Ceramics, polymers and composites

4.10.3.3 · Using resources · revision notes

How glass and clay ceramics are made, why the conditions used to make poly(ethene) change its properties, how thermosoftening and thermosetting polymers differ in structure, and what composites are. This is in GCSE Chemistry only, not in Combined Science. Expect recall, structure-based explanations and questions where you compare data to select a material on Paper 2.

Key facts

- Soda-lime glass: sand + sodium carbonate + limestone
- Clay ceramics (pottery, bricks): shape wet clay → heat in a furnace
- HD poly(ethene): lower temperature and pressure, catalyst → mostly unbranched chains, high density
- Thermosetting: covalent cross-links between chains → does not melt when heated
- Borosilicate glass: sand + boron trioxide; higher melting point
- LD poly(ethene): very high pressure, trace of oxygen → branched chains, low density
- Thermosoftening: no cross-links, weak intermolecular forces → melts when heated
- Composite = matrix (binder) + reinforcement (fibres or fragments)

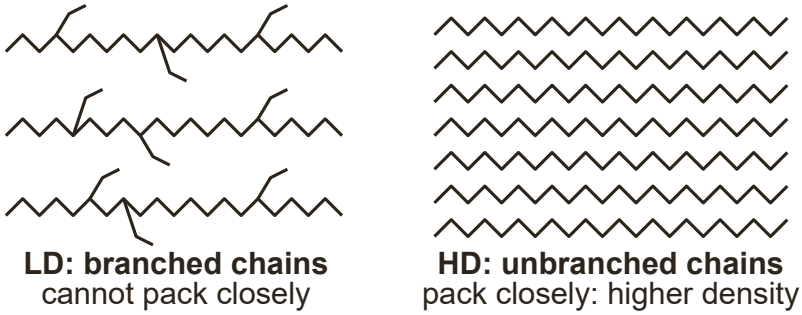
Notes

Glass and clay ceramics

- Most glass is **soda-lime glass**, made by heating a mixture of **sand, sodium carbonate and limestone**.
- **Borosilicate glass** is made from **sand and boron trioxide**. It melts at a higher temperature than soda-lime glass, so it is used for ovenware and laboratory glassware.
- **Clay ceramics**, including pottery and bricks, are made by shaping wet clay and then heating it in a furnace.
- Glass and clay ceramics are hard but brittle, and are good insulators.

LD and HD poly(ethene)

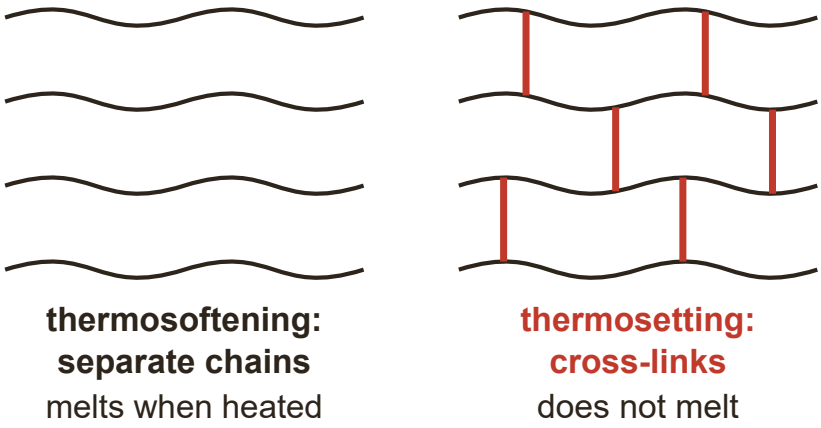
- The properties of a polymer depend on **which monomers** it is made from and the **conditions** under which it is made.
- **Low density (LD) poly(ethene)** is made from ethene at a very high pressure, with a trace of oxygen. Its chains are highly branched, so they cannot pack closely: lower density, softer and more flexible (e.g. carrier bags, cling film).
- **High density (HD) poly(ethene)** is made from ethene at a lower temperature and pressure, using a **catalyst**. Its chains are mostly unbranched, so they pack closely: higher density, stronger, more rigid, and softens at a higher temperature (e.g. milk bottles, pipes).



