STUDENTS' CONCEPTIONS OF IONIC BONDING

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INTRODUCTION

Chemical bonding is an abstract topic, something far removed from the daily experiences of secondary school students; one cannot see an atom, its structure and how it reacts with other atoms. Thus, many students have difficulty in understanding the concepts in chemical bonding, and there is great likelihood for the formation of alternative conceptions. Teachers need to be aware of their students' conceptions of chemical bonding in order to develop teaching strategies to enable their own students to construct ideas of chemical bonding which are compatible with the scientific concepts. This article discusses students' conceptions of ionic bonding and presents some suggestions for chemistry teachers to help students better understand ionic bonding.

REVIEW OF RESEARCH

Students' alternative conceptions

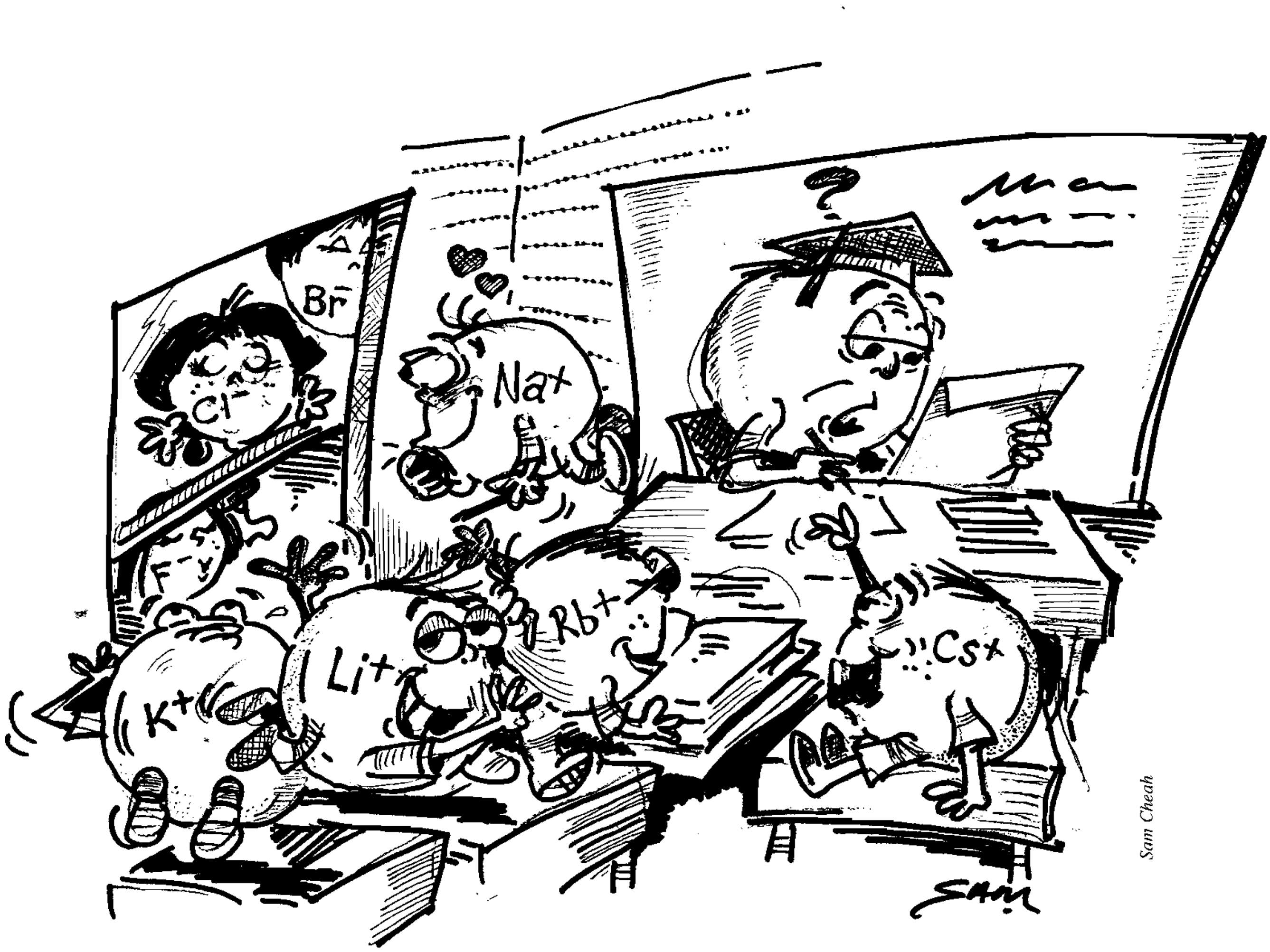
Previous research has identified a range of difficulties associated with understanding ionic bonding. Butts and Smith (1987) found that most Grade 12 Chemistry students associated sodium chloride with ionic bonding and the transfer of electrons from sodium to chloride, but many did not understand the three dimensional nature of ionic bonding in solid sodium chloride. A few students thought sodium chloride exists as molecules, and these molecules were held together in the solid by covalent bonds. Others thought that sodium and chlorine atoms were bonded covalently but that ionic bonds between these molecules produced the crystal lattice. A three dimensional ball-and-stick model of sodium chloride also caused confusion among the students as many interpreted the six wires attached to each ball (ion) as each representing a bond of some sort.

