

Key concept (age 11-14)

CPS3.1: Rearrangement of atoms

What's the big idea?

A big idea in chemistry is that during a chemical reaction, atoms are rearranged resulting in the formation of a new substance or substances.

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

This key concept develops the big idea by linking the rearrangement of atoms during a chemical reaction to the formation of products with different properties to the reactants.


The conceptual progression starts by checking understanding of the link between the arrangement of atoms and properties of a substance. It then develops the idea of the rearrangement of atoms during chemical reactions in order to enable understanding of observations of oxidation and decomposition reactions.

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:	<p>CONCEPTUAL PROGRESSION →</p> <p>Observable learning outcomes to guide my teaching focus</p>
Diagnostic questions	Questions to find out what my students know and understand
Response Activities	Activities to move my students' understanding forwards

Progression toolkit: Rearrangement of atoms

Learning focus	During a chemical reaction, atoms are rearranged and a new substance (or substances) are formed with different properties.				
As students' conceptual understanding progresses they can:					
As students' conceptual understanding progresses they can:	<p>Explain that the properties of a compound may not be inferred from the properties of elements made up of its constituent atoms. (see CPS2.2)</p> <p>P</p>	<p>Use particle diagrams to represent the reactants and products of a reaction between elements.</p>	<p>Evaluate models of the rearrangement of atoms during a chemical reaction between two elements.</p>	<p>Explain observations of reactions in which elements combine in terms of a change in arrangement of atoms resulting in new properties.</p>	<p>Use a chemical formula to predict possible products of a thermal decomposition reaction.</p>
Diagnostic questions		Thinking in diagrams	Modelling chemical reactions	Explaining oxidation	Formula help
Response activities			Sweet model	Explaining melting points	Possible products

Key:

P Prior understanding from earlier stages of learning

B Bridge to later stages of learning

What's the science story?

During a chemical reaction no atoms are created or destroyed. The atoms are rearranged. This results in the formation of new substances with different properties to the starting substances.

What does the research say?

Research (Kern et al., 2010) based on a large sample of over 1000 of high school students in the United States found that whilst well over half of the students (65%) could correctly balance a given chemical equation, fewer than half (31%) could provide an adequate particle representation. This implied that students did well at an algorithmic level in terms of problem-solving but much less well in terms of conceptual understanding. The students struggled to link their understanding of a chemical reaction at the sub-microscopic, macroscopic and symbolic levels described by Johnstone's triangle (Johnstone, 1991).

Research (Cheng and Gilbert, 2017) describes model-based reasoning as "the ability to provide explanations to physical phenomena, usually based on theoretical and unobservable entities or processes". The paper notes that the school chemistry curriculum typically includes two models of chemical reactions:

- i) a simple rearrangement of (unchanged) particles
- ii) an interaction of chemical species with protons and electrons that can change during a chemical reaction (e.g. atoms becoming ions)

This key concept checks student understanding of the first model.

The progression pathway begins by checking prior understanding (key concept 2.1: Atoms and molecules) of the reasons for the difference in properties between a compound and its constituent elements. It then assesses the extent to which students are able to visualise, through diagrams and models, the rearrangement of atoms during a chemical reaction. The aim, by the end of the progression pathway, is that students are able to use this way of thinking to explain observations of specific types of chemical reaction.

Guidance notes

The chemical reactions used to introduce the concept of chemical change should be chosen with care. The particle explanations developed in this key concept relate to two basic types of reaction:

Reactions of elements (including oxidation of metals) which take the generalised form $A+B \rightarrow C$.

Decomposition of compounds (thermal decomposition) of the form $A \rightarrow B+C$.

At this stage reactions with one or more reactant in solution have been avoided due to the added conceptual complication of the presence of water as a solvent.

Research (Johnson, 2000) found that even when students were introduced to the idea of substance and chemical change as the formation of a new substance “very few seemed happy with such a face-value description”. It may therefore be of benefit for this key concept on the rearrangement of atoms to run in parallel with key concept: CCR1.1 Formation of new substances which focuses on students’ interpretation of macroscopic observations. For this reason, the types of reactions referred to in this pathway match those in CCR1.1.

Possible example reactions could include oxidation of copper, burning magnesium and the thermal decomposition of copper carbonate.

References

- Cheng, M. M. W. and Gilbert, J. K. (2017). Modelling students' visualisation of chemical reaction. *International Journal of Science Education*, 39(9), 1173-1193.
- Johnson, P. (2000). Children's understanding of substances, part 1: recognizing chemical change. *International Journal of Science Education*, 22(7), 719-737.
- Johnstone, A. H. (1991). Why is chemistry difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, 7, 75-83.
- Kern, A. L., et al. (2010). A qualitative report of the ways high school chemistry students attempt to represent a chemical reaction at the atomic/molecular level. *Chemistry Education Research and Practice*, 11, 165-172.
- Talanquer, V. (2007). Students' predictions about the sensory properties of chemical compounds: Additive versus emergent frameworks. *Science Education*, 92(1), 96-114.