St Ninian's High School

Chemistry Department

National 5 Chemistry

Unit 3: Chemistry in Society

Plastics

Summary Notes

Name _____

Learning Outcomes

After completing this topic you should be able to :

1	state that plastics and synthetic fibres are made from oil
2	state what is meant by synthetic
3	state that a thermoplastic plastic is one which can be melted or reshaped; and that a thermosetting plastic is one which cannot be reshaped in this way give examples of uses of thermosetting plastics
4	state what is meant by monomer, polymer and polymerisation
5	state that plastics are examples of polymers
6	state that many plastics are made from small unsaturated molecules
7	describe how the small unsaturated molecules join together by the opening of the carbon to carbon double bond
8	state what is meant by addition polymerisation
9	explain that the making of polyalkenes are an example of polymerisation
10	state the name of the addition polymer, given the name of the unsaturated monomer
11	explain using full structural formulae, how ethene forms polythene
12	work out the repeating unit and the monomer structures, given the structure of an addition polymer
13	state that condensation polymers are made from monomers with two functional groups per molecule
14	draw the structure of a condensation polymer given the monomer structures and vice versa
15	identify the repeating unit in condensation polymers
16	state that a small molecule (often water) is produced when a condensation polymer is formed
17	state that polyesters are examples of condensation polymers
18	state that polyesters are formed when diols and dicarboxylic acids react
19	state that starch, cellulose and proteins are natural condensation polymers made by living things
20	state that starch is made when glucose monomers polymerise
21	state what is meant by a smart material.

Plastic and Synthetic Materials

Natural or Synthetic?

Our modern world depends on synthetic materials, they are made by the chemical industry for use in so many ways. Plastics are examples of **synthetic** materials - they are not natural, they are manmade. Most plastics and synthetic fibres are made from chemicals obtained from oil. This means the production of plastics is using up finite resources since oil is limited.

Plastics are everywhere - consider how they have changed the world around us:

Plastic bags instead of paper bags. Plastic bottles instead of glass. Non-stick frying pans with a plastic coating. Bullet proof vests are made of a strong plastic called Kevlar. Plastic pipes rather than metal. Plastic clothes such as polyester or nylon over natural fibres.

cups

bottles

ducks

toys - Lego

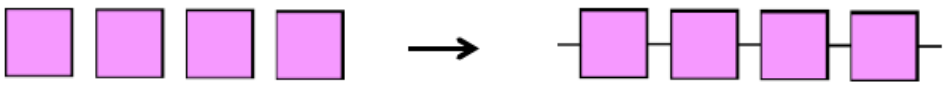
Thermosetting and Thermoplastics

Plastics can be classified according to what happens to them on heating. **Thermoplastics** soften when heated such as Nylon, polystyrene and PVC or poly(vinyl chloride). **Thermosetting** plastics do not soften on heating and keep their shape. Once they have been moulded into a particular shape they cannot be reshaped. They are often very tough materials with high melting points. Urea-methanal, the plastic used in electrical plugs is a thermosetting plastic. Thermosetting plastics are often used in pot handles, oven controls and kettles where they are often exposed to heat. Formica is a thermosetting plastic which can be used for heat resistant surfaces.

Burning plastics is dangerous since incomplete combustion usually occurs which causes carbon monoxide to be released. Plastics containing chlorine burn to produce the acidic gas hydrogen chloride while plastics with nitrogen burn to release hydrogen cyanide.

Making Plastics

The molecules in plastics are made by joining up lots of small molecules called **monomers** ('mono' meaning one or single unit) to make very long chains, often consisting of thousands of atoms linked together. The large molecules which are formed from monomers are called **polymers**. Plastics are examples of polymers. When polymers join together this is called a **polymerisation** reaction.



monomers → polymer

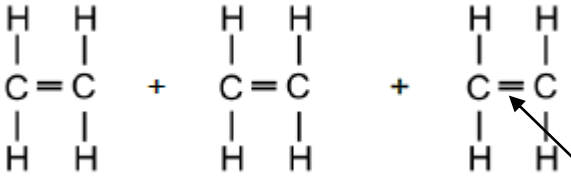
Addition Polymers

Addition Polymers - Structure

Example 1: Poly(ethene)

Poly(ethene) is formed from ethene monomers. When drawing part of an addition polymer structure we show how three monomer molecules join to produce part of the polymer chain as shown below.

