Polymers

4.2.2.5 · Bonding, structure and the properties of matter · revision notes

Why polymers such as poly(ethene) are solids at room temperature, and how to recognise a polymer from a diagram. Questions are usually short: explain the state of a polymer in terms of forces, or pick out the polymer from diagrams of different structures.

Key facts

- Polymer = very large molecule made of many repeating units
- Relatively strong intermolecular forces between chains → solid at room temperature
- Poly(ethene) repeating unit: $(–CH_2–CH_2–)_n$
- Strong covalent bonds between the atoms in each chain
- Diagram: repeating unit in brackets, bonds through the brackets, n outside
- Melting a polymer overcomes intermolecular forces, not covalent bonds

Notes

What a polymer is

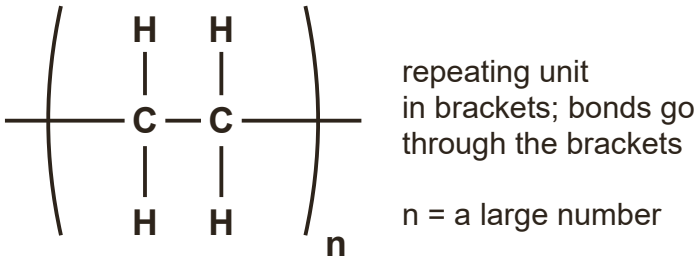
- Polymers have **very large molecules**: long chains that can contain thousands of atoms.
- Each chain is made of many copies of the same small section, called the **repeating unit**.
- The atoms in each chain are joined to each other by **strong covalent bonds**.
- Example: poly(ethene), used for plastic bags and bottles, is a long chain of carbon atoms, each carbon also bonded to two hydrogen atoms.

Why polymers are solids

- Between the polymer molecules there are **intermolecular forces**.
- Because the molecules are so large, these intermolecular forces are **relatively strong**: much stronger than the forces between small molecules.
- So more energy is needed to overcome them, and polymers are **solids at room temperature**.
- When a polymer such as poly(ethene) melts, it is the intermolecular forces between the chains that are overcome; the covalent bonds in the chains do not break.

Recognising a polymer in a diagram

- A polymer is usually drawn as its **repeating unit** inside brackets, with a small **n** after the brackets (n is a large number).
- The bonds at each end of the repeating unit go **through the brackets**, showing that the chain carries on.
- Poly(ethene): two carbon atoms joined by a single bond, each with two hydrogen atoms, inside brackets with n.



Poly(ethene): the chain carries on in both directions.

- Compare: a small molecule is drawn complete, with no bonds going off it; a giant covalent structure is a network of bonds going off in all directions, with no brackets or n; an ionic structure shows + and − ions.

How to answer each type of question

Identify a polymer from diagrams 1 to 2 marks **Grade 5**

1. Look for brackets with n and bonds that go through the brackets: that is a polymer.
2. A complete small unit is a small molecule; a network of bonds in all directions is giant covalent; + and − ions are ionic.

Example. Four structures are described.
A: a molecule of one oxygen atom bonded to two hydrogen atoms.
B: two carbon atoms, each bonded to two hydrogen atoms, inside brackets, with bonds through the brackets and n after them.
C: a regular lattice of + and − ions.
D: carbon atoms each bonded to four other carbon atoms in a network that continues in all directions.
(a) Which structure is a polymer?
(b) Which structure is a giant covalent structure?

Model answer.

(a) B (1)
(b) D (1)

Explain why a polymer is a solid at room temperature

2 to 3 marks | Grade 5

1. Say the polymer molecules are very large.
2. Say the intermolecular forces between them are relatively strong.
3. Link this to the energy needed to overcome them, and compare with small molecules if asked.

Example. Ethene, C_2H_4, is a gas at room temperature. Poly(ethene) is a solid.
Explain why, in terms of the forces between molecules.

Model answer. Poly(ethene) molecules are much larger than ethene molecules (1). So the intermolecular forces between poly(ethene) molecules are much stronger and need more energy to overcome (1). Ethene has only weak intermolecular forces, which are overcome at a low temperature (1).

Compare a polymer with a giant covalent substance

3 marks | Grade 7

1. Say the polymer is made of separate large molecules.
2. Say melting it overcomes intermolecular forces.
3. Say melting the giant covalent substance means breaking many strong covalent bonds, which needs much more energy.

Example. Poly(ethene) softens and melts at about 120 °C. Diamond does not melt until well over 3000 °C.
Explain this difference.

Model answer. Poly(ethene) is made of separate (very large) molecules (1). When it melts, only the intermolecular forces between the chains are overcome (1). To melt diamond, many strong covalent bonds must be broken, which needs much more energy (1).

Don’t lose marks

- Saying polymers are solid because of strong covalent bonds between the chains. The chains are held together by intermolecular forces; the covalent bonds are inside the chains.
- Calling a polymer a giant covalent structure. Polymers are made of separate, very large molecules.
- Drawing a repeating unit without the bonds through the brackets, or leaving out the n.
- Calling the intermolecular forces in polymers 'strong' without a comparison. They are relatively strong compared with those between small molecules, but much weaker than covalent bonds.

More tips

Memory tricks

- Poly means many: a polymer is many repeating units joined in a chain.
- Spot it: brackets + n + bonds sticking out through the brackets = polymer.
- Melting point ladder: small molecules (low) < polymers (solids, but melt fairly easily) < giant covalent (very high).

Exam technique

- Use comparisons: 'the molecules are larger, so the intermolecular forces are stronger'. Examiners want the link between size and the strength of the forces.
- In 'which diagram' questions, check every option: usually one is a small molecule, one ionic and one giant covalent.
- Name the right forces: intermolecular forces between polymer chains, covalent bonds within them.

What each grade needs

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

Grade 3 — **State that polymers have very large molecules**
Polymer molecules are long chains made of many repeating units.

Grade 4 — **State that polymers are solids at room temperature**
The forces between their large molecules are strong enough to keep them solid.

Grade 5 — **Describe the bonds in a polymer chain**
The atoms in each chain are linked to each other by strong covalent bonds.

Grade 5 — **Recognise a polymer from a diagram**
Look for a repeating unit in brackets with bonds through the brackets and n after them.

Grade 5 — **Explain why polymers are solids at room temperature**
Their large molecules have relatively strong intermolecular forces, which need more energy to overcome than those between small molecules.

Grade 7 — **Tell polymers from giant covalent structures**
Polymers are separate chain molecules with forces between them; a giant covalent structure is one continuous network of covalent bonds.

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