Taber (1994), in interviews involving A-level students, found that many students adopted a molecular framework for ionic bonding. He found that many students believed that:

1. The atomic electronic configuration determines the number of ionic bonds formed, for example, a sodium atom can only donate one electron, so it can form only one bond.

2. Bonds are only formed between atoms that donate or accept electrons, for example, in sodium chloride, the chloride is bonded to the specific sodium atom that donated an electron to it.

3. Ions interact with the counterions around them, but for those not ionically bonded these interactions are just forces. For example, in sodium chloride, a chloride ion is bonded to one sodium ion and attracted to a further five sodium ions, but just by forces and not bonds.



Students' Conception of Ionic Bonding

Boo (1998) interviewed 48 students and found that some students had difficulties in picturing and drawing the ionic bond, while others thought that the attraction between oppositely charged ions in an ionic compound results in the neutralisation of the charges, leading to the formation of a lattice consisting of neutral molecules. In another paper, Taber (1996) highlighted that a student thought that sugar contained ionic bonds, perhaps because it is crystalline. Another student stated that protons and electrons were transferred during ion formation. Novel forms of bonding such as 'atomic bonding' and 'magnetic bonding' were mentioned by several students but there was no agreement on what these bondings meant.

Diagnostic instruments

Teachers need to know their students' alternative conceptions in order to help them see the limitations of these conceptions and the advantages that the accepted science concepts have over them. Unfortunately, teachers are often unaware of their students' alternative conceptions. Methods used by researchers to determine students' understanding of concepts include concept mapping, interviews and pen-and-paper tests. Multiple choice or true/false type diagnostic instruments are more readily administered and scored than the other methods, and thus are particularly useful for classroom teachers.

Taber (1997) designed a thirty "true or false" item test, "Truth About Ionic Bonding Diagnostic Instrument" which he administered to GCSE and A-level chemistry students and the results supported his earlier findings (Taber, 1994) and those by Butts and Smith (1987). Taber (1997) believed that many students' understanding of chemistry:

- over-emphasises the process of electron transfer;
- explicitly or tacitly uses the notion of ion-pairs as molecules;
- is restrained by an inappropriate consideration of valency;
- pays heed to an irrelevant "electron history" i.e. the sources and the recipients of electrons which were transferred;
- distinguishes between what are actually equivalent interactions between ions.

Tan (1994) designed a two-tier multiple choice diagnostic instrument to determine O-level chemistry students' understanding of chemical bonding following the procedures prescribed by Treagust (1988; 1995). Tan and Treagust (1999) administered the chemical bonding diagnostic instrument to 119 Secondary Four chemistry students from a secondary school in Singapore. Some of their findings are given below:

- Only 17% of the students pointed out that sodium chloride forms an ionic lattice. A high percentage of them (80.4%) believed that sodium chloride exists as molecules, and 46.1% thought that one sodium ion and one chloride ion formed an "ion pair molecule" (Taber, 1994). Many students (22.5%) also indicated that when atoms of metals and non-metals combine, they form covalent bonds.
- When students were asked to predict the formula of the ionic compound formed from two elements, it was found that 10% of the students thought that the number of electrons transferred depends only on the number of electrons that the atoms of the non-metal need to achieve a stable octet. In another similar question involving the prediction of the structure of an ionic compound, it was found that a few students (4%) were able to apply the octet rule to ensure that both the metal and the non-metal ions had stable octets of electrons, but did not consider the ratio of the metal and non-metal ions required.

