Conception, threshold concepts and troublesome knowledge in chemical reactions topic

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Abstract. This study aims to analyze the conception, threshold concept, and troublesome knowledge in chemical reaction topic. This study uses qualitative methods, document analyses, as well as interviews with chemistry teachers to obtain information about threshold concepts and troublesome knowledge. From the results of the analysis of several journals obtained that there were still many misconceptions encountered when students study chemical reactions. While the results of the interview, threshold concept in chemical reaction consisted of mixtures, physical and chemical properties, material changes, concepts of protons and electrons, electron configurations, chemical bonds, intermolecular forces, attractive forces between charges, compound nomenclatures, chemical formulas, and Lavoisier's laws. While troublesome knowledge includes complexity of particles involved, complexity of interactions that may occur, complexity of applying Lavoisier's Law, and language used.

1. Introduction

A chemical reaction is one concept that is the basis for further learning chemistry because almost all chemical matter always involves chemical reactions. By understanding the concept of chemical reactions students can understand the phenomena that occur around them, for example, photosynthesis, the combustion process, iron solidification, even the digestive processes that occur in the human body. At the beginning of the chemistry learning process, students are introduced to the concept of chemical reactions, usually by the way students carry out their chemical reactions or through teacher demonstrations. However, the reason why chemical reactions occur in general is not at all considered, students are only introduced to the nature of chemical bonds and related ideas of chemical energy [1].

For students to understand chemical reactions, they must distinguish between concepts such as elements, compounds, mixtures, atoms and molecules. Besides, they must also recognize changes in material form and understand that atoms are rearranged to form new substances with different chemical properties [2]. To understand the material in chemistry learning, students need to connect the three levels of chemical representation. Students' ability to connect the three levels of chemical representation reflects the mental models that students have [3]. Mental models are defined as simple representations of ideas in a person's mind that are used to describe and explain a phenomenon [4]. Students use mental models to reason, describe, explain, predict phenomena, test new ideas, and present data based on the knowledge they have to communicate it to others or solve problems in learning chemistry [5,6]. When students can connect the three levels of chemical representation to a concept, students have a complete mental model.
For students to have a complete mental model, the teacher needs to improve the learning strategy continuously. The right learning strategy can be obtained by analyzing the advantages and disadvantages of the learning strategies that have been done before. Based on the results of the analysis, the teacher can find out what conception students have in learning material. While based on conceptual characteristics, a teacher must analyze what is the threshold concept of the concept that students will learn and what can potentially be trouble (troublesome knowledge) in learning the concept. So the purpose of this study is to find out conceptions, threshold concepts, and troublesome knowledge in chemical reactions from various studies that have been done before and from the teaching experience of chemistry teachers.

2. Method
This study used qualitative methods including document analysis such as journal articles. Several conception journals, threshold concepts and troublesome knowledge related to chemical reactions were analyzed. In addition, this study also conducted interviews with four chemistry teachers to get more information related to threshold concepts and troublesome knowledge. Chemistry teachers interviewed were teachers who were or had taught chemical reaction in class. The teacher is given questions that will reveal what are the threshold concepts and troublesome knowledge in chemical reaction. In addition, the teacher is also asked to explain the reasons for the answers. The next step is to make a transcript of interview result. For troublesome knowledge, from some of the teacher's answers are categorized into six categories of troublesome knowledge, namely ritual knowledge, inert knowledge, conceptually difficult knowledge, alien knowledge, tacit knowledge, and troublesome language.

3. Result and Discussion
3.1. Conception in chemical reactions
According to Duit [7], conception is a mental representation of outside world characteristics or theoretical domains. Conception is a manifestation of one's interpretation of an object being observed which often even appears before learning, so it is often termed pre-learning conception. The conception that will be discussed in this article consists of conceptions that are following scientific concepts (the appropriate concepts) and concepts that are not by scientific concepts (misconceptions) in chemical reactions. Conception was identified from several research articles that had been done before. Research conducted by Ahtee and Varjola [2] found that students provide answers that include at least one component that shows a good understanding of chemical reactions, namely atomic reorganizations, breaking and reformation of bonds, and changes in physical or chemical properties. Few students can properly explain the meaning of chemical reactions. Meanwhile, according to Yarroch [8] half of the 14 students he interviewed could correctly explain the relationship of atoms in a molecule (using a circle representing an atom). Research conducted by Chandrasegaran [9] found that students could correctly mention the symbol of an atom. In addition students can also explain that the change in color occurs due to the formation of new compounds. Most students can also write each substance on the reactants and products in the same amount, this shows that students understand about Lavoisier's Law. Students can also write net ionic equations correctly without involving the spectator ion in them.

