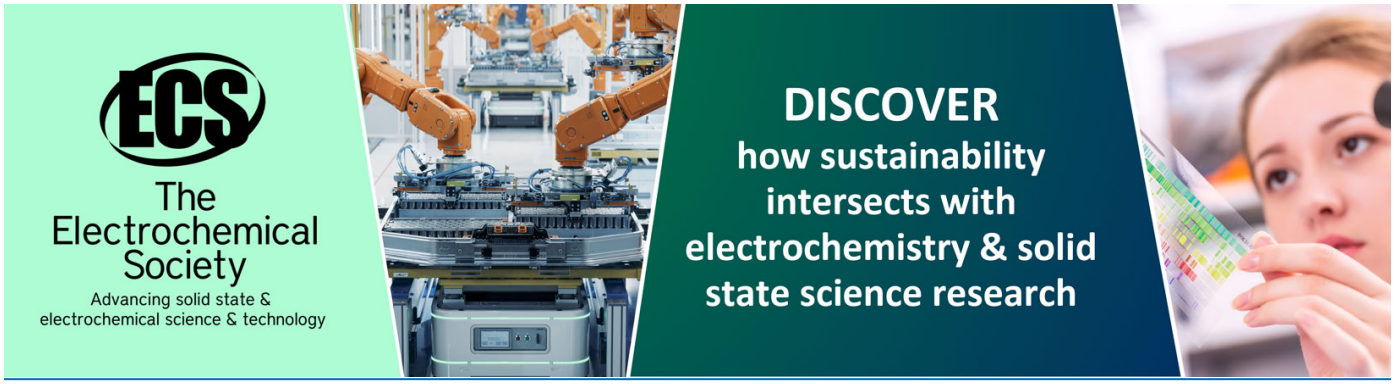
Misconceptions and threshold concepts in chemical bonding



Misconceptions and threshold concepts in chemical bonding

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Abstract. In the last few decades, research has shown that chemical bonding is a difficult concept for students that can lead to misconceptions. The purpose of this research is to know the misconceptions and threshold concept in chemical bonding from various research studies and teacher experiences. This study uses a qualitative method including document analysis which mostly the journal articles which presented research studies about misconceptions. Beside, this study also conducted a clinical interview with three chemistry teachers to get information from a real practice. Based on the analysis of the journal, the book and the interview with chemistry teachers, there are a frequent misconceptions of the chemical bonding such as: ionic bonding was sharing electron; there is a transfer of electrons in covalent bonding; the atoms of Na and Cl attract each other and form NaCl; covalent bonding have very different electronegativity; equal sharing of the electron pair occurs in all covalent bonding; and metallic bonding was a transfer of electron. Meanwhile, the threshold concepts for chemical bonding are periodic properties of the elements, electron configuration, and metal/non-metal/metalloid.

1. Introduction

In the last few decades, research has shown that chemical bonding is a difficult concept for students. Chemical bonding is one of the subjects that has a very varied discussion ranging from simple one to abstract and complex [1]. In general, students have difficulties when studying chemical bonding. Students find it difficult to provide a correct explanation of the phenomenon of bonding and the process of bonding formation [2]. More specifically, students have difficulty defining ionic bonding, covalent bonding or polar covalent bonding [2,3]. Students also have difficulty when describing chemical compound in the three levels of chemical representation which is macroscopic, submicroscopic and symbolic level. They cannot see the connection between those particular levels. Finally, they tend to build non-scientific mental models in chemical bonding [1].

Student's difficulties can be sourced from the threshold concept that students do not understand. Threshold concept can be considered as a concept similar to a gate, opening up new ways of thinking about a subject that was previously inaccessible and potentially become a difficulty for students [4]. Threshold concept can be identified using two ways, that are through professional reflection on the nature of subject as a conceptual entity based on curriculum and identify student conception inductively through analyzing students responses based on their own experience [5]. The main objective in identifying the threshold concept for a discipline is to provide a starting point for focusing on redesigning the curriculum, since a deliberate approach to teaching the threshold concept is likely to result in the greatest improvement in student learning [6,7].

