$C_{10}H_{21}$

Prefix given when more than one group is attached of that type	
Prefix for multiple groups	**Number of that attached group**
Di	2
Tri	3
Tetra	4

Naming Other Attached Groups	
Name	**Atom**
Chloro	Cl
Fluoro	F
Bromo	Br
Iodo	I

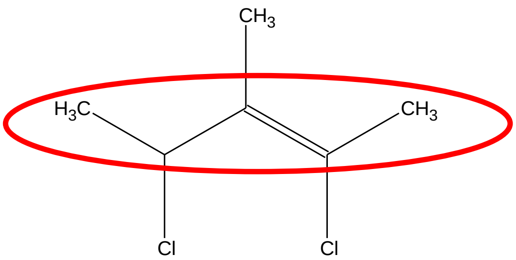
These prefixes are used a lot so it is important to become comfortable with using them.

These rules are set out below and we will be naming the below structure



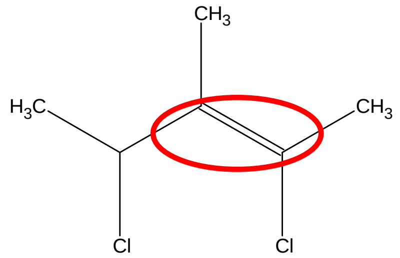
1. Find and name the longest carbon chain.

   In this case it is 5 carbons and therefore starts with **pent**



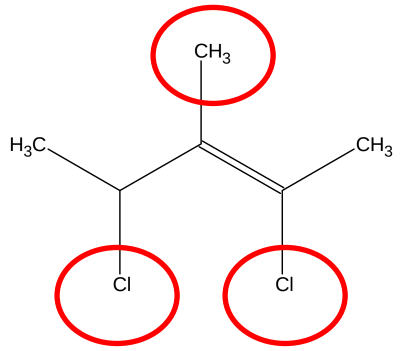
2. Identify, name and state the position of the functional group

In this case there is a double bond so the functional group is an alkene. Therefore this substance is **2-pentene** **OR** **pent-2-ene**



3. Name and number the position of the attached groups.

   In this case there is a methyl group attached to the 3rd carbon and two chloro groups one attached to the 2nd carbon and one to the 4th carbon. Therefore the full name of this substance is **2,4-dichloro 3-methyl 2-pentene** **OR** **2,4-dichloro 3-methyl pent-2-ene**



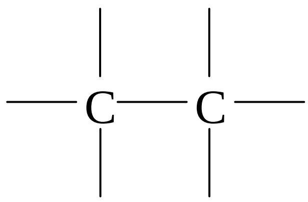
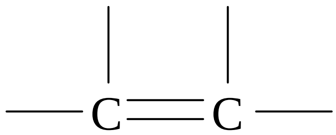
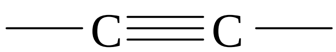
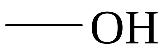
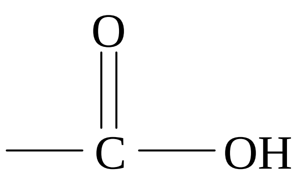
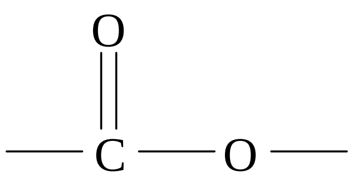
Homologous Series

Organic chemistry is highly organised to make the study of it as easy as possible. There are far too may compounds to study individually, instead they are splint into families of compounds called homologous series.

Homologous series have the same four characteristics
- They have similar chemical properties
- As the chain lengths get larger they increase their melting and boiling points and decrease their solubility.
- Each member in the homologous series differs from the one above and the one below by CH_2
- Each homologous series can be expressed using a general formula (alkanes = C_nH_{2n+2})

Functional Groups

Functional groups are the working or active part of the organic compound, the part which all the chemical properties stem from. A list of the common functional groups is shown below

Functional Group Name	Structure Name	Structure
Alkane	Single bond	
Alkene	Double bond	
Alkyne	Triple bond	
Alcohol	Hydroxy group	
Carboxylic Acid	Carboxy group	
Ester	Carboxylate group	

Alkanes

Alkanes are saturated hydrocarbons meaning that they contain only single bonds and contain only hydrogen and carbon. They seem to be very unreactive, however they are the most important of all organic compounds as they occur naturally in large quantities and chemists use the to make almost all other synthetic organic compounds. They have a general formula of C_nH_{2n+2}.

Physical properties:

- Insoluble in water
- Less dense than water
- Low melting and boiling points

Chemical properties:

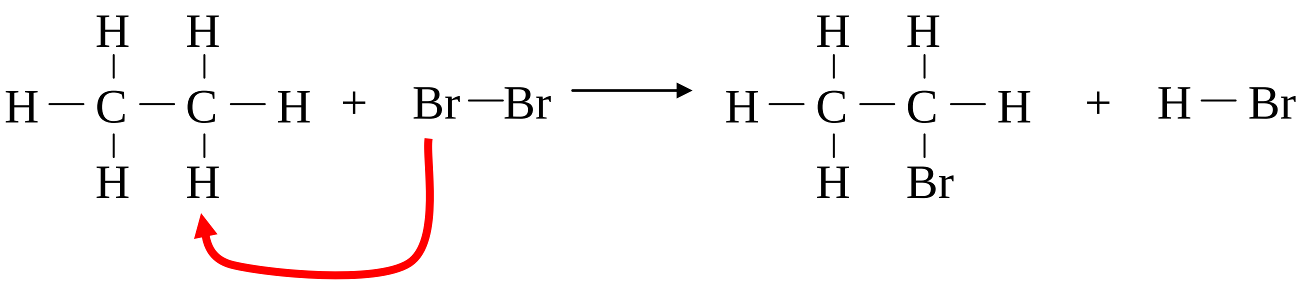
- Do not react with concentrated acid or alkali
- Do not react with strong oxidants
- Do not react with bromine at low temperature

Combustion of alkanes – The most important use of alkanes is their use as fuels.

When we consider combustion we are always talking about complete combustion. This means that the substance burns in excess oxygen, more than it needs. Under these circumstances the fuel will always burn with a clean, blue flame and will produce carbon dioxide and water. Incomplete combustion, where there is not enough oxygen, burns with a dirty, yellow flame and produces carbon monoxide and/or soot (solid carbon) instead of carbon dioxide.

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O + \text{energy}$$

Substitution Reactions - Substitution reactions are where an atom or group of atoms is displaced by another atom or group of atoms, in other words one is swapped for another. Alkanes find this hard to do, but can only undergo substitution reactions as there are no double or triple bonds that they can break.



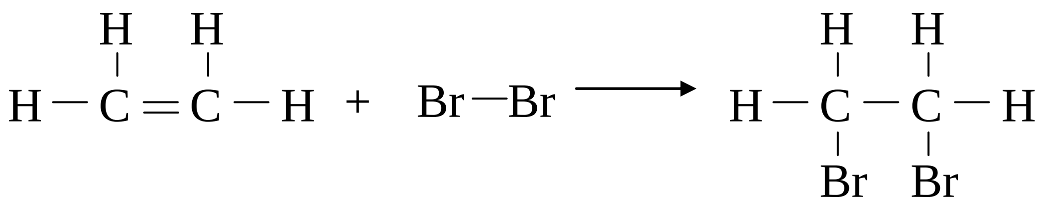
Alkenes

Alkenes are unsatured hydrocarbons because the contain hydrogen and carbon and have a double bond that can be broken. This double bond is the only reactive part of the molecule the rest consists of single bonds and is therefore unreactive. Physical properties include low melting and boiling points, insolubility in water and density lower than water. They have a general formula of C_nH_{2n}

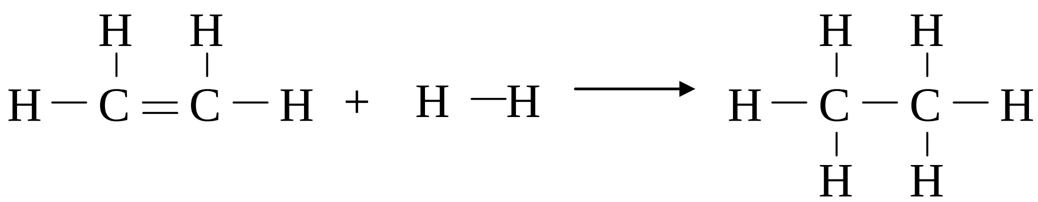
Combustion – Due to the higher carbon to hydrogen ratio and the double bond, alkenes generally burn with a smoky flame due to incomplete combustion.

Addition Reactions – There are many addition reactions that can take place with alkenes due to the double bond that can be broken. These include:

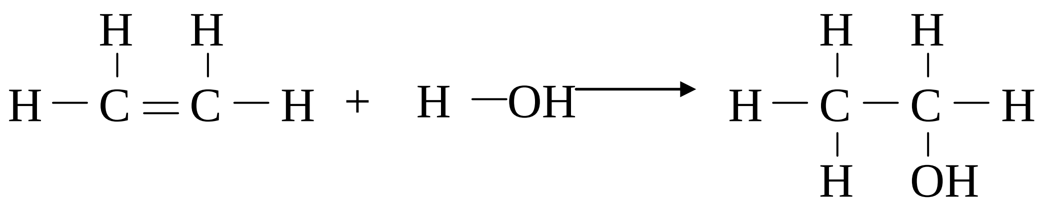
Addition of bromine – Colour change from orange to clear, this is a test for unsaturation.



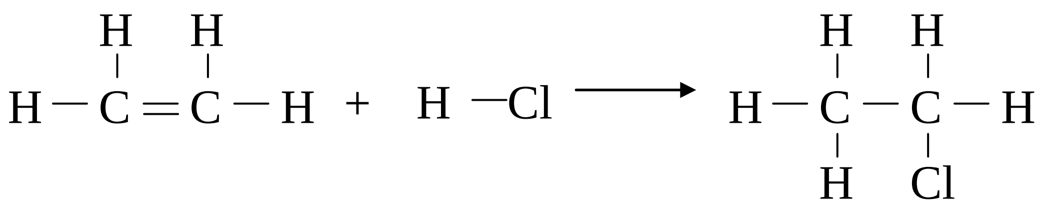
Addition of hydrogen – This is used to turn vegetable oils into margarine and peanut oil into peanut butter. This process is known as hydrogenation.



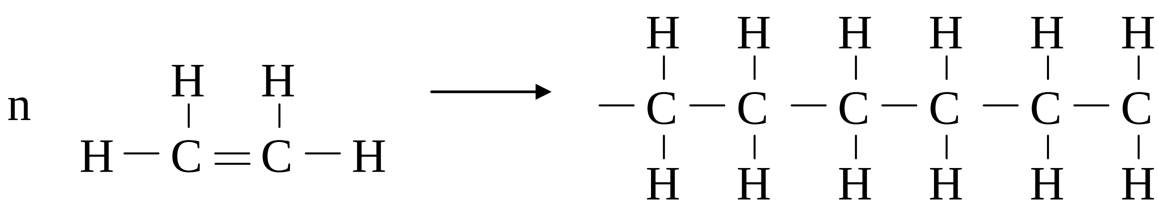
Addition of water – This is one of the major ways of making ethanol which is the alcohol found in methylated spirits



Addition of acids



Polymer Formation – Alkenes can add to each other to form alkanes which form very large molecules called polymers, over 200,000 can join together in one chain.



Alkynes

Alkynes are unsatured hydrocarbons because the contain hydrogen and carbon and have a triple bond that can be broken. This triple bond is the only reactive part of the molecule the rest consists of single bonds and is therefore unreactive. Physical properties include low melting and boiling points, insolubility in water and density lower than water. They have a general formula of C_nH_{2n-2}

