

Key concept (age 11-14)

CPS2.1: Atoms and molecules

What's the big idea?

A big idea in chemistry is that all matter is made up of particles called atoms. The structural arrangement and movement of atoms and the forces between them, explain the properties of different materials. A key concept of this big idea is that the structural arrangement of atoms gives rise to the properties of substances.


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

This key concept develops the big idea by introducing the concept of different types of atom and the structural arrangement of these atoms as separate molecules or giant structures.


The conceptual progression starts by checking understanding of the difference in properties between a compound and its constituent elements. It then supports the development of understanding of different types of atom, in order to enable understanding of the link between differences in properties and the structural arrangement of the atoms.

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:	
Learning focus	What I am teaching
As students' conceptual understanding progresses they can:	
Diagnostic questions	<p>Observable learning outcomes to guide my teaching focus</p> <p>Questions to find out what my students know and understand</p>
Response activities	<p>Activities to move my students' understanding forwards</p>

Progression toolkit: Atoms and molecules

Learning focus	The properties of elements and compounds arise from the structural arrangement of their constituent atoms.				
As students' conceptual understanding progresses they can:					
Diagnostic questions	Link the properties of an element to the collective behaviour its atoms.	Explain differences in melting and boiling points between elements in terms of their structure (separate molecules or a single giant structure).	Identify the number of substances (elements or compounds) represented in a particle diagram	Distinguish particle diagrams for elements, mixtures and compounds.	Explain that the properties of a compound may not be inferred from the properties of elements made up of its constituent atoms.
Diagnostic questions	Properties of copper	Element differences	Counting substances	Element, mixture or compound?	Which colour?
Diagnostic questions	Property mistakes	Changing to gas state		Diagram practice	

What's the science story?

All matter is made up of atoms. Each element is made up of a different type of atom. A single atom does not have the properties of that element. The properties of an element arise due to the arrangement and behaviour of the atoms collectively. A compound is made up of two or more types of atom joined together. As different atoms are joined than in the separate elements, the compound has properties that are distinct from the elements that are made up of its constituent atoms.

Elements and compounds have one of two types of basic structure. Some are made up of separate groups of two or more atoms (molecules) whereas the atoms in others are joined to make one giant structure. These structures influence properties such as melting and boiling points because there are weaker forces between molecules than within molecules.

What does the research say?

A key difficulty of students in integrating macroscopic with sub-microscopic understanding of an observed property is the use of an additive rather than an emergent framework. A research study (Talanquer, 2007) included a question to investigate this. Students were shown a particle diagram for a blue substance and a yellow substance, each made of one type of atom. The students were then asked to predict the colour of a third substance made up of a combination of the two types of atom. Many responses took an additive approach and predicted that the colour of the compound would be green.

Research (Rappoport and Ashkenazi, 2008) found that, in comparison with their students, university lecturers used an emergent way of thinking that considered the atoms or molecules interacting as part of an overall system. This was much less the case with students. Some students made connections in the reverse direction, that is to say they inferred properties on the atoms or molecules that related to the macroscopic property. The research concludes that the explicit inclusion of an emergent way of thinking in teaching programmes would be beneficial to students and would help to dispel some misunderstandings.

The progression pathway has been constructed to check understanding of the link between properties and the structural arrangement, and type of atom that a substance (element or compound) is made up of. It also uses findings from the Children's Learning in Science Project (Briggs and Holding, 1986) which showed that many students do not adequately understand particle diagrams including the significance of the circles touching (atoms joined) or not touching (atoms not joined).

Guidance notes

This topic introduces elements and compounds as two types of substance. This forms part of the big idea on substance and properties. However, in terms of conceptual development the focus is on the sub-microscopic representation of particles (atoms) that make up elements and compounds and how their structural arrangement determines their properties. For this reason, the key concept is placed in the particles and structure big idea.

References

- Briggs, H. and Holding, B. (1986). *Children's Learning in Science Project. Aspects of secondary students' understanding of elementary ideas in chemistry: Full report*. [Online]. Available at: <https://www.stem.org.uk/elibrary/resource/26944>.
- Rappoport, L. T. and Ashkenazi, G. (2008). Connecting levels of representation: Emergent versus submergent perspective. *International Journal of Science Education*, 30(12), 1585- 1603.
- Talanquer, V. (2007). Students' predictions about the sensory properties of chemical compounds: Additive versus emergent frameworks. *Science Education*, 92(1), 96-114.