Less understanding of the threshold concept in chemical bonding can lead to misconceptions. The misconception is a wrong concept and is incompatible with scientific concepts [8]. The misconception is not a brief idea, but more resistant to change [2]. Other terms used in the literature to describe this idea include misunderstanding, naive conceptions, alternative conceptions, conflicting notions, classroom mismatches, erroneous conceptions, children's science, and intuitive beliefs [9]. For simplicity, in this article we will use the term misconception which means a concept that differs from the scientific concept. The purpose of this research is to know the misconceptions and threshold concepts in chemical bonding from various research studies and teacher experiences.

2. Method

This study uses a qualitative method including document analysis such as journal articles and book. Some journals of misconceptions in chemical bonding and journal of threshold concept was analyzed, while the book analyzed is "Misconception in chemistry" by Hans-Dieter Barke. Beside, this study also conducted a clinical interview with three chemistry teachers to get information from a real practice.

3. Results and discussion

3.1. Misconceptions in chemical bonding

In this article, we will discuss the misconceptions on chemical bonding identified from several sources that are research studies, book, and chemistry teachers. The misconceptions in chemical bonding identified from the research studies such as students think there is an equal attraction of shared electrons from atoms participating in the covalent bond. This is valid for all types of the covalent bonds, but students have not considered the influence of electronegativity [10]. These results are consistent with Al-Balushi *et al.*'s [11]; and Peterson and Treagust's [12] findings. Nicoll [2] has also investigated students' misconceptions of chemical bonding and revealed that students believed ionic bonding was a sharing of electrons, and this misconception is consistent with Coll and Taylor's [13]; Luxford and Bretz's [14]; Vrabeck and Proksa's [15] findings.

Luxford and Bretz [14] have investigated student's misconceptions in chemical bonding that are covalent bonds have very different electronegativities; covalent CCl_4 has a transfer of electrons; and covalent PCl_5 also has a transfer of electrons. These misconceptions are consistent with Vrabeck and Proksa's [15] findings, there are 16.9% of students argue that covalent bonds have very different electronegativities; and 12.5% of students think that there is a transfer of electrons in covalent bonding. While Peterson *et al.*[10] reported that 22% of grade -11 held misconceptions, that is the polarity of a bond is dependent on the number of valence electrons in each atom involved in the bond; and 26% of grade-11 assume that ionic charge determines the polarity of the bond.

In another study, Taber [16] reported that students tended to classify bonds as either covalent or ionic; students also assume that metals also had covalent or ionic bonding. Furthermore, Nicoll has investigated students' misconceptions and found that when there are two atoms near each other that are opposite in polarity, they repel each other; when you have two electrons, they're negatively charged ions [2]. They don't want to come together. But sometimes they do, and that's a chemical bond; and the only types of bonding were hydrogen bonding and glycosidic bonding. Coll and Taylor have investigated students' misconceptions in chemical bonding that are continuous metallic and ion lattices are molecular in nature; and molecular iodine is metallic in nature [13].

Al-Balushi *et al*. reported that more than one-third of sample thinks that bonds could be broken into two parts; the majority of participants (68.2%) could not identify the correct covalent bonding between sulfur and oxygen in the sulphuric acid [11]. Some of them reasoned that sulphuric acid ionized completely in water support the expectation that the bond type between the sulfur and oxygen atom in sulphuric acid is ionic (or hydrogen bond). Another misconception is that 28.9% of participants assume that there is a covalent bond between the calcium atom and the chlorine atom in $CaCl_2$. Furthermore, Luxford and Bretz [14] found a misconception that occurs in chemical bonding that carbon is more electronegative than chlorine; and only 1 Na and 1 Cl can bond.

In another study, Bouayad *et al*. found 21% of students argue that there are two types of chemical bonds (σ and π), besides those students also reduced the definition of chemical bond in the covalent bond by saying that chemical bond is defined as the sharing of two electrons. In addition, there are some students who reduced the definition of chemical bond in ionic bond by saying that chemical bond is an electrostatic force that binds the atoms or the ion [17]. Furthermore, Vrabeck and Proksa conducted a study of students in Slovakia to identify misconceptions on chemical bonding and found that NaCl is a molecule for 17.6% of students; and 21.1% of students argue that the atoms of Na and Cl attract each other and form NaCl [15].