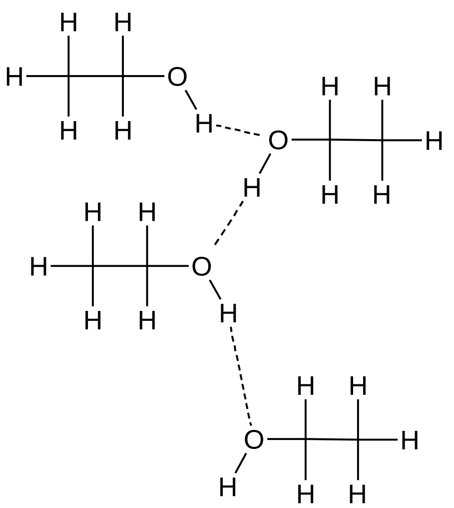
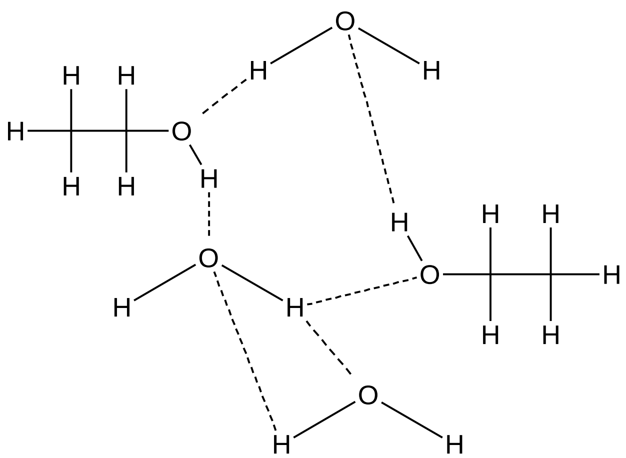
Reactions are very similar to those of alkenes. Of all the alkynes only one is of any significant importance and that is ethyne, also known as acetylene. Acetylene is used extensively in metal working as the flame temperature in oxygen rich environments is about 3000 degrees, this is enough to cut metal with some ease. The other reaction of importance is it's reaction with hydrogen chloride gas to produce vinyl chloride, the monomer of poly vinyl chloride (PVC)

Alcohols

Alcohols are probably the most widely known of all organic compounds to people both with a chemistry and non-chemistry background. Some common alcohols are ethanol (found in beer, wine and spirits), cholesterol (can cause heart problems), glycerol (also known as glycerine, found in cosmetics)

Alcohols have a hydroxy functional group and have a general formula of $C_nH_{2n+1}OH$. The first three alcohols are completely soluble in water after which solubility decreases. The boiling and melting points are higher than that of the corresponding alkanes as there are no gaseous alcohols at room temperature.

The difference in boiling points can be attributed to hydrogen bonding between molecules. Organic substances are on the whole relatively non-polar. However with the addition of functional groups this is disturbed as the functional groups are more than often polar.

Since the charge is not distributed equally there is a slight charge on the ends of these molecules. Therefore there can be an attractive force between these ends and although not a strong bond like ionic or covalent bonds, it is enough to hold together at room temperature. These hydrogen bonds are also the reason for their solubility in water.

Alcohols burn with a clean blue flame to give carbon dioxide and water.

$$C_2H_5OH \quad + \quad 3O_2 \longrightarrow 2CO_2 \quad + \quad 3H_2O$$

Alcohols can be oxidised relatively easily to carboxylic acids. The belief that really old wine tastes like vinegar is true, because it does in fact turn to vinegar. If the cork is damaged and it allows air to enter, oxygen mixes with the ethanol in the wine by the following equation

$$C_2H_5OH \quad + \quad O_2 \longrightarrow CH_3COOH \quad + \quad H_2O$$

Alcohols can also be oxidised by warming them with acidified potassium dichromate, the expected colour change should be from orange to green, again the product would be the corresponding carboxylic acid.

$$C_2H_5OH \longrightarrow CH_3COOH$$

Ethanol is the most important member of the alcohols. It is not only used as a beverage, industrially it is very important as a solvent. Methylated spirits is 95% alcohol with a poison added for the remaining 5%. This makes it undrinkable and therefore cheaper as it avoids the government tax. There are two methods of making ethanol fermentation and addition reactions.

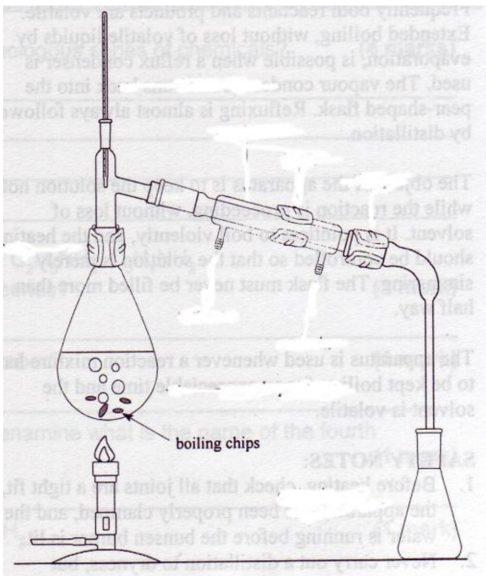
Fermentation accounts for about 80% of ethanol production and is used mainly for alcoholic beverages, fermentation of different base products, barley, potatoes, grapes, all give different alcohols. Fermentation is the production of ethanol from sugars using yeast as an enzyme.

