ChemFactsheet

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Degradable Polymers

To succeed in this topic you need to understand:

- the formation and structure of addition and condensation polymers
- the reasons why the use and disposal of polymers can be an environmental problem
- the benefits and problems associated with the recycling of polymers

After working through this FactSheet you will be able to:

- explain the meaning of the terms biodegradable and photodegradable
- state which types of polymers are likely to degrade
- explain the advantages and disadvantages of degradable polymers

Why do we need degradable polymers?

One of the biggest issues surrounding the use of plastics is their disposal. Most plastics are disposed of in landfill sites, where they may take many hundreds of years to decompose. As an alternative to landfill, plastic waste can be incinerated. This provides heat energy for offices and shops, but also releases the greenhouse gas, carbon dioxide, and many other pollutants. Degradable polymers have the potential to provide a solution to these problems.

What are degradable polymers?

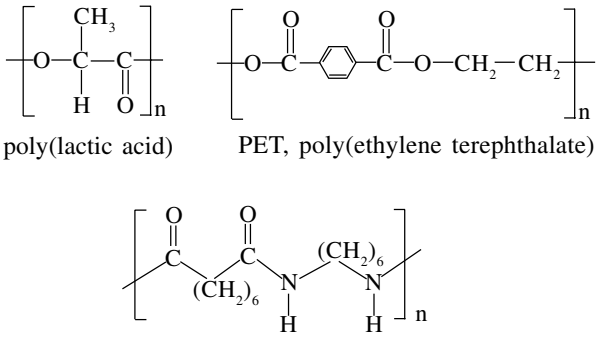
Degradable polymers are used to make plastics which will break down in the environment. There are two main types of degradable polymer: **photodegradable** and **biodegradable**. Both types of degradable polymer can be made either from substances derived from crude oil, or from renewable raw materials like sugar and cellulose.

Photodegradable polymers break down in the presence of sunlight. This can take place because the polymer contains certain bonds which absorb energy and break when exposed to sunlight. Another way of making a plastic photodegrade is to include a chemical additive which absorbs light energy, and then attacks the polymer chains to break them down.

There are two major disadvantages of photodegradable polymers. The first is that it is tricky to control the degradation since as soon as the plastic is exposed to light it will begin to break down, causing problems during its use. The second is that, if buried in a landfill site, it may not receive enough light for degradation to occur. Photodegradable polymers often simply break down into small particles of plastic, rather than fully degrading.

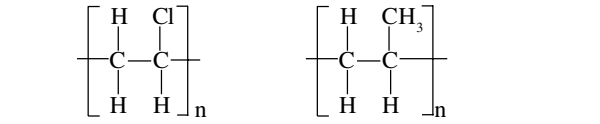
Biodegradable polymers break down through the action of enzymes in bacteria and fungi which can break up the polymer chains. The most biodegradable polymers are the ones which contain polar bonds such as carbon-oxygen or carbon-nitrogen. These bonds may also break through the reaction with water. The polymers most likely to contain these bonds are condensation polymers like polyesters and polyamides (Fig 1).

Fig 1. Condensation polymers – two polyesters and a polyamide



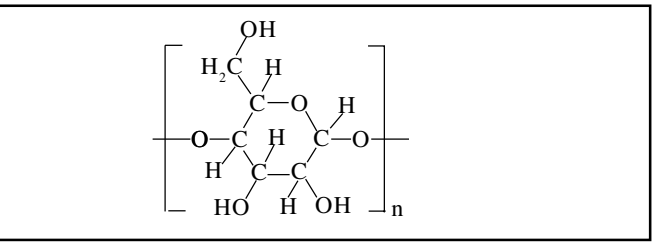
Addition polymers such as poly(ethene) are less likely to be biodegradable because the polymer chains are highly unreactive, with no polar bonds for enzymes to attack (Fig 2).

Fig 2. Two addition polymers



Starch (Fig 3) is a natural polymer which biodegrades readily, due to the carbon-oxygen bonds linking its chains of glucose molecules. Research is being carried out into the use of starch for packaging materials, whether on its own or as an additive to other polymers. When added to other polymers to form plastics, the starch biodegrades leaving fragile pieces of the plastic, which break down more readily.