Sources of students' alternative conceptions

Many of the findings from the local study by Tan and Treagust (1999) are similar to that by Taber (1994; 1997) and Butts and Smith (1987). This seems to imply that students from different parts of the world have similar alternative conceptions. It is very likely that these alternative conceptions arise due to similar methods of teaching and/or presentation of content in textbooks (Taber, 1997; Tan & Treagust, 1999) as students only encounter ideas about bonding during formal instruction.

Taber (1994) believed that the way in which teachers present their lessons on ionic bonding may have encouraged their students to develop the above alternative conceptions. Teachers illustrate ionic bonding by drawing the transfer of an electron from a sodium atom to a chlorine atom to form a positive sodium ion and a negative chloride ion. They then point to the pair of ions and say that the sodium and chloride ions are attracted together by strong electrostatic forces. Thus the picture of a discrete unit of sodium chloride can be implanted in the minds of the students. Ionic lattices typically are only introduced a few lessons later when the students learn about the structure of solids, but many of them would not make the link between the formation of ionic bonds and ionic lattices. Covalent bonding is taught before ionic bonding in most schools and Taber believes that the teaching of covalent bonding with its emphasis on valency and molecules influences the adoption of molecular ideas in ionic bonding. In addition, Boo (1994) suggested that the lack of understanding of what chemical formulae represent also contributes to the problem. For example, ionic sodium chloride is represented as "NaCl" which is very similar to covalent hydrogen chloride "HCl", and so students might have the idea that one particle of sodium is bonded to one particle of chlorine just as one atom of hydrogen is bonded to one atom of chlorine.

Got it !

CONCLUSION

Chemistry teachers need to be conversant with research investigating students' alternative conceptions in the various chemistry topics. They also need to determine their own students' understanding of the topics; they can either design their own diagnostic instruments or use what is available in the literature. Besides the diagnostic instruments on ionic bonding (Taber, 1997) and chemical bonding (Tan, 1994; Tan & Treagust, 1999) there is also another on covalent bonding and structure for A-level chemistry (Peterson, 1986). This was used by Peterson and Treagust (1989), Goh, Khoo and Chia (1993) and Birk & Kurtz (1999) to determine students' alternative conceptions in bond polarity, shape and polarity of molecules, intermolecular forces and the octet rule.

IMPLICATIONS FOR TEACHERS

The following strategies may help to minimise alternative conceptions in ionic bonding (Taber, 1994, 1997; Tan & Treagust, 1999).

1. ***Focus on the electrostatic lattice forces, rather than ion formation***
   Teachers should emphasise the non-directional nature of the ionic bonds and clearly distinguish between ion formation (electron transfer), and ionic bonding. Include an example of an ionic material formed via precipitation, for example, barium sulphate (VI), to emphasise that ionic bonds can form even if no electron transfer takes place between the barium and sulphate (VI) species.

2. ***Do not restrict diagrams to those showing molecular-like entities (pairs of atoms and pairs of ions), but include ensembles of ions.***
   Encourage students to draw out the "molecules" of ionic compound and have their attention focussed on the fact that the metal atom cannot achieve a stable octet if it forms covalent bonds.

3. ***Make sure that if the "reason" for ion formation is the stability of noble gas electronic configurations, this is not also considered sufficient reason for the subsequent formation of bonds between ions.***
   For example, a sodium ion does not only form one bond with the chloride ion it transferred its electron to.

4. ***Discuss the differences (as well as similarities) between lattices held together by ionic, covalent and intermolecular forces.***

5. ***Discuss explicitly the meaning of electrovalency in terms of ionic charge formed, and compare this with covalency.***
   Make it clear that the number of ionic bonds formed is not determined by electrovalency.

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