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This is a summary of the lecture given to the Didactics Division of the Italian Chemical Society School on Education Research and Chemistry Didactics, Rome, which with summaries of the other talks was included in Chimica nella Scuola (published by Società Chimica Italiana)

A video of the full presentation may be viewed at:

https://science-education-research.com/publications/miscellaneous/alternative-conceptions-of-the-chemical-bond/

Keith S. Taber
Emeritus Professor of Science Education, University of Cambridge
kst24@cam.ac.uk

A ‘compound’ of learning impediments: alternative conceptions of the chemical bond

The lecture discussed student thinking about chemical bonding, and, in particular, how a range of alternative conceptions commonly exhibited by students can be understood to be linked into a general conceptual framework for understanding chemistry - a framework that is inconsistent with canonical science.

As background, the lecture briefly discussed the significance for teaching of learners’ alternative ways of thinking (‘misconceptions’) in terms of how learning is an interpretive, incremental and iterative process [1]; and how ‘teaching-learning’ needs to be understood as a system where teaching is informed by assumptions about what a person already knows and understands, and how they will interpret new subject content. Such a system is susceptible to system ‘bugs’ or learning impediments. A particular challenge in chemistry teaching concerns what is sometimes known as the chemist’s triplet: how phenomena observed at the bench are both (i) redescribed in a theoretical conceptual language; and (ii) explained in terms of unseen, conjectured entities (‘quanticles’) at a submicroscopic scale; and (iii) represented in a specialised symbolic language, part of which is shared by (and so can bridge) the macroscopic and quanticle level descriptions [2]. Chemical bonding is commonly discussed as if a property of actual substances, but strictly belongs to the quanticle level descriptions.

A common way of thinking about ionic bonding was described, and it was explained how this amounts to a conceptual framework (a ‘molecular’ framework) based on several common alternative conceptions that collectively offer a coherent account, albeit one at odds with curriculum science. This was linked to a ubiquitous type of image (see Figure 1), often seen on websites and in textbooks, which inappropriately associates ionic bonding (for example,

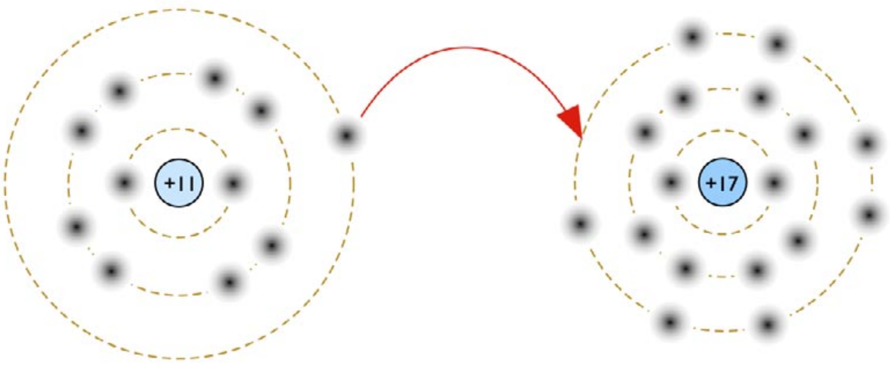

Fig. 1 A common type of representation of ionic bond formation that is based on an assumption of sodium and chlorine existing as discrete atoms that somehow seek to obtain octets/full outer shells of electrons despite the process illustrated being energetically non-viable.

in NaCl) with an unlikely and energetically non-viable electron transfer event involving isolated atoms of sodium and chlorine.

This example reflects two misleading principles that students very commonly adopt in chemistry. One of these is *the assumption of initial atomicity*, which involves thinking about chemical reactions as starting with atoms - despite very few substances being atomic under common conditions, and those that are (e.g., He, Ne, Ar) tending to be largely chemically inert. The other tenet is *the full outer shell explanatory principle* which explains chemistry in teleological terms, seeing the purpose of chemical processes as to allow atoms to obtain full outer shells or octets of electrons. Students readily adopt this principle even though most reactions they learn about in introductory chemistry have reactants in forms already having these 'desirable' configurations. Yet this is not obvious to students if they imagine reactants in the form of discrete atoms rather than molecules, ions, or metallic lattices. This is often an anthropomorphic form of explanation: that reactions happen because atoms 'want' or 'need' to donate, share, or accept, electrons to obtain octets or full outer shells. Indeed, these alternative conceptions tend to form an extensive conceptual framework [3] - that is, a

