Natural rubber is made of repeating units. It is obtained from Latex from Trees.

Natural:

monomer polymer

Isoprene
(2-methylbuta-1,3-diene)

poly(isoprene)
natural rubber

(Dienes are alkenes with two double bonds)

In early attempts of producing synthetic rubber, polymerisation of dienes was used but this produced rubber with both a cis and trans isomer mixture. Only cis rubber was preferred because it had a higher boiling point than trans rubber. Better quality of rubber was obtained by polymerising butadiene to produce poly(cis-1,3-butadiene). Rubber of a higher quality is a copolymer, which can be obtained by combining dienes with alkenes.

Synthetic:

monomer polymer

Butadiene poly(cis -1,3-butadiene)

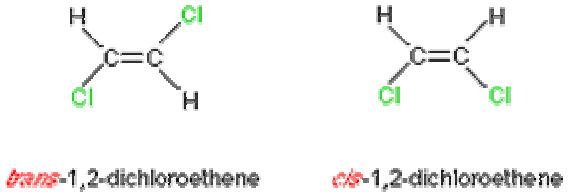
A process called emulsion polymerisation is used to produce a 'natural like' rubber.
In this process different reactants are polymerised in water to produce rubber.

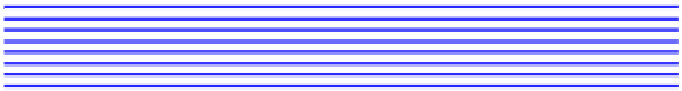
Both Synthetic and Natural rubber are obtained by addition polymerisation.
They both have double bonds in monomers of their isomers.
When the monomers react to produce polymers, they both break two bonds and form one bond. (2)

Synthetic rubber uses emulsion Polymerisation.
Synthetic rubber can be made from various raw materials and reactions.
In synthetic rubber there can be a mixture of cis and trans isomers. (2)

Natural rubbers configuration across the double bond is 98 % cis (both CH2 groups are on the same side of the double bond) and this allows the chain to increase in strength when they are stretched (they form crystalline regions). These are regions where the long chains of monomers line up very close together in straight lines.

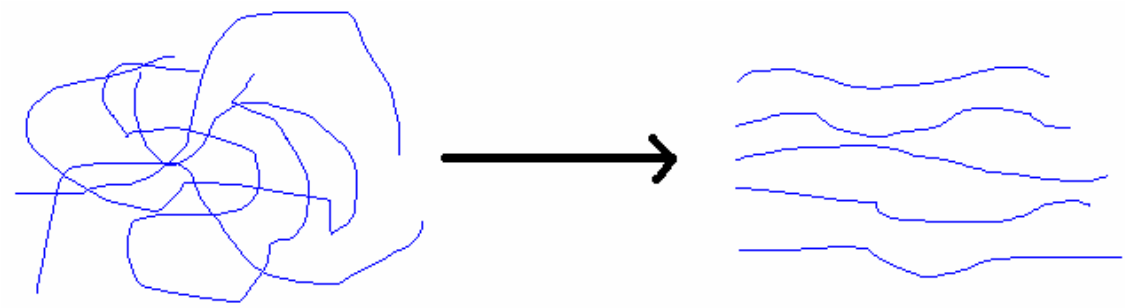
An example of cis and trans isomers (2)





The chain of poly(isoprene) in a crystalline regions (1)

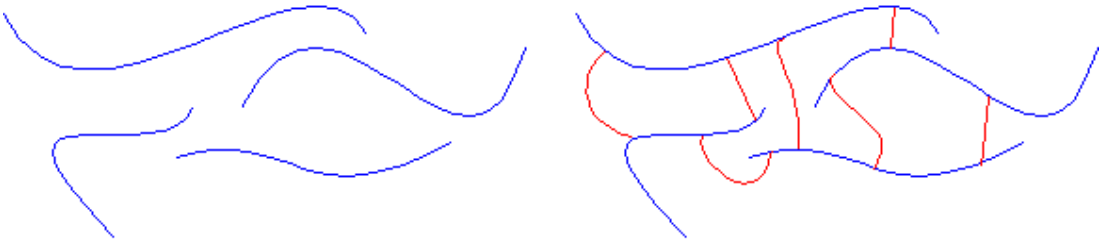
We know that rubber is very stretchy (high resilience). This has to do with entropy(1). We also know that any molecules want to get as high entropy as possible. The same rule applies for rubber. It has high entropy and when stretched the molecules line up in one direction so entropy decreases.



rubber in normal state

rubber stretched

Natural rubber has a property called Thermoplasticity, which tends to make the rubber sticky and soft at high temperatures; while making them brittle and stiff at low temperatures. Charles Goodyear accidentally produced rubber, which lost its property of Thermoplasticity. He heated rubber with sulphur to produce a new version of rubber, which did not flow or become sticky at high temperatures.
This process was named Vulcanisation in which cross-linking occurs. Here sulphur cross-links with the long polymer chains, which makes the rubber stronger.



