Problems In The Understanding Of "Chemical Bonding" From The Chemistry Textbook

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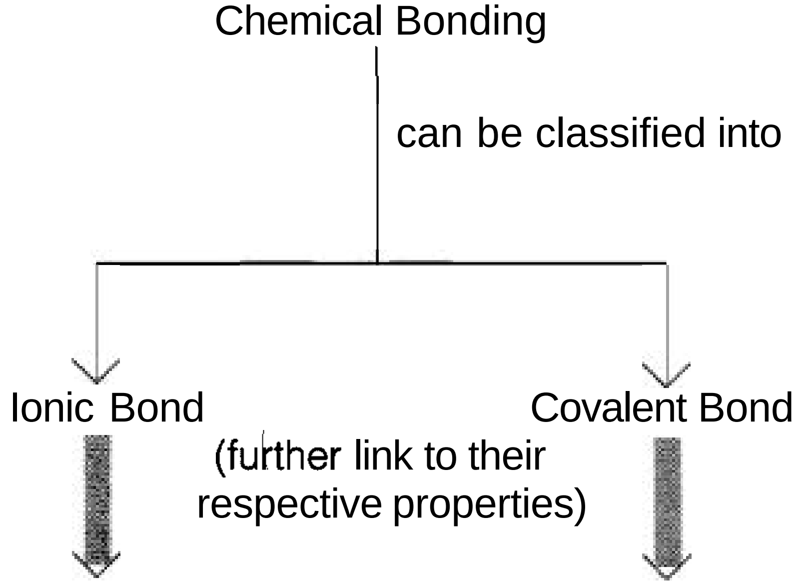
Introduction

Chemistry teachers and students share the common perception that chemical bonding and its related concepts are some of the difficult topics to be dealt with (Goh & Chia, 1989). Although students are confident in repeating the definitions of the terms used under the topic 'chemical bonding', they encounter problems in actual understanding of the physical meaning of the terms and consequently problems in applying appropriately these concepts learnt. What could be the origin of such problems?

In one of the post tests in our research project on 'learning strategies', one group of secondary three students, who had just completed the learning of the topic on 'chemical bonding', was asked to draw their own concept maps to show link among ionic and covalent bonds and their related concepts. With some exceptions most students presented their maps in the following pattern:



Such cognitive structure, no doubt, is a reflection of the consequence of certain learning pattern taking place during the process of teaching and learning this topic. Could this provide a hint to a partial solution to the problems mentioned above?