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH \quad + \quad 2CO_2$$

Fermentation works best in environments with no oxygen (anaerobic conditions) and in temperatures less than 30 degrees. Fermentation will not create alcohol of a greater concentration than about 14%. After this they die and are packed into vegemite jars.

However almost all spirits are greater than 14% alcohol, typically they are about 40% alcohol. Excess water is removed by a process called fractional distillation. This process relies on the differences in boiling points between ethanol (78 degrees) and water (100 degrees). By carefully heating the ethanol-water mixture, the ethanol will be boiled off, cooled down and collected whilst the water will be left in the container therefore producing ethanol of up to 99%. To this water is added to dilute it to the required alcohol content.

.



The other way to produce ethanol is by addition of water to alkenes. This is the process used to make solvents and accounts for 20% of all ethanol production. The addition reaction for this process is found above in the alkenes section

Carboxylic Acids

Carboxylic acids are the name given to all organic acids. They have a carboxy functional group and have a general formula of $C_nH_{2n+1}COOH$. They are very common in nature, responsible for the sour taste in unripe fruit, and the taste of ripe lemons. Physical properties include a sharp taste and characteristic odour. The first 4 are infinitely soluble in water and solubility decreases after this.

Chemical properties

- They are weak monoprotic acids. This means that they donate only one proton (H^+) ion, and they ionise only partially in water. At room temperature only 4 out of every 1000 molecules ionise.

$$CH_3COOH \dashrightarrow CH_3COO^-_{(aq)} + H^+_{(aq)}$$

- They change the colour of indicators
- They neutralise bases
- The are weak electrolytes. Due to partial ionisation they will conduct an electrical current, however they will not conduct much

Esters

May of the fruity odours and flavourings found naturally and as artificial flavourings are esters, banana, peach, apricot and pears are a few examples, fats and oils also are esters. Without esters our food would lack most of its flavour.

Esters are made by a process called esterification. This process involves heating an acid and an alcohol in the presence of a strong acid such as sulfuric acid. Both heating and acid are needed to speed up the reaction as it is very slow at room temperature.

$$CH_3COOH + C_2H_5OH \longrightarrow CH_3COOCH_2CH_3$$

Esterification reactions are also classified as a condensation reaction as water is produced as a result of the reaction

This process can be done by a process called hydrolysis. Hydrolysis is simply when a compound is reacted with water normally in the presence of a catalyst such as an acid or strong base

Polymers

Polymers (meaning many parts) are big molecules made from at least 100 smaller molecules called monomers (meaning one part). They are covalently bonded molecules and because of carbon's tetravalence they are generally organic compounds.

Polymers are literally found every where both naturally and synthetically some examples include:

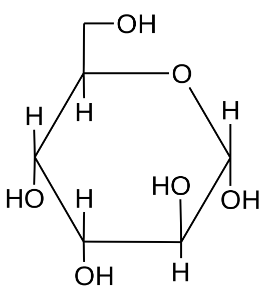
- In the body (hair, skin, muscle, DNA)
- In the Earth (rocks, glass, bricks)
- In our food (carbohydrates and protein)
- In our society (clothing, bank notes, paper, furniture, carpet, toys, shopping bags)

The impact of polymers has been so massive that it is regarded as one of the most important chemical discoveries ever made. Polymers is a name given to a huge range of different compounds, this can be broken down into a range of smaller families.