Research on wrong conceptions or misconceptions about chemical reactions has been carried out by experts. Chandrasegaran et al. [9] show there are 14 misconceptions in chemical reaction because students are still confused in macroscopic and submicroscopic representations. Students tend to guess to predict substances at the macroscopic level to submicroscopic levels, and limited understanding in the representation of symbolic levels. Then when writing the chemical equation Yarroch [8] examined that of the 14 high school students he interviewed, only half were able to represent the arrangement of atoms in the molecule correctly. Although students can write chemical equations and equate equations correctly but do not understand the meaning of these particles. This shows that new students can understand chemistry at the macroscopic and symbolic level, whereas for the submicroscopic level they have not been able to analyze and interpret it. Baah and Ampiah [10] identifies the inability of students
to balance combustion reaction equations involving hydrocarbons, the inability of students to predict the correct product of the reaction due to difficulties in writing the correct formula of the product and the inability of students to translate reactions in the form of statements in symbolic equations.

Katmiati's research [11] revealed several misconceptions that occur in chemical reactions, namely molecules and compounds formed from cations and molecules, polyatomic ions decompose into smaller particles and mistakenly write down ion charges and chemical formulas of a compound. This is in line with the research conducted by Hasanah [12]. She added several misconceptions that occur in chemical reactions, including cations that bind to positively charged atoms and anions will bind to negatively charged atoms, products of aqueous or solids (precipitation) are present as ions, and ionic compounds in solids are present in the form of the molecule.

3.2. Threshold concept in chemical reactions
Threshold concepts can be considered a concept similar to gates, opening up new ways of thinking about subjects that were previously inaccessible and potentially becoming difficulties for students [13,14]. Threshold concepts in chemical reactions were identified from interviews with four chemistry teachers (can be seen in Table 1). Information obtained from interviews with chemistry teachers based on teaching and learning experiences that the threshold concepts for chemical reactions are concept of mixtures, physical and chemical properties, material changes, concepts of protons and electrons, electron configurations, chemical bonds, forces between molecules, attractive forces between charges, compound nomenclatures, chemical formulas, and Lavoisier’s law.

Table 1. Threshold concepts in chemical reactions based on interviews with teachers

| Teacher | Threshold Concept |
|---------|------------------|
| Teacher 1 | Concept of mixtures, physical and chemical properties, material changes |
| Teacher 2 | Concept of protons and electrons, electron configurations, chemical bonds, forces between molecules, attractive forces between charges |
| Teacher 3 | Physical and chemical properties, compound nomenclatures, chemical formulas |
| Teacher 4 | Compound nomenclatures, Lavoisier’s law |

The first teacher said that the concept of mixtures, physical and chemical properties, and material changes had been studied by students during junior high school. In the learning concept of mixtures, the teacher will usually explain solvents, solutes, and various phases of compounds. So when the teacher gives examples of compounds in chemical reactions such as NaCl(aq), students will understand that water is a solvent and NaCl as a solute. The third teacher reveals when students understand changes in physics and chemistry, students can find out what changes occur in a reacted compound. For example, the occurrence of chemical changes can be seen from several observable changes such as color changes, gas formation, the formation of precipitations and changes in temperature. So when shown a chemical reaction that produces precipitations, students can imagine what a chemical reaction might be. Also, by understanding the nomenclature of compounds and chemical formulas students can formulate chemical formulas which will be written in the reaction equation.

The second teacher reveals that students must understand the concepts of protons and electrons to determine the number of protons or electrons in the number of ions. Besides, students must also understand electron configurations so students can determine the number of valence electrons in an element. Because to react to an element or compound, students must know in advance the number of electrons in the valence of these elements. Another concept that becomes the threshold concept in a chemical reaction is chemical bonds. Students must understand chemical bonds to determine the characteristics of compounds when dissolving or settling or forming gases. Also, to find out whether a compound breaks down into ions or forms molecules and also understands the charge of each atom or element in forming a bond. Students must understand that a compound is formed due to the presence of
chemical bonds, this bond is due to the attraction of the atoms in the molecule. If this force is disturbed or given activity, a chemical reaction will occur.

In addition to some of the concepts above, the fourth teacher reveals that students must also understand Lavoisier's Law before studying chemical reactions. Because when students equate the reaction equation, students must know that the number of atoms contained in the compound before and after the reaction or in the reactants and products must be the same as the sound of Law Lavoisier. The results of research on the threshold concept can be used to develop curriculum and teaching materials so that students do not experience obstacles and difficulties in learning [15,16,17].

3.3. Troublesome knowledge in chemical reactions

Meyer and Land [13] suggest that knowledge that is conceptually difficult or problematic for students is called troublesome knowledge. Troublesome knowledge in students will be the main obstacle to learning. Similar to the threshold concept, troublesome knowