

Key concept (age 11-14)

CCR1.1: Formation of new substance

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 which have different properties.

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

This key concept develops the big idea by introducing chemical reactions, at the macroscopic scale, as a type of process that results in the formation of a new substance or substances (a chemical change).

The conceptual progression starts by checking understanding of physical and chemical change. It then supports the development of a macroscopic understanding of the concept of chemical reaction starting with observational evidence of the formation of a new substance. This leads to an understanding of why decomposition is a chemical reaction, even though it has one reactant.

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: Formation of new substance

Learning focus	During a chemical reaction a new substance (or substances) are formed which have different properties.				
As students' conceptual understanding progresses they can:					
Diagnostic questions	Categorise everyday observations of change. P	Distinguish examples of physical change from chemical changes. P	Explain observations of a chemical reaction in terms of the formation of a new substance (or substances) with different properties.	Explain, at a macroscopic level, a reaction in which elements combine (e.g. oxidation).	Explain observations of a thermal decomposition reaction.
Response activities	Grouping changes	Which change?	Colour change	Burning magnesium	Heating a compound
Response activities			Counter arguments	Reacting elements	Copper compounds

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 a new substance or substances are formed. This can happen when the atoms of elements combine (e.g. oxidation) or compounds split apart (e.g. thermal decomposition).

What does the research say?

Research (Stavridou and Solomonidou, 1998) investigated how student thinking about chemical reactions develops. This research showed that initially many students did not understand chemical reactions as changes, rather they saw them as events. The students' focus was on the most obvious feature such as a colour change, gas release or explosion. Later students developed the idea of the formation of a new product however this did not necessarily indicate a fully scientific understanding of a chemical reaction. Some students held the view that a chemical reaction requires two initial starting materials to be mixed. Others considered that the product could be something different that was not a substance for example, fire.

The progression pathway starts by checking students' existing conceptual development in terms of categorising physical and chemical change.

The research found that a significant number of students had difficulties in identifying chemical reactions because they were unable to identify that a new product had been formed. The conclusion was therefore drawn that the development of the chemical substance concept is critical for the understanding of chemical reactions (see key concept: CSU1.1 Substance).

The central learning outcome focuses on students' ability to interpret macroscopic observations of chemical reactions in terms of the formation of new substance. Research (Johnson, 2000) concluded that some students did not interpret their observations as the formation of a new substance. Instead they used the idea of mixing to explain the observed changes. This is consistent with findings by Talanquer (2007) that concluded that many students use an 'additive framework' to predict the properties of chemical compounds rather than recognising that a compound has new properties that emerge as a result of a new arrangement of atoms (see key concept: CPS2.1 Atoms and molecules). These ideas are explored more specifically in the fourth learning outcome. The misunderstanding that a chemical reaction results in the mixing of the original substances causes particular difficulty for students in understanding that decomposition is a type of chemical change. This has therefore been included as the final learning outcome.

Johnson 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 formation of new substances to run in parallel with key concept: CPS3.1 Rearrangement of atoms. . For this reason, the types of reactions referred to in this pathway match those in CPS3.1.

Guidance notes

The chemical reactions used to introduce the concept of chemical change should be chosen with care. This key concept refers to two basic types of reaction:

Reactions between 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.

References

Johnson, P. (2000). Children's understanding of substances, part 1: recognizing chemical change. *International Journal of Science Education*, 22(7), 719-737.

Stavridou, H. and Solomonidou, C. (1998). Conceptual reorganization and the construction of the chemical reaction concept during secondary education. *International Journal of Science Education*, 20(2), 205-221.

Talanquer, V. (2007). Students' predictions about the sensory properties of chemical compounds: Additive versus emergent frameworks. *Science Education*, 92(1), 96-114.