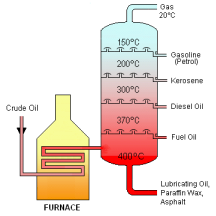
# Materials and their properties
# Polymers

**A: Polymers** were first introduced into consumer products in the 1950s. Their ability to be coloured, shaped and formed, along with their cost and versatile range of working properties has allowed designers and manufacturers to improve the performance of products and replace the use of more traditional materials.

The majority of polymers are manufactured from the non-renewable resource crude oil. Crude oil is made into polymers using a process called Fractional Distillation.

The use of crude oil is not sustainable and chemical engineers are constantly looking for reliable alternatives to petrochemical-based polymers. The increase in popularity has meant that the environmental impact of polymer use has grown and designers must consider this when selecting materials for use.



Fractional Distillation

Polymers can be categorised into two groups: **thermoforming** polymers and **thermosetting** polymers.

**B: Polymer additives**

The properties of polymers can be further enhanced through the introduction of additives.

- Plasticisers can be added to make the polymer soft and flexible, as often found in PVC
- Pigments can be added to change the colour of the polymer
- Stabilisers can be added to help the polymer withstand UV light damage, which is especially useful in products that may be used outdoors
- Fillers can be used to increase the bulk of the polymer; this can help improve its impact resistance

**C: Polymer problems**

One of the useful properties of polymers is that they are unreactive, so they are suitable for storing food and chemicals safely. Unfortunately, this property makes it difficult to dispose of polymers.

Polymers can be burnt or incinerated. They release a lot of heat energy when they burn and this can be used to heat homes or to generate electricity. However, here are problems with incineration. Carbon dioxide is produced, which adds to global warming. Toxic gases are also produced unless the polymers are incinerated at high temperatures.

Many polymers can be recycled. This reduces the disposal problems and the amount of crude oil used. But the different polymers must be separated from each other first, and this can be difficult and expensive to do.

**D: Thermoforming polymers**

These polymers do not resist heat well. They are easily formed into different shapes by heating, melting and remoulding. This means they are easy to recycle.

| Polymer | Characteristics and uses of thermoforming polymers |
|---|---|
| Acrylic (PMMA) | Hard, excellent optical quality, good resistance to weathering, scratches easily, brittle. Used for car light units, bath tubs, shop signage and displays. |
| High-impact polystyrene (HIPS) | Tough, hard and rigid, good impact resistance, lightweight. Use for children's toys, yoghurt pots, refrigerator liners. |
| High-density polythene (HDPE) | Hard and stiff, excellent chemical resistance. Use for washing up bowls, buckets, milk crates, bottle and pipes. |
| Polypropylene (PP) | Tough, good heat and chemical resistance, lightweight, fatigue resistant. Used for toys, DVD and blu-ray cases, food packaging film, bottle caps and medical equipment. |
| Polyvinyl chloride (PVC) | Hard and tough, good chemical and weather resistance, low cost, can be rigid or flexible. Used for pipes, guttering, window frames. |
| Polyethylene terephthalate (PET) | Tough and durable, lightweight, food safe, impermeable to water, low cost., excellent transparency. Used for drinks bottles, food packaging. |

**E: Thermosetting polymers**

These polymers resist heat and fire which makes them useful when manufacturing electrical fittings and pan handles. Thermosetting polymers undergo a chemical change when heated and moulded to make a product. They become permanently hard and rigid. This means they are not recyclable because they can't be melted and reshaped.

| Polymer | Characteristics and uses of thermosetting polymers |
|---|---|
| Epoxy resin | Electrical insulator, good chemical and wear resistance. Use for adhesives such as Araldite™, PCB component encapsulation. |
| Melamine formaldehyde (MF) | Stiff, hard and strong, excellent resistance to heat, scratching and staining. Used for kitchen work-surface laminates, tableware. |
| Phenol formaldehyde (PF) | Hard, heat and chemical resistant, good electrical insulator, limited colours available. Used for electrical fittings, saucepan handles, bowling balls. |
| Polyester resin | Brittle but becomes tough when laminated with glass fibre, hard and resistant to UV. Used for GRP boats, car body panels. |
| Urea formaldehyde (UF) | Stiff and hard, heat resistant, good electrical insulator. Used for white electrical fittings, toilet seats, adhesive used in MDF. |

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## F: Keywords

- Primary source: where materials originate (polymers from oil, timber from trees etc) and the raw material that needs to be converted into a workable form
- Fractional distillation: separation of a liquid mixture into the different chemical components by a chemical distillation process
- Thermosetting polymers: polymers that can only be shaped and formed by heat once
- Thermoforming polymers: polymers that can be softened by heating, shaped and set over and over again
- Non-renewable: a resource that cannot replenish itself quickly and therefore will eventually run out
- Sustainable: naturally replenished within a short period of time
- Unreactive: having little tendency to react chemically

## G: Video and web-links

- Polymers: https://www.youtube.com/watch?v=j5hOj7J6YmA
- Thermoforming polymers: https://www.youtube.com/watch?v=HPtE0VQMc58
- Thermosetting polymers: https://www.youtube.com/watch?v=jfo8Yx3kNHQ

## Revision Checklist

| | |
|---|---|
| I know the primary source of materials for producing thermoplastic and thermosetting polymers | |
| I can recognise and characterise different types of thermoplastic and thermosetting polymers | |
| I understand how the physical and working properties of a range of thermoplastic and thermosetting polymers affect their performance | |
| I understand the impact polymers have on the environment | |
| I can explain some of the problems associated with the use and disposal of polymers | |
| I know the reasons why additives would be introduced to polymers | |

## Test yourself

1. What are the common properties that nearly all polymers have?
2. Explain the difference between thermoforming and thermosetting polymers.
3. What is the primary source of most polymers?
4. Name a polymer which could be used to make a water bottle and explain why it is suitable.
5. Give an example of a polymer additive and explain why it is used.