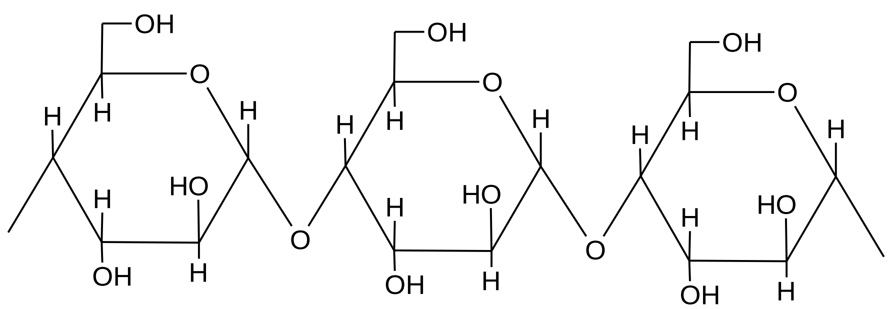
Plastics	– polymers which can be moulded
Elastomers	– polymers which are stretchy, like rubber
Adhesives	– polymers which cement surfaces together by forming more bonds
Fibres	– long thin polymers which can be woven.

Fibres

One of the major uses of polymers is in the clothing industry. All clothes are made from either natural or synthetic fibres, or a combination of both. Natural fibres include such things as wool, cotton, silk. In plants these fibres are derived from cellulose a polymer of glucose. Cellulose accounts for over half of the organic carbon found on the Earth. This compound is the major structural material in plants



Glucose



Cellulose

However not all clothing is made from these natural fibres. Many fibres in clothing have been made by chemists and are therefore called synthetic fibres. These fibres have revolutionised the clothing industry as they are cheaper, more durable and easier to look after. However in hot weather they do not absorb moisture and are therefore less comfortable than natural fibres. Some examples of synthetic fibres include Rayon, nylon and polyesters amongst others.

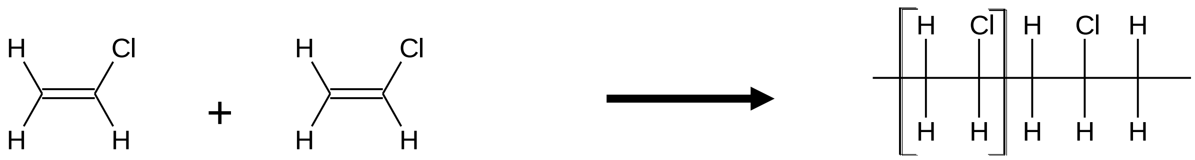
Polymerisation

When small molecules bond to form big molecules this process is known as polymerisation. There are two different chemical ways that this can occur by addition polymerisation and by condensation polymerisation

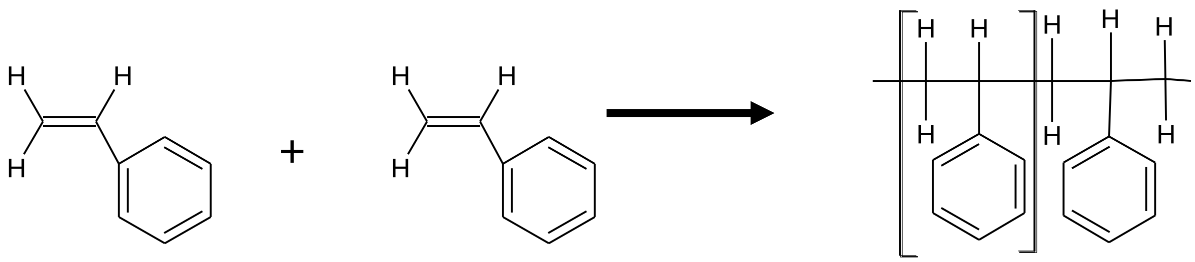
Addition Polymers

Addition polymers are when the monomers, which are generally alkenes, add together to form long chains without the production of another product. Ethene is the most important compound in polymer chemistry as it is used to make polyethylene and the monomers for polyvinyl chloride (PVC) and polystyrene. These three plastics are the most important ones that we have. Polyethene will on average contain a chain length of 150,000 carbon atoms