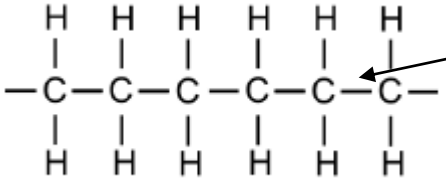
Ethene monomers



Addition polymerisation

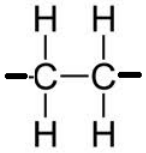
Each carbon to carbon double bond breaks open and the monomers add together.

Poly(ethene) molecule



Addition polymers have a two carbon **repeating unit**. This is based on the two carbons originally formed by the double bond.

The repeating unit in poly(ethene) is:

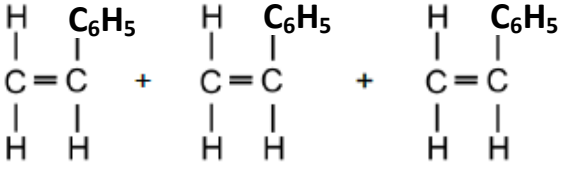


When drawing monomers it is easier to show the molecule in the form of a rugby goalpost.

Example 2: Poly(phenylethene) or Poly(styrene)

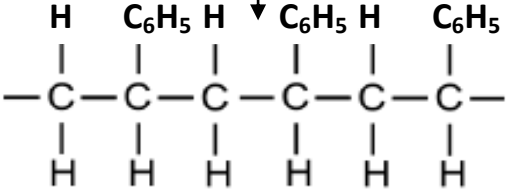
Poly(styrene) is a common addition polymer formed when styrene (or phenylethene) monomers join together as the double carbon to carbon bonds break.

Styrene monomers

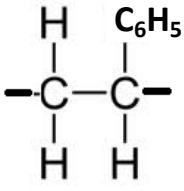


Addition polymerisation

Poly(styrene) molecule



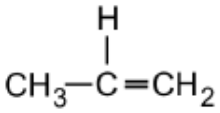
The repeating unit in poly(styrene) is:

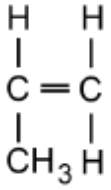


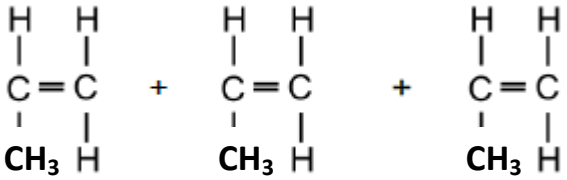
Addition Polymers

Example 3: Poly(propene)

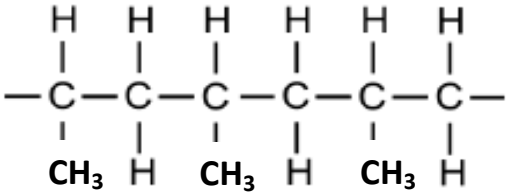
Poly(propene) is a thermoplastic often used in food containers and ropes. In drawing the polymer structure for propene it is easier to show the monomer in the rugby goalpost style.

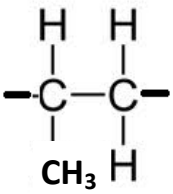
Propene molecule 

or alternatively as a monomer 



Addition polymerisation



repeating unit 

Addition Polymerisation

Many of the monomers are small unsaturated molecules, i.e. small molecules with a carbon to carbon double covalent bond. The monomer molecules join together as the carbon to carbon double bonds open and to give a long chain of carbon to carbon single covalent bonds. Polymers formed in this way are called addition polymers and the process is called addition polymerisation.

Addition polymers are named according to the monomer from which they are made. Some examples are given in the table.