Fig 3. Repeating unit of a starch polymer



Biodegradation will only take place by the action of micro-organisms if the conditions are right. Once the plastic is buried, there may be insufficient oxygen or insufficient water for biodegradation to take place.

Table 1 summarises the two types of biodegradable polymer.

Table 1: Comparison of photodegradable and biodegradable plastics

	Photodegradable	**Biodegradable**
What causes it to degrade?	Light	Micro-organisms such as bacteria and fungi
How does it degrade?	1. Bonds in polymer absorb light energy and break 2. Additive absorbs light energy and attack the polymer chains	Action of enzymes in micro-organisms
What does it degrade into?	Small plastic particles	Carbon dioxide and water. It may also release methane
Disadvantages	• Will not degrade efficiently if buried in landfill • Difficult to control degradation while the plastic is still in use	• Only a limited number of polymers biodegrade • Release carbon dioxide and methane on degradation i.e greenhouse gases • Sufficient oxygen and water must be present for micro-organisms to act

What are the disadvantages of biodegradable polymers?

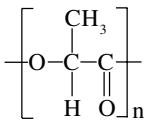
The advantage of biodegradable polymers is their potential to reduce the amount of waste which remains for many years in landfill sites. However, as biodegradable polymers break down, they release the greenhouse gases carbon dioxide and methane, and leave small pieces of plastic behind. Disposal in landfill also means that the plastic is removed from the system and cannot be recycled. Since most plastics are still made from non-renewable crude oil derivatives, disposal necessitates the further use of these resources in making replacements. The extraction and manufacturing from new raw materials also uses significantly more energy than recycling.

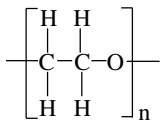
In view of these issues, environmental groups have expressed some major reservations with the continued development of biodegradable polymers. They stress that money would be better spent on improving and increasing the recycling of all plastics, and on the development of plastics which are derived from renewable raw materials such as starch or cellulose.

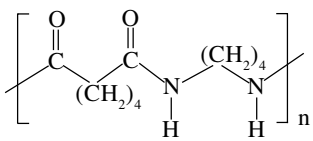
Practice Questions

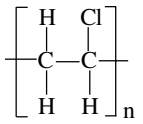
1. Define these terms:
   (a) photodegradable; (b) biodegradable;
   (c) addition polymer; (d) condensation polymer.

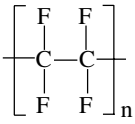
2. Which of these polymers is/are likely to be biodegradable?

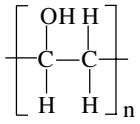
(a) 
poly(lactic acid)

(b) 
poly(ethane-1,2-diol)

(c) 
nylon-4,6

(d) 
poly(chloroethene)

(e) 
poly(tetrafluroethene)

(f) 
poly(ethenol)

3. What are the advantages of starch over poly(ethene) as a packaging material?

4. What are the disadvantages of sending degradable plastics to landfill?

Answers

1. (a) photodegradable means that the substance breaks down by the action of light;
   (b) biodegradable means that the substance breaks down by the action of micro-organisms;
   (c) addition polymers are formed repeated self-addition reactions of alkenes with no by-products produced;
   (d) condensation polymers are formed by repeated condensation reactions between dicarboxylic acids (or derivatives such as diacyl chlorides) and diamines or diols. Water (or sometimes hydrochloric acid) is a by-product of the polymerisation process.

2. Polymers which are likely to biodegrade are poly(lactic acid), nylon-4,6 and poly(ethane-1,2-diol) because they all contain polar C-O or C-N bonds. The polymers which are unlikely to biodegrade are poly(chloroethene) and poly(tetrafluoroethene). Poly(ethanol) may biodegrade, but probably only very slowly indeed.

3. Advantages of starch include the fact that it is from a renewable, plant-based source, and that it can biodegrade.

4. Disadvantages include the greenhouse gases released on degradation, the need for the correct conditions for degradation, and the fact that landfill removes the plastics from the system, leading to the need for further manufacture of new plastics.

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