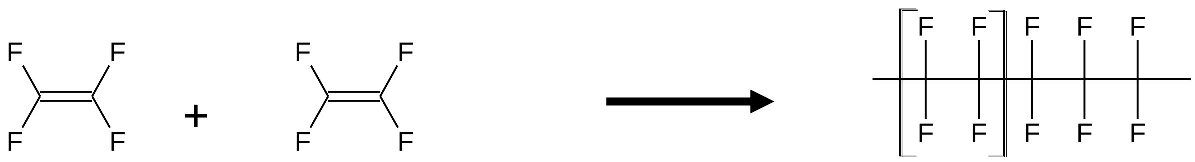
Ethene (ethylene) Polyethene (polyethylene)



Chloroethene (vinyl chloride) Polyvinyl chloride (PVC)



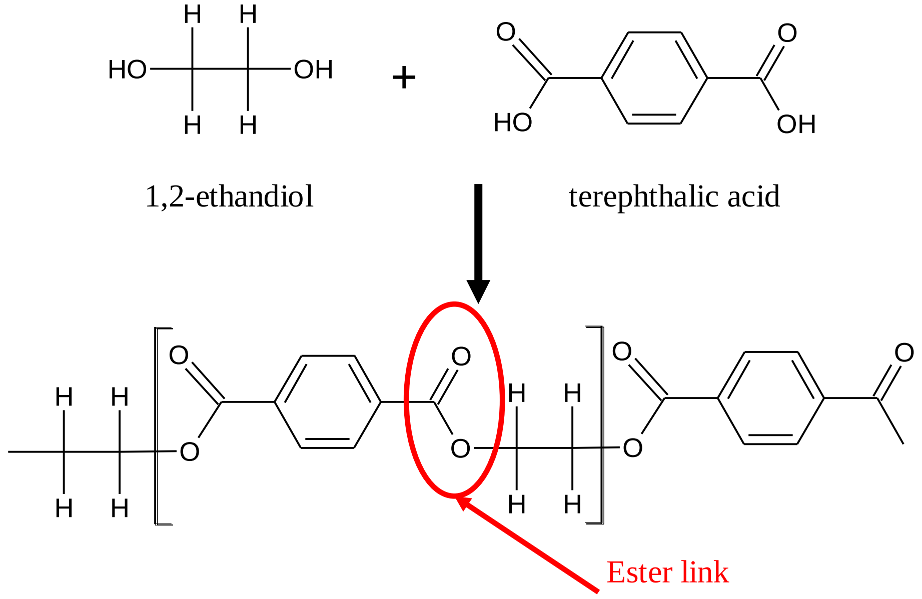
Styrene Polystyrene



Tetrafluoroethene Polytetrafluoroethene (Teflon)

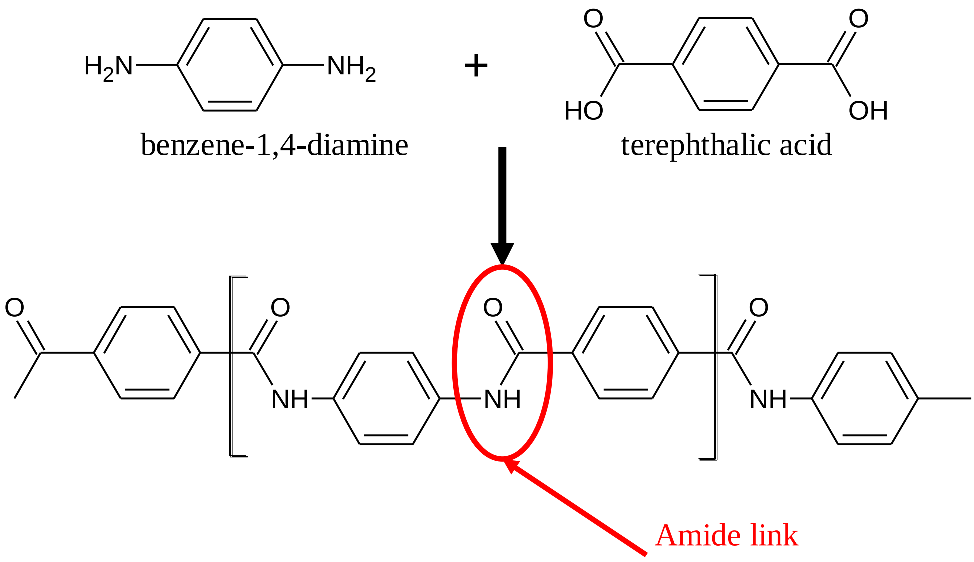
Condensation Polymers

Condensation polymers are where two organic molecules link producing water. There are two types of condensation polymers, polyesters and polyamides. In polyesters an acid group reacts with an alcohol group to form the linking group. Generally one is a diol and the other is a dioic acid, however there can also be the case where there is an acid and alcohol group on the one molecule, this can also form a polymer. They are called polyesters as they have an ester group joining the monomer units.



