Chemistry > Big idea CPS: Particles and structure > Topic CPS2: Atoms and molecules

Key concept (age 11-14)
CPS2.2: Symbols and formulae

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 symbols and formulae may be used to represent both the macroscopic substance (elements and compounds) and to provide quantitative information on the composition of a substance.

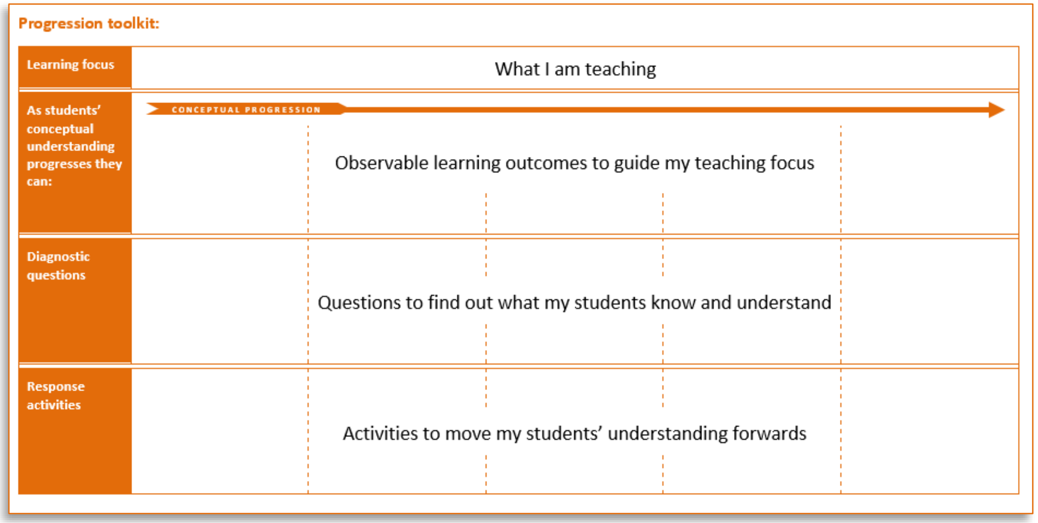
How does this key concept develop understanding of the big idea?

This key concept develops the big idea by relating chemical formulae to particle diagrams.

The conceptual progression starts by checking understanding of element symbols. It then supports the development of interpretation of chemical formulae in order to enable understanding of the difference between multiplying coefficients (large numbers) and subscript numbers.

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: Symbols and formulae

Learning focus	A chemical formula provides information on the composition of a substance.				
As students' conceptual understanding progresses they can: (CONCEPTUAL PROGRESSION →)	Describe what an element symbol represents.	Recognise a chemical formula.	Select an appropriate chemical formula for a given, simple, molecule.	Select an appropriate expression to represent a diagram showing more than one molecule.	Interpret the meaning of a chemical formula in terms of the ratio of atoms in a macroscopic sample of the substance.
Diagnostic questions	What does C represent?	Chemical formula?	Formula choice	More than one molecule	Interpreting chemical formulae
Response activities			Formula practice	Molecule expressions	

What's the science story?

The element symbols that form part of a chemical formula represent the types of atom that make up that particular compound. The subscript numbers in a chemical formula show the ratio of these different types of atom. For molecular substances, the number in a formula also gives the number of each type of atom in a molecule.

What does the research say?

A review of empirical research (Taskin and Bernholt, 2012) revealed three problem areas for students:

Language

This includes problems with the meaning, function and syntax of chemical formulae.

Conceptual understanding

This problem area arises from either "a misunderstanding or a missing understanding" of the particulate nature of matter or from difficulties in making transitions between symbolic expressions and sub-microscopic representations or macroscopic observations.

Inadequate selection and interpretation of formulae

Difficulties in this area become more significant in more advanced study of chemistry. It includes difficulties in deciding when to attach which meaning to a particular chemical representation or when to choose a specific chemical representation for a given purpose.

A research study (Al-Kunifed, Good and Wandersee, 1993) also showed that many students regard element symbols and chemical formulae only as simple abbreviations. This misunderstanding risks being reinforced by introductory teaching of the topic. A wide range of research has found that students have difficulty moving between representational 'levels' (symbolic, sub-microscopic and macroscopic) summarised in Johnstone's triangle (Johnstone, 1991).

The first two student outcomes therefore begin with interpretation of element symbols and chemical formulae to check that students recognise that they can represent more about substance than just the name.

The next two outcomes specifically address difficulties students experience in linking symbolic representations to sub-microscopic representations. Diagnostic questions check whether students can match chemical formulae (or expressions including a multiplying coefficient) with particle diagrams. This type of activity risks giving rise to the misunderstanding that all chemical formulae represent discrete molecules. The final outcome therefore relates to the interpretation of chemical formulae as a ratio.

Guidance notes

The fluent use of chemical representations has been found to be associated with successful problem-solving in chemistry. This key concept has therefore been placed near the beginning of the subject map. The aim is that the development of a firm foundation in understanding of symbols and chemical formulae will improve students' fluency at a later stage when writing and interpreting balanced chemical equations.

If students have not yet met the concept of ratio in mathematics, simple word expressions could be used such as 'For every carbon atom there are two oxygen atoms.' Use of giant covalent structures as examples could help to avoid difficulties with terminology met with the use of giant ionic structures which consist of ions rather than atoms.

References

Al-Kunifed, A., Good, R. and Wandersee, J. (1993). Investigation of high school chemistry students' concepts of chemical symbol, formula and equations: Students' prescientific conceptions. ERIC Document ED376020.

Johnstone, A. H. (1991). Why is chemistry difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning,* 7**,** 75-83.

Taskin, V. and Bernholt, S. (2012). Students' understanding of chemical formulae: A review of empirical research. *International Journal of Science Education,* 36(1)**,** 157-185.