Chemistry as a foreign language (Note †)

Many chemistry words look and sound like English, but are really a different language.[2] For example, in common Australian English, salt refers to sodium chloride of biological purity, but in chemistry, salt usually refers to an ionic compound, which might or might not be soluble, and may be various grades of purity: *acid plus base gives salt plus water*. The language of science is full of examples where the scientific meaning is different from the common meaning. An object that absorbs all radiation is called a black body in physics and in physical chemistry. Conservation of energy means that the black body will also emit radiation, but does so across the entire electromagnetic spectrum. This emission is called white light: a black body emits white light.

Professor Alex Johnstone, of the University of Glasgow, has found that students from an English-as-a-second-language (ESL) background have difficulty learning chemical terminology and the associated concepts and ideas. However, native English speakers also have difficulty, though to a lesser extent.[3-6]

In any discipline, students will need to learn new vocabulary, such as enantiomer, ligand, molecular formula, monomer, neutron. While this is tedious, it is essentially rote learning and recall, which is the easiest type of thinking task,[7,8] and students cope relatively well with this. The problem arises with words, which have a different meaning in common Australian English, such as salt or sugar. Even more problematic are words, which have more than one variation in meaning. Consider the common English word, *wind*. When using a Craig tube to separate crystals from solvent in a re-crystallisation, a student has to *wind* a piece of wire around the plastic plug part of the Craig tube. The word, *wind*, has several meanings, including: an air movement; scent or smell (get wind of); breath or breathing; empty talk; flatulence; a type of musical instrument; bend or turn; twist; blow (wind a horn). The student is required to *bend or turn* the piece of wire *into a spiral* around the plastic plug.

Philip Ponder, of Penleigh and Essendon Grammar School, has identified a fourth type of confusion, when a word might have more than one variation in *chemical* meaning.[9] It is generally accepted that there has been increasing levels of carbon dioxide in the atmosphere since industrialisation. As a consequence, the concentration of dissolved carbon dioxide in the oceans has also increased, leading to what some have called *ocean acidification*,[10] with serious impact on ocean organisms.[11] We want students and the general public to understand these phenomena, but the use of the words, *acid* and *acidification*, are confusing to teachers, students and the general public.[9]

The most common non-scientific understanding of the words, *acid* and *acidic*, is that they refer to pH values below 7. This non-scientific meaning of *acid* is based on the ratio of H_3O^+ and OH^- ions, and thus linked to the (scientific) Arrhenius meaning of *acids* and *bases*, being sources of H_3O^+ and OH^- ions when dissolved in water. The ocean pH is currently between 8.05 and 8.10, and dropping at about 0.1 per century,[12] which means that it may be several hundred years before the ocean pH drops below 7 to become Arrhenius-acidic. This fact permits the climate change deniers to claim that scientists are exaggerating or falsifying climate, atmospheric and oceanographic data.[9,13]

A second scientific meaning of *acid* is that of a donor of H^+ moieties. For example, CH_3COOH can donate H^+ moieties to water molecules, forming H_3O^+ ions. (The H^+ has no independent existence as an ion, but is merely the moiety being donated from the CH_3COOH to water.) Thus in this Lowry-Brønsted meaning of *acid*, it is possible for a liquid to become *more acidic* as the

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concentration of H^+-donating species, such as dissolved carbon dioxide, increases. Finally there is the Lewis meaning of *acid*, which is as an electron-pair-accepting species.

Confusion arises because scientists are using the Lowry-Brønsted dialect of chemistry language, while the general public and climate-change deniers are using common Australian English. If students are to successfully learn and understand chemical concepts, they must also have an appreciation of these languages. Many school chemistry and tertiary teachers and educators have argued that teaching students about communication is not their job, but rather that of the English teachers.[14] Not so. The new National Curriculum makes it very clear that part of learning science and chemistry is to learn how to communicate scientific ideas and information for a particular audience and purpose,[15] which includes using words with implied meanings appropriate for that audience. At university level, the Academic Standards have equivalent learning outcomes.[16,17] We cannot delegate this task to the English faculty. We have to help our students learn this foreign language, called chemistry.

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