(1)

Vulcanisation improves the quality of the tyres because of the cross linking in polymer chains. This produces rubber, which is more rigid. These cross-links restrict the movement of the polymer chains so this makes harder and more durable tyres. This property is excellent for tyres as they eventually wear out due to many different forces.

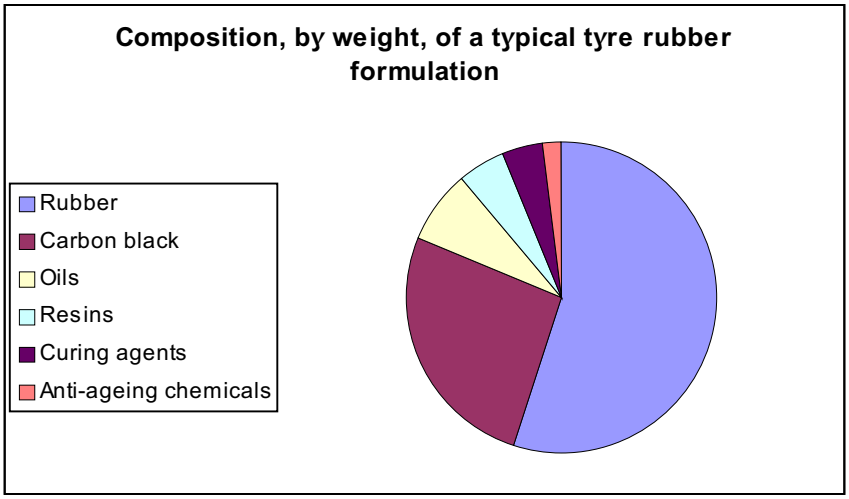


Table 1 in Article 1

The benfits of all the additives:

- Carbon Black strengthens the rubber and aids abrasion resistance.
- Oils are added to make the process to make the tyre easier, to make the tyre more flexible and to lower the cost of the tyre because oil is cheap as a raw material.
- Resins improve the processing characteristics and adhesion of the rubber components during tyre building. They also make the tyre stiff.
- When Carbon Black is added to improve the tyre, the tyre takes too long to cure so curing agents are added to accelerate this process.
- Anti-ageing chemical are added to increase the lifetime of the tyre.
- Synthetic rubbers are added for example Butyl rubber. These also give improving properties to the tyre like good air retention and good heat resistance.

All these additives are added to improve the performance of the tyres.

Recycling the tyres is very difficult because they are very hard. Nearly 2 million tonnes of tyres are scrapped each year within the EU therefore it is a big problem.

Recently tyres used to be buried but this lead to following problems:

1. Damage of the environment
2. Decrease of land availability. This makes the land more expensive.
3. Risk of fire and cause of pollution in the environment.

One possibility to stop the problems is to use the Pyrolysis process. Pyrolysis is the degradation of the rubber in tyres using heat in the absence of oxygen. The tyre breaks down and gives oil and gas. Carbon with its steel casing is left over. Now these four products can be recycled.
The oil produced has similar properties to diesel but not enough to be used as a fuel. The gas contains hydrogen, methane and different hydrocarbons. The carbon, which is left over, can be used again as a low grade Carbon black, fuel, reinforcing agent in new rubber tyres, paint or ink.

Another possibility is to thermally decompose the scrap tyres by using fluidised bed and fixed bed technology. In this process again oils and gases are produced. Carbon is left over. The oil contains alkenes, alkanes and aromatic compounds. All these products can be used as feedstocks.

This oil can be processed to produce oil with benzene. This benzene can either be used as industrial chemical feedstock (raw material for chemical processes) or can be processed further to produce other feedstocks such as cumene, phenol and propanone. Derivatives of benzene are used to produce commercially important products such as plastics and solvents.

Cumene Process

Activated Carbon is obtained from the carbon left over from the pyrolysis. Its properties are that it has a high surface area of over 600 m2 g-1 and it is a good adsorbent. The activated carbon from scrap tyres has sulphur contents, which makes them excellent products to remove mercury (a toxic metal) from waste gases in industrial processes.

Activated carbon is an excellent adsorbent and therefore is used in gas masks as it absorbs large quantities of gases and can therefore also be used to remove polluting gases from the air.

A Gas Mask (5)

Activated Carbon is produced from many feedstocks including some non-renewable sources such as coal and peat. Recycled tyres produce better activated carbon than commercially produced carbons. The recycling of tyres allows non-renewable source to be conserved.

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