Monomer name	Polymer name
ethene	poly(ethene)
propene	poly(propene)
chloroethene	poly(chloroethene)
tetrafluoroethene	poly(tetrafluoroethene)
phenylethene	poly(phenylethene)

Condensation Polymers

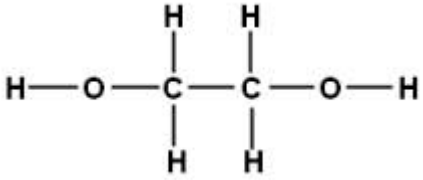
Condensation Polymerisation

In Unit 2 Topic 2 you learned that esters are made by the reaction of alcohols with carboxylic acids.

Alcohol + Carboxylic Acid ⟶ Ester + Water

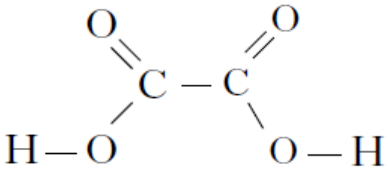
A molecule of water is formed each time an ester is made. This type of reaction is called a **condensation** reaction since water is released. **Polyesters** are formed when the molecules used to make esters have two functional groups at each end of the molecule.

The monomers used to make polyesters are **diols** and **diacids**. A diol is a molecule with two hydroxyl (or alcohol) groups and a diacid contains two carboxyl (or acid) groups as shown below.



diol molecule

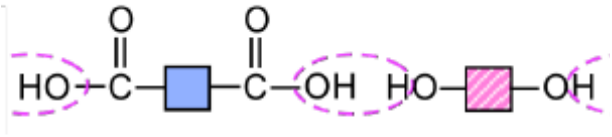
Ethane-1,2-diol



diacid molecule

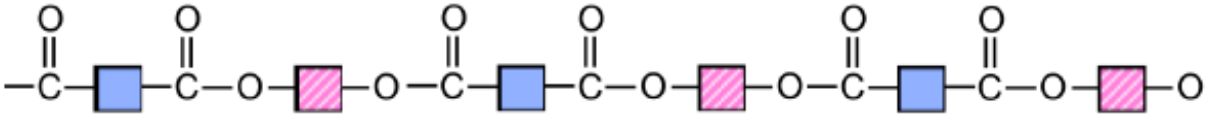
Ethane-1,2-dioic acid

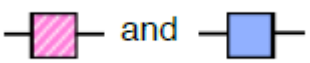
Since each molecule has two functional groups this means that the condensation reactions can occur at both ends of the molecule and so create a long chain condensation polymer molecule.



carboxylic acid **alcohol**

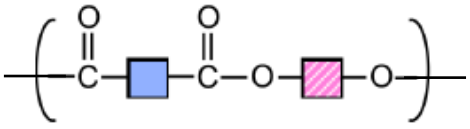
condensation polymerisation





represents different arrangements of carbon and hydrogen atoms.

The repeating unit is based on one molecule from the carboxylic acid and one from the alcohol.



from acid **from alcohol**

Condensation Polymers

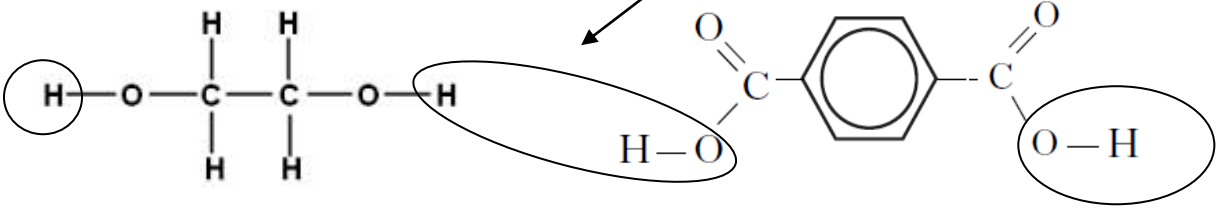
Example: Polyethylene terephthalate or PET

This is the polymer used to make most fizzy drink bottles and it was the first commercially useful polyester to be manufactured. It is made from the monomers ethane-1,2-diol and terephthalic acid.

