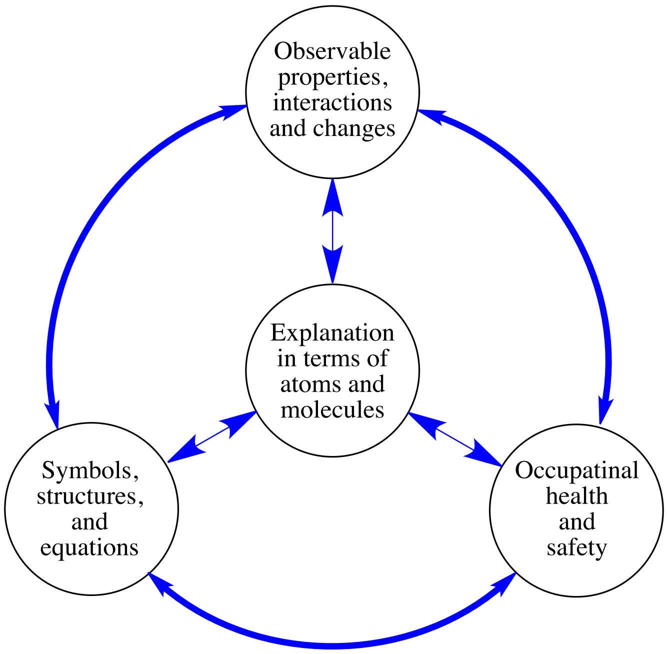
The underlying assumption in chemistry education (Note †)

The underlying assumption in chemistry education is that the discipline of chemistry is real, distinct and clearly differentiable from other sciences. So what makes chemistry special?

Chemistry is the study of matter and its interactions with other matter and with energy, but the four aspects which distinguish chemistry and chemical knowledge are: macroscopic observations and descriptions of properties and change; understanding of these observations and descriptions in terms of atoms and molecules; use of abstract representations to describe and communicate chemical concepts; and occupational health and safety inherent in modern chemical practice. These four aspects are not unique to chemistry, but it is the combination of these factors that make chemistry special and distinct from other sciences.

For example, many sub-disciplines of physics and engineering do not depend on the existence of atoms. Bulk water can be described as a continuous, non-molecular fluid with properties of specific heat capacity, thermal mass, density, viscosity, compressibility, surface tension, vapour pressure. Likewise, genetics can be understood without appreciation of the molecular basis of DNA. However, a chemist thinks of interatomic forces between water molecules and internal energy being stored in atomic motions and molecular potential energy. Similarly, the genetic code is understood in terms of hydrogen-bonded base pairs, linked by polymers of phosphoric esters and carbohydrates. This molecular viewpoint is a central feature of chemistry.



Atoms have not been directly observed with the naked eye. There is evidence in the form of x-ray diffraction patterns, computer images from atomic force microscopy and electron microscopy, and other instrumental techniques. For the most part, chemists represent these unseen atoms and molecules, by atomic symbols, empirical and molecular formulae, and chemical equations. Chemists also use mathematical equations. Lewis structures, Kekulé structures, wedge-bond structures, ball-and-stick drawings, and other diagrams represent 2- and 3-dimensional shapes. Some researchers have compared chemical representations to hieroglyphics or pictograms. [2] Chemical words seem similar but are a foreign language: "salt" does not necessarily mean the substance sprinkled on food; there are many types of "water"; carbon atoms in "linear" alkanes are not co-linear. There are superscripts and subscripts, upper and lower case letters; the same letters can have different meanings depending on the context: for example, the combination of "m" and "n" have several meanings, including, but not limited to, manganese, mass of neutron, meganewton, meganormal,

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metres-raised-to-the-power-*n*, millinewton, millinormal, molar-raised-to-the-power-*n*, and *n* number of metal atoms. Chemical communication uses many codes and languages.

The transformation of one substance to another through a chemical reaction dates back to alchemy and before. The use of colourful an eye-catching reactions is often used in chemistry "magic shows" and to capture the attention of novice learners. Primary school students make vinegar-and-bicarbonate volcanoes. Such observations and investigations by themselves do not constitute chemistry, but must be combined with an understanding of the phenomena in terms of atoms and molecules, and the representation and communication of the phenomena and its explanation through chemical imagery and language.

Finally, there is occupational health and safety. Chemical substances have a variety of uses in a range of settings. Properties, including potential hazard, depend on the context. Corn flour, when stored in the kitchen pantry presents little hazard, but when thrown in the air, can make an easily ignitable air-fuel mixture. When used or stored inappropriately, many substances can be hazardous or can pollute the environment. Modern chemical practice seeks to maximise the benefits to the community, while minimising undesirable consequences like waste, energy use, hazards, and health risks.

Over the last three years, there has been a major review of science education at school levels from "foundation" through to year 12 or year 13, in the formulation of the Australian National Curriculum.[3,4] There has also been a review of undergraduate education through the Learning and Teaching Academic Standards Project.[5] In both cases, individual RACI members and chemistry professionals, including school teachers, and RACI working party and workshop, have articulated the unique nature of chemistry and the need for chemistry education as a separate subject.

1 K. F. Lim, "The underlying assumption in chemistry education", *Chem. Aust.,* 2012, **2012 (February)**, 39.

2 H. Föllmer, F. Mathey, H. W. Roesky and J. Troe (ed.), *Chemistry and Mathematics: Two Scientific Languages of the 21st Century,* Deutschen Akademie der Naturforscher Leopoldina (German Academy of Natural Scientists Leopoldina), Halle (Saale, Germany), 2003, Nova Acta Leopoldina N. F., Bd. 88, Nr. 330.

3 ACARA, Australian Curriculum, Assessment and Reporting Authority (ACARA), *Australian Curriculum: Science (F-10),* <http://www.australiancurriculum.edu.au/Science/Curriculum/F-10>, 2011 (accessed April 2011).

4 ACARA, Australian Curriculum, Assessment and Reporting Authority (ACARA), *Draft Senior Chemistry National Curriculum,* <http://www.australiancurriculum.edu.au/SeniorYears/Science/Chemistry>, 2010 (accessed June 2010).

5 S. Jones, B. Yates and J.-A. Kelder, *Science: Learning and Teaching Academic Standards Statement*, Australian Learning and Teaching Council, Strawberry Hills (NSW), 2011 <http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-science-2011>.

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