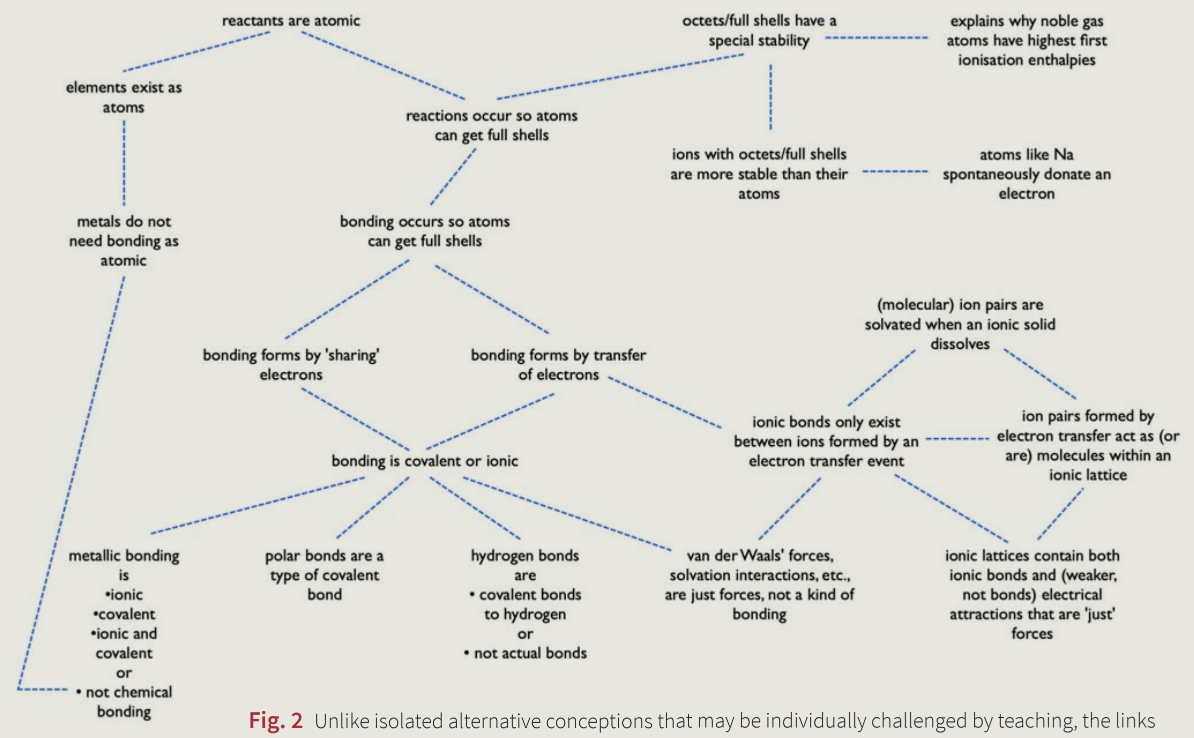

Fig. 2 Unlike isolated alternative conceptions that may be individually challenged by teaching, the links that 'compound' an alternative conceptual framework are mutually reinforcing, making it more difficult for learners to shift their thinking.

'compound' of *connected* ('bonded') alternative conceptions, rather than just an assortment of discrete ideas - that is applied widely (see Figure 2). It leads to seeing ionic and covalent bonding as a dichotomy that makes learning about bond polarity difficult, and which may suggest that hydrogen bonding is covalent, and that metallic bonding, solvation forces, and intermolecular interactions, must be something other than chemical bonding.

This 'octet' conceptual framework (which subsumes the molecular framework for ionic bonding) leads to students making incorrect, and sometimes extreme, predictions of ionic stability (so Na^{7-} is often considered chemically stable as it has an outer shell octet - despite being a highly charged metallic anion). It is also applied in explaining patterns in ionisation enthalpies: so, for example, explaining that Ne and Ar have the highest ionisation energies in their periods because of some mystical special stability of their octet structures (despite these elements fitting with the general 'trends' of increasing first ionisation energy with increasing core charge).

Being a 'compound' of linked and mutually reinforcing conceptions [4], these alternative ideas are especially insidious, and so are often retained despite teaching.

References

[1] K. S. Taber, *Student Thinking and Learning in Science: Perspectives on the nature and development of learners' ideas*, Routledge, New York, 2014.

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[4] K. S. Taber, in *Concepts of Matter in Science Education* (Eds. G. Tsaparlis, H. Sevian), pp. 391-418, Springer, Dordrecht, 2013.

Video

Per il video della relazione completa, clicca il seguente link: https://science-education-research.com/publications/miscellaneous/alternative-conceptions-of-the-chemical-bond

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