*Chemistry > Big idea CMS: Materials science > Topic CMS2: Designing materials*

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| **Key concept (age 11-14)** |
| **CMS2.1: Polymer properties** |

**What’s the big idea?**

A big idea in chemistry is that understanding the properties of different materials allows the selection of the most suitable material (or combination of materials) for a purpose. Understanding of the underlying structure of a material enables materials scientists to design new materials with the specific properties required.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by introducing polymers as being molecules made up of tens of thousands of atoms.

****The conceptual progression starts by checking understanding of polymer molecules and the relationship between length and melting point. It then supports the development of an understanding of how structural features can affect the properties of polymers in order to enable understanding of how materials scientists can design polymers to have specific properties.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Polymer properties**

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| **Learning focus** | Materials scientists can design polymers with specific properties. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Explain why a long molecule has a higher melting point than a similar but shorter molecule. | Recognise that a polymer molecule can be made up of thousands of atoms. | Describe how linear or branched molecules affect the mass of a given volume of polymer. | Explain how the addition of plasticisers between molecules can make a polymer softer and more flexible. | Explain how cross links between polymer molecules affect the properties of a polymer.  **B** |
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| **Diagnostic questions** | Melting points | Molecule size | Plastic labels | PVC | Thermoset plastic |
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| **Response**  **activities** | Melting a polymer | Polymer chain |  | Explaining plasticisers | Cross linked PVA |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Melting points** | **Molecule size** | **Plastic labels** | **PVC** | **Thermoset plastic** |
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| Confidence grid | Simple multiple choice | Confidence grids | Talking heads | Confidence grid |
| **Melting a polymer** | **Polymer chain** | **Explaining plasticisers** | **Cross linked PVA** |  |
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| Critiquing a representation | Critiquing a representation | Critiquing a representation | PEOE |  |

**What’s the science story?**

All materials have mechanical properties which reflect a material’s reaction to an applied force. An individual material also has specific physical properties such as melting and boiling point. A material may conduct heat or electricity. Materials such as metals, polymers and ceramics may be classified using their mechanical and physical properties. Materials may be combined to produce composite with a combination of properties of the original materials.

An understanding of the chemical structure of different materials allows materials scientists do design new materials with the required properties.

**What does the research say?**

In one article (Moore and Stanitski, 2017) the authors describe how they have integrated polymers into a general chemistry course. They recommend introducing polymers after discussion of intermolecular forces. This is why the key concept follows key concept CPS2.1: Atoms and molecules which checks student understanding of the idea of simple and giant molecules and the idea of forces of attraction between molecules.

The progression therefore starts by checking that students link boiling point with the attractive force between molecules (intermolecular forces). It then finds out whether students appreciate the very large number of atoms that form a polymer molecule.

Research (Krnel, Watson and Glažar, 1998) suggests that density is an important property in the identification of materials. Without formally introducing density as a topic the progression aims to find out whether students can link the packing of linear and branching polymers with the mass of a given volume of HDPE (high density polyethylene) and LDPE (low density polyethylene).

The introduction of plasticisers or cross links changes the properties of a polymer. Research (Cooper, Williams and Underwood, 2015) found that the understanding of the U.S. undergraduate students of intermolecular forces was “highly problematic, fractured and unstable”. The progression therefore checks that, at a very basic level, students can link the structural features with how they affect the properties of the polymer.

**Guidance notes**

This key concept introduces the basics of the structure of polymers. At this stage it is not expected that students understand this structure in terms of repeating units of monomers of covalently bonded atoms. This forms part of a BEST 14-16 key concept.

The key concept builds also builds on ideas from CMS1.2: Classifying materials. This introduced the idea that whilst types of materials (metals, ceramics and polymers, have similar properties they can also have differences. This key concept progresses student understanding to include, at a basic level, how the properties of a polymer are linked to its structure.

**References**

Cooper, M. M., Williams, L. C. and Underwood, S. M. (2015). Student understanding of intermolecular forces: A multimodal study. *Journal of Chemical Education,* 92**,** 1288-1298.

Krnel, D., Watson, R. and Glažar, S. A. (1998). Survey of research related to the development of the concept of 'matter'. *International Journal of Science Education,* 20(3)**,** 257-289.

Moore, J. W. and Stanitski, C. L. (2017). Lengthening the chain: Polymers in geneal chemistry. *Journal of Chemical Education,* 94**,** 1603-1606.