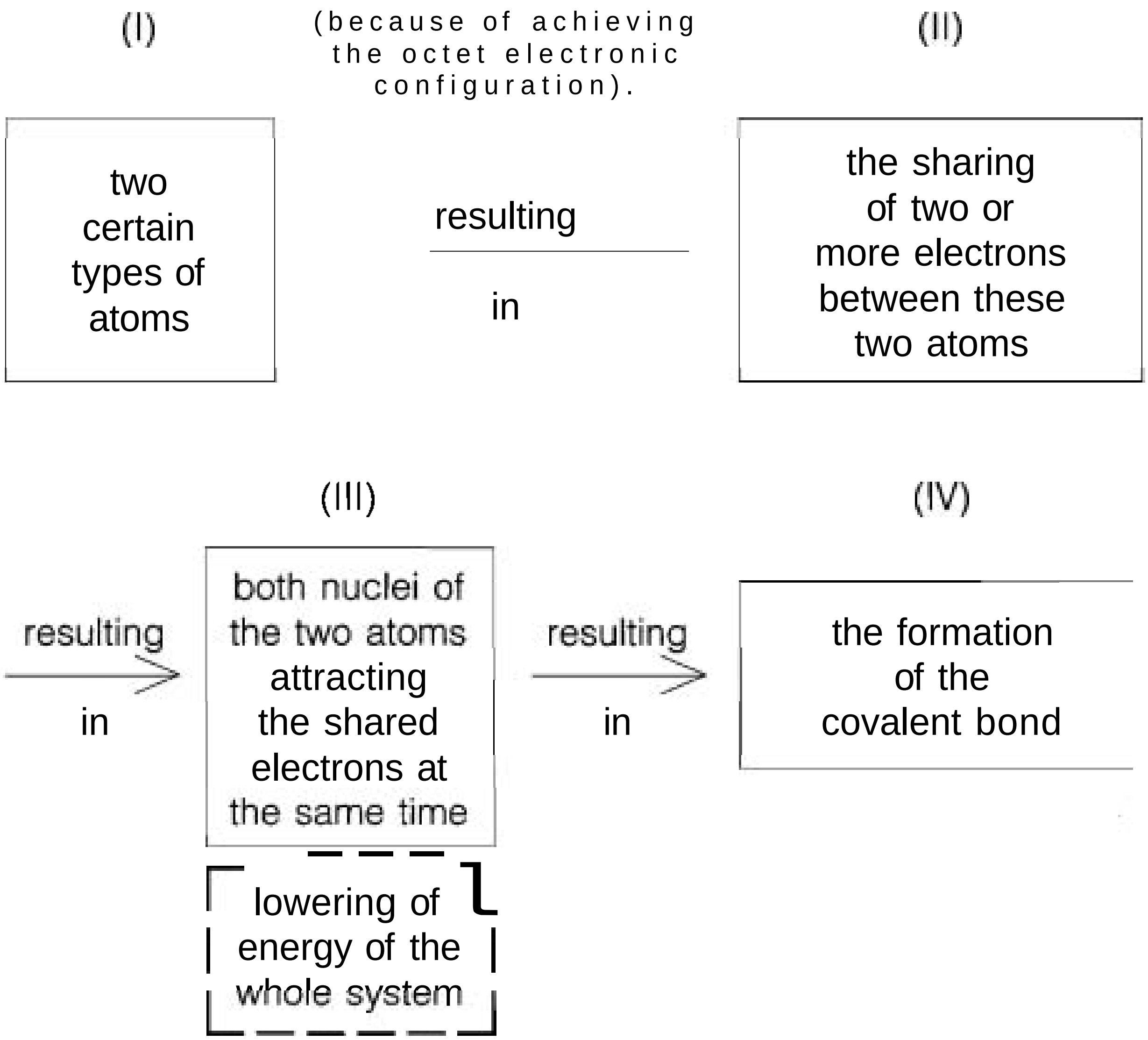
Problems and Consequences

The structure of the map given above adheres closely to the sequence presented in many of the standard textbooks approved by the MOE (1988), i.e. each type of bonding and then followed by the general properties of those compounds possessing the respective type of bonding. Out of the map, there is no real indication whether students who show the correct classification, are able to distinguish the essential difference in characteristics between the ionic bond and the covalent bond. If we ask students what is ionic bond and what is covalent bond, they will promptly provide us the following standard definitions given in the textbooks:

Ionic bond is formed by complete transfer of electrons from one atom to another or when atoms gain or lose electrons to attain a stable octet.

Covalent bond is formed when electrons on the two combining atoms are shared.

But if students are queried about the nature of these bonds, their extent of understanding is shown to be limited. In the case of ionic bond, the process of how it is formed has usually been illustrated clearly in the textbooks. Hence, the physical meaning of ionic bond is much more concrete in the sense that it is some sort of force resulting from the attraction of two different, oppositely, charged particles. To accept this concept is not a problem for students. But it is not the case for the covaient bond. How can the sharing of electrons lead to the formation of a bond? Because of both atoms involved in bonding achieving the octet electronic configuration – Is this the answer? In fact, the cause-effect relationship should read as follows:



The lack of (III) in many textbooks confuses students about the nature of covalent bond. Hence it is not surprising that

(i) a lot of students have the misconception that ionic bond is stronger than covalent bond, and

(ii) students cannot distinguish the difference between intermolecular forces and intramolecular forces.

2. Even though the concept of ionic bond can be accepted easily by students, sufficient evidence show that they have difficulty in comprehending the term 'ions'. They even confuse ion with atom and molecule (Garforth, Johnstone and Lazonby, 1976). Usually before introducing the ionic bond or covalent bond, the textbook writer will describe briefly how the stability of the

electronic configuration of atom relates to octet rule, using very specificlstandard examples, e.g. sodium, chlorine etc. This will then lead to the discussion of formation of ionic bond or covalent bond. In between, insufficient practice has been given to students to consolidate the change of electronic configuration resulting from the octet rule. And, in general, the nature of 'ions' has always been described as 'charged particles', but its origins as 'charged particles' have usually been ignored.

3. With regard to the properties of ionic compounds/covalent compounds, such information is usually listed out one by one in the textbooks without having much explanation. Consequently, students can remember the properties well but fail to apply them, especially in a newlunfamiliar situation. It is not surprising when we interview students why there is this or that property of a particular compound, the answers are either 'uncertain' or 'don't know' (Chng, 1989). This poor ability in applying the concepts related to the properties of the compounds could also be associated with the poor understanding of the physical meanings of covalent bond and ions which have been discussed above. The use of very specificlstandard examples as .mentioned in problems 2 tends to promote the idea 'these are the only . . .' and hence students tend to fall back to those examples and consequently weaken their ability and confidence in the application of concept in a new/unfamiliar situation.

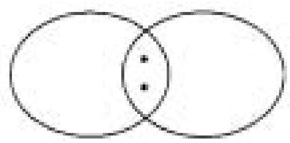
How to tackle the problem?