Branches keep LD chains apart, so LD poly(ethene) is less dense and softer.

Thermosoftening and thermosetting polymers

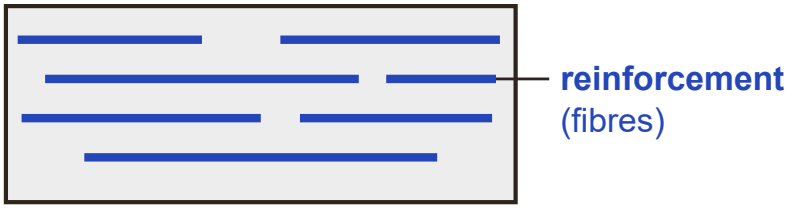
- **Thermosoftening** polymers are separate polymer chains held together by weak **intermolecular forces**. On heating these forces are overcome, the chains slide past each other and the polymer **melts**, so it can be remoulded. Example: poly(ethene).
- **Thermosetting** polymers are long chains with strong covalent **cross-links** between them. Too much energy is needed to break the cross-links, so the polymer does **not melt** when heated (it chars at very high temperatures). Example: melamine.
- Thermosoftening polymers are easier to recycle: they melt, so can be reshaped.



Strong covalent cross-links hold thermosetting chains in place.

Composites and choosing materials

- Most **composites** are made of two materials: a **matrix** (or **binder**) surrounds and binds together fibres or fragments of the other material, the **reinforcement**.



matrix (binder) surrounds and holds the fibres
e.g. fibreglass: glass fibres in a polymer resin

The composite combines the strength of the fibres with the properties of the matrix.

- Examples: **reinforced concrete** (steel rods in concrete); **fibreglass** (glass fibres in a polymer resin); **carbon fibre** composites (carbon fibres in a polymer resin); **wood** (cellulose fibres in a natural matrix called lignin).
- A composite combines the useful properties of its parts: concrete is strong when squashed but weak when stretched, and the steel rods make reinforced concrete strong when stretched too.
- Typical properties: metals are strong, malleable, dense and conduct; polymers are light, flexible insulators that soften at low temperatures; composites can be both strong and light.
- To select a material, match the data given to what the use needs and reject each other material with a reason.

How to answer each type of question

Explain how LD and HD poly(ethene) differ 2 to 3 marks **Grade 6**

1. Say that both are made from the same monomer, ethene, but under different conditions.
2. Give a difference in conditions: LD at very high pressure with a trace of oxygen; HD at a lower temperature and pressure with a catalyst.
3. Link the structure to the property: fewer branches means the chains pack more closely, so the density is higher.

Example. (a) Give **one** difference between the conditions used to make LD poly(ethene) and HD poly(ethene). (1 mark)
(b) Explain why HD poly(ethene) has a higher density than LD poly(ethene). (2 marks)

Model answer.

(a) LD is made at a much higher pressure / HD is made at a lower temperature and pressure / HD is made using a catalyst, whereas LD uses a trace of oxygen (1)

(b) The chains in HD poly(ethene) have fewer branches (are mostly straight) (1), so they can pack more closely together, giving more mass in the same volume (1).

Explain thermosoftening and thermosetting polymers

3 to 4 marks | Grade 7

1. Describe the structure of each: separate chains, or chains joined by cross-links.
2. Name the forces or bonds: weak intermolecular forces, or strong covalent cross-links.
3. Link to heating: weak forces are overcome, so the chains slide and it melts; cross-links hold the chains in place, so it does not melt.

Example. Saucepan handles are made from a thermosetting polymer. Food bags are made from a thermosoftening polymer.
Explain, in terms of structure, why the handle does not melt when heated but the bag does. (4 marks)

Model answer. In the thermosoftening polymer the chains are separate and held together only by weak intermolecular forces (1). When heated these forces are overcome, so the chains slide past each other and the polymer melts (1). In the thermosetting polymer there are (covalent) cross-links between the chains (1). The cross-links are strong and hold the chains in place, so the polymer does not melt (1).