Soft Drink bottles

A hydrogen atom is lost from the hydroxyl group and an OH group lost from the carboxyl group to produce water (H_2O).

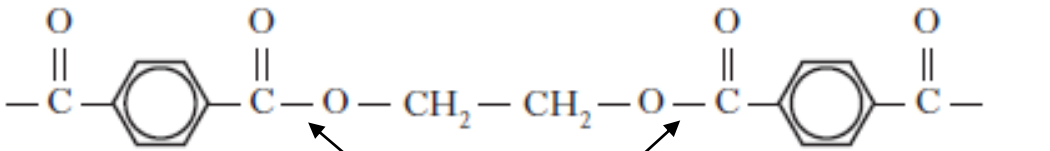
Monomers



ethane-1,2-diol monomer **terephthalic acid monomer**

Condensation polymerisation

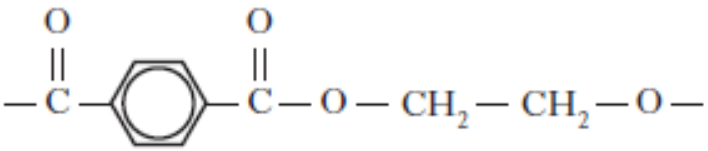
Polymer molecule



+ nH_2O

New ester link bonds formed in the polyester chain.

Repeating unit:



All polyesters are examples of condensation polymers. A condensation polymer can be identified since the backbone of the molecule contains an ester link (COO). Addition polymers can be recognised since they have a carbon backbone structure.

Natural & Unusual Polymers

Natural Polymers

There is only one naturally occurring addition polymer and that is rubber. Rubber is obtained from rubber trees as a white liquid (latex). All other natural polymers are condensation polymers.

The most common natural polymers are a family of compounds called polyamides, examples include silk, wool, hair, proteins and DNA (deoxyribonucleic acid).

Starch (found in bread and potatoes) and cellulose (the main constituent of wood and paper) belong to a set of polymers called polysaccharides. Starch molecules are formed when smaller glucose molecules join together with the loss of water. Most green plants store the glucose produced during photosynthesis as starch.

Unusual Polymers

There are some polymers which have unusual properties. **Kevlar** is a condensation polymer which is very strong. In fact it is 5 times stronger than steel on an equal mass basis. It is lightweight and is used for a variety of applications such as bulletproof vests, bicycle tyres, space suits and racing helmets.

Poly(ethenol) is also a condensation polymer but it is soluble in water and therefore will dissolve when placed in water. Poly(ethenol) is used in hospital laundry bags and laundry or dishwasher tablets. Poly(ethenol) is also used to make surgery stitches; the thread dissolves in water and does not need to be removed.

Poly(ethyne) is an addition polymer made from the monomer ethyne. It has delocalised electrons through the carbon backbone and is therefore able to conduct electricity. Through the carbon backbone there are single and double carbon-to-carbon bonds and the electrons which make up the double bonds are not confined to one place and are able to move along the molecule. Its electrical conductivity compares well with metallic conductors like copper.

Biodegradable plastics are plastics that will rot away naturally by bacteria or other living organisms. Biodegradable plastics are now used in carrier bags or food waste bags. The use of biodegradable plastics is likely to increase as governments try to reduce the amount of waste which ends up in land fill sites.

Novel Materials

Novel materials are materials that don't resemble anything that was previously known or used. Some novel materials are classified as smart materials. **Smart materials** are materials which change shape in response to changes in its environment. Shape memory alloys (SMAs) are mixtures of metals which 'remember' their original shape and when they are heated above a certain temperature they will return to that shape, no matter how much they have been bent or folded. The atoms are arranged in a particular way and at a particular temperature, the structure of the atoms changes therefore changing the shape of the SMAs.

Hydrogels are smart materials which are polymers and are used in daily life since they absorb water. Hydrogels are often found in disposable nappies. Smart polymers have been developed that change colour depending on the temperature. These polymers can be used to indicate temperature.