To solve the problem of understanding the physical meaning of 'ion', the process of formation of ion from the atomlatoms should be appreciated by the learner. Hence sufficient practice is necessary in order to internalize the concept of ion. Students can be asked to get a list of changes by using the following relationship as well as the elements in the periodic table as a data base:

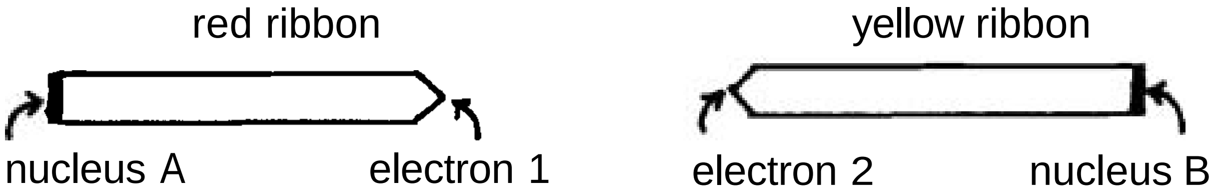
$$\text{positive ion} \xleftarrow{-ne^-} \text{Atom} \xrightarrow{+ne^-} \text{negative ion}$$

Furthermore, the illustration of the nature of ions could make students ease in distinguishing ions (charge'with volume) from positive charge or negative charge (charge without volume). The use of models/diagrams could be useful in clarifying the difference between ion (with electric field) and atom and molecule (without electric field). The magnetic ring could be ideal to represent an ion since the field can be made visualized. Similarly, the use of molecular models can be used to highlight the difference between intermolecular forces and intramolecular forces.

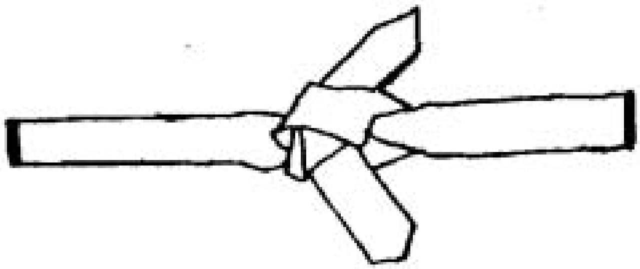
With regard to the introduction of covalent bond, the highlighting of the statement given in (III) is crucial since this will provide the reason why the two participating atoms are bonded in this way. Ideally, the teacher should point out that as a result of (II) and (III), the energy of the whole system is lowered. This results in the formation of the covalent bond. But at this level, students are not mature enough to accept such relationship, and hence we may temporarily omit this aspect. Though the diagram showing the outermost shells and bond electrons, such as:



is commonly used for illustration, more concrete aid could be used to show the bond, e.g.



Two different colours of ribbons will be used to present the two different atoms from the respective elements. Both will be cut in shape as shown in the diagram. The flat and darker end simulates the position of nucleus, while the end with the shape  represents the electron. The length of the ribbon could represent the attraction between nucleus and electron. If the two ribbons are tightened together as follows,



they simulate the formation of a covalent bond. Students can even be asked to pull the two tightened ribbons in opposite direction to get the feeling of bond. This is one of the advantages of using this simulation. Instead of tightening the two ribbons, if each adhesive-based fastener is being pasted on the position of each ribbon where electron is located, the simulation of the formation of a covalent bond can be easily carried out by just putting the two fasteners together.

3. Although the use of specific examples for illustrations of the formation of bonds is unavoidable, we should bear in mind that students should be given a chance to generalize what is being learnt. The use of the periodic table as a data base has been illustrated in Point 1. Furthermore, under certain circumstances, we should turn away from textbook style. Let students create their own situation, e.g. select their own examples, such as any element from the periodic table, could be a solution to the problem of application.

4. Finally, the problems with the understanding of the properties of particular type of chemical bonding lie fundamentally on the fact that these concepts are abstract and complex and it requires time to digest, consolidate and understand. As a result, we would like to suggest that a spiral curriculum can be adopted. Concepts like 'dissolving' and 'conducting electricity' etc. can be introduced at a specific time. If the process of

'dissolving' or 'conducting electricity' have to be explained clearly to the secondary three students the use of aids/models is necessary. In the case of 'dissolving', model of molecules, e.g. H_2O, and lattice, e.g. NaCl, can be used to illustrate how interaction takes place and the consequence of such interaction. In the case of 'conducting electricity', a recall on how a simple circuit (one battery, one bulb and a wire) works could help students further build the new knowledge upon the old experience. However, guiding students to focus on the essential change is also important. Here, the role of electron (e.g. the movement of electron in the close circuit) should be stressed. Once students have mastered the concept of ion and appreciated the role of electron, the concept of 'conducting electricity' becomes simple.

Conclusion

The above discussion shows clearly that if students learn 'chemical bonding' from the textbook there are certain shortcomings. As a teacher, we should be aware of and alert to such shortcomings, and hence adjust our teaching strategies to overcome them.

References

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