Explain the properties of a composite

2 to 3 marks | Grade 5

1. Identify the matrix (binder) and the reinforcement.
2. Give the useful property each part brings, using the information given.
3. Link these properties to the use of the composite.

Example. Canoes can be made from fibreglass, which is glass fibres set in a polymer resin.
(a) Which part of fibreglass is the reinforcement? (1 mark)
(b) Glass fibres are strong but brittle. The polymer resin has a low density but is weak.
Explain why fibreglass is better for a canoe than either material on its own. (2 marks)

Model answer.

(a) The glass fibres (1)

(b) The glass fibres make the composite strong (1); the resin binds the fibres together, so the canoe has a low density and does not shatter like glass alone (1).

Compare data to select a material

3 to 4 marks **Grade 5**

1. List the properties the use needs.
2. Check each material against every requirement, quoting values with units.
3. Rule out the unsuitable materials with a reason each.
4. State the best choice and why it beats the rest.

Example. A company needs a material for the outer case of an electric kettle. It must be an electrical insulator, must not soften at 100 °C, and should be light and not brittle. The table gives data about four materials.

Material	Density (g/cm^3)	Electrical	Softening or melting	Brittle?
W: soda-lime glass	2.5	insulator	softens at about 700 °C	yes
X: LD poly(ethene)	0.92	insulator	softens at about 90 °C	no
Y: thermosetting polymer	1.5	insulator	does not soften	no
Z: stainless steel	7.9	conductor	melts at about 1400 °C	no

Which material should be used? Explain your answer. (4 marks)

Model answer. Y (1). Z conducts electricity, so it would be unsafe for the case (1). X softens at about 90 °C, below the 100 °C of boiling water, so the case would soften (1). W is an insulator and does not soften at 100 °C, but it is brittle and denser than Y (2.5 g/cm^3 compared with 1.5 g/cm^3), so Y is lighter and less likely to break (1).

Don’t lose marks

- Saying thermosetting polymers have 'strong intermolecular forces'. They have covalent cross-links between the chains.
- Saying covalent bonds break when a thermosoftening polymer melts. Only the weak intermolecular forces between chains are overcome.
- Saying LD and HD poly(ethene) are made from different monomers. Both are made from ethene; the conditions and catalyst differ.
- Mixing up the matrix and the reinforcement: the matrix surrounds and binds; the reinforcement is the fibres or fragments.
- Choosing a material from data without saying why the others are unsuitable.

More tips

Memory tricks

- Soda-lime glass = 'SSL': Sand, Sodium carbonate, Limestone.
- BOROsilicate glass contains BORON trioxide.
- LD = lots of branches, loosely packed; HD = hardly any branches, densely packed.
- Thermo-SETTING: once set, it stays set (cross-links). Thermo-SOFTENING: softens every time it is heated.
- In a composite, the reinforcement gives strength and the matrix is the glue that holds it together.

Exam technique

- Structure-based 'explain' questions need a chain of three links: structure → forces or bonds → property.
- In data questions, quote numbers with units and compare them, e.g. ‘density 1.5 g/cm^3, lower than glass at 2.5 g/cm^3’.
- Learn at least one composite with its matrix and reinforcement named: reinforced concrete and fibreglass are the safest.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Name the raw materials for soda-lime glass**
Sand, sodium carbonate and limestone, heated together.

Grade 4 — **Describe how clay ceramics are made**
Wet clay is shaped and then heated in a furnace, e.g. to make pottery and bricks.

Grade 4 — **Name the two parts of a composite**
A matrix (binder) surrounds and binds together fibres or fragments of the reinforcement.

Grade 5 — **Give examples of composites and their parts**
Reinforced concrete is steel rods in concrete; fibreglass is glass fibres in a polymer resin.

Grade 5 — **Select materials by comparing data quantitatively**
Use values such as density, strength and softening temperature to justify the best material for a use.

Grade 6 — **Explain why LD and HD poly(ethene) differ**
Both are made from ethene but under different conditions, giving branched or mostly unbranched chains.

Grade 7 — **Explain thermosoftening vs thermosetting using structure**
Thermosetting polymers have cross-links between chains so do not melt; thermosoftening polymers have only weak intermolecular forces between chains.

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