The finding of Vrabeck and Proksa are consistent with the misconceptions from the book entitled "Misconception in chemistry" by Hans-Dieter Barke that is sodium chloride consists of sodium and chlorine atoms [15] [8]. Each chlorine atom takes an electron from the sodium atom so the chlorine atom will have a negative electrical charge, the sodium atom a positive one; Regarding the question which particles are found in mineral water which contains calcium chloride, many students answer ‘‘Cl-Ca-Cl molecules’’. In studying the chemical bonding most of the elaborated bonds involve electron pairs and only slightly describe ionic bond. So that the students will not have the concept of ion bonds are durable. Teachers are more focused on explaining covalent bonds than ionic bonds so that many students have difficulty explaining ionic bonds and causing students misconceptions on ionic bonds. In interviews with chemistry teachers, it was learned that many students had difficulty in differentiating ionic bonds and covalent bonds, and also in differentiating metallic bonds and ionic bonds. Thus, found misconceptions in chemical bonding that students assume that HCl has a transfer of electrons; HCl is an ionic compound; and metallic bonding has a transfer of electrons.

The misconceptions can be expected because learning only focuses on a symbolic level without involving macroscopic and submicroscopic levels of chemical representation. Students also have difficulty in connecting the three levels of chemical representation which is macroscopic, submicroscopic, and symbolic. Students cannot see the connection between those particular levels, so students tend to build non-scientific mental models in chemical bonding [1]. Previous research has shown that helping students in connecting the three levels of chemical representation led to successful learning [18]. On the other hand, textbooks used by students can also be a source of misconceptions. The way chemistry concepts are presented to students in textbooks that not accompanied with submicroscopic level can lead to misconceptions in students. Other possibilities that could be a source of misconceptions other than textbooks are teacher instruction, language and words, daily life experience, social environment, causal effect and intuition [19].

3.2. Threshold concepts in chemical bonding

Threshold concept of chemical bonding is identified from research study and interviews with chemistry teachers. Information obtained from interviews with chemistry teachers based on teaching and learning experiences that threshold concepts for chemical bonding are electron configuration, periodic properties of the elements, and metal/ nonmetal/metalloid. Teachers said that students cannot understand the concept of chemical bonding and will have difficulty in learning it without understanding the threshold concept in chemical bonding first. These findings are consistent with Park who has studied toward 20 high school chemistry teachers and found seven concepts identified as threshold concepts in high school level chemistry: mole, ideal gas law, periodic table, atomic structure and electron configuration, orbital, chemical bonding and chemical equilibrium [20]. When teachers were asked about the transformative features of chemical bonding, they mention the related concepts to describe the conceptual changes in their learning experience. The related concepts to chemical bonding mentioned by the teachers are periodic table, properties of atoms, and metal/non-metal/metalloid.

Threshold concept can be considered as a concept similar to a gate, opening up new ways of thinking about a subject that was previously inaccessible and potentially become a difficulty for students [4]. Based on the definition of threshold concept, interviews with chemistry teachers, and analysis of research study, it can be concluded that threshold concepts for chemical bonding are electron configuration, periodic properties of the elements, and metal/non-metal/metalloid. In this article, there

are misconceptions and threshold concept in chemical bonding from several sources, such as journals, book, and chemistry teachers, so for further research can be confirmed directly to students about misconception and threshold concept in chemical bonding.

4. Conclusion

The most common misconceptions in chemical bonding such as: ionic bonding was sharing electron; there is a transfer of electrons in covalent bonding; the atoms of Na and Cl attract each other and form NaCl; covalent bonding have very different electronegativity; equal sharing of the electron pair occurs in all covalent bonding; and metallic bonding was a transfer of electron. Meanwhile, the threshold concepts for chemical bonding are periodic properties of the elements, electron configuration, and metal/non-metal/metalloid.

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