Terylene

They other type of condensation polymer, polyamides, are formed generally from a dioic acid and a diamine, but it can also be made from an amino acid. The joining group is known as an amide link or in the case of proteins a peptide link.

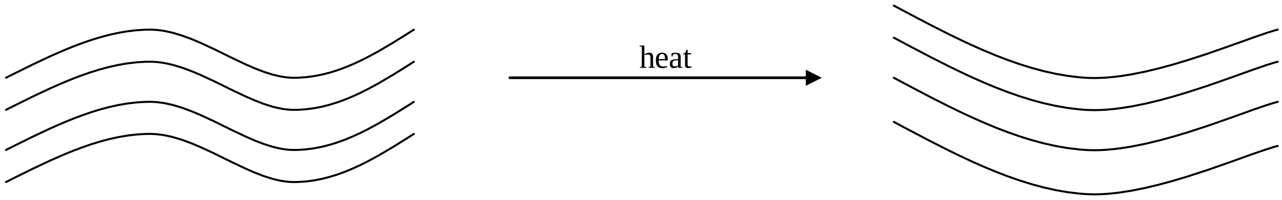


Kevlar

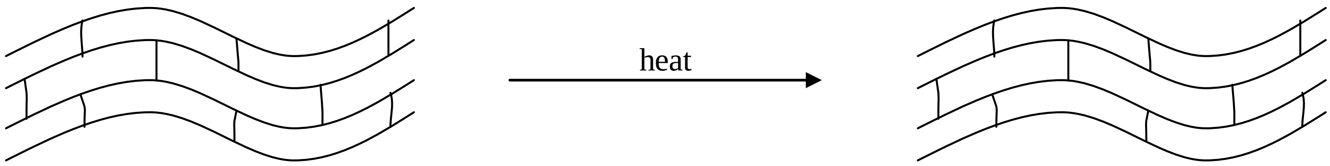
Plastics

Plastics are compounds that can be shaped. They are more and more replacing traditional building materials such as wool, leather, wood and metal. They do not rot like wood, rust like metal or need repainting like both metal and wood. Plastics are classified according to whether they can be reshaped (or remoulded) by using heat. Those that can be reshaped when heat is applied are known as thermoplastics and those that cannot be reshaped are known as thermoset plastics.

Thermoplastics tend to have a low softening temperature and are very versatile. They are not linked to other chains by covalent bonds. When heated the polymer chains are free to move and can take different shapes. Examples include polyethylene, polyvinyl chloride and polystyrene.



Thermoset plastics are generally two pack products, where each part contains a different monomer. In these plastics there are strong cross-linking bonds between polymer chains. Due to these cross-links they do not change shape when heated, instead they can char or burn when heated too strongly. Examples include polyurethane, araldite and bakelite.



Disposal of Plastics

The disposal of plastics is a massive problem as every year more and more plastic is being added to landfill around the world. Being such large molecules they take a very long time to break down in the soil. However there are three ways that the problem can be dealt with. Firstly making more permanent structures, replacing the need to replace the polymers regularly. Secondly is to make biodegradable polymers, ones which can easily be broken down, such as new plastic bags that can be made from corn starch. The third way of dealing with plastics is by recycling.

Recycling codes are stamped onto many common materials made of plastics in order for them to be dealt with. Recyclable plastics are generally thermoplastics as they can be melted down and remoulded into something new. A list of the recycling codes is shown below.

Polymer	Recycling Code	Use
Polyethylene terephthalate	1-PET	Soft drink bottles
High density polyethylene	2-HDPE	Bottles
Polyvinyl chloride	3-V	Floor mats
Low density polyethylene	4-DPE	Grocery bags
Polypropylene	5-PP	Furniture
Polystyrene	6-PS	Molded articles
Mixed plastics	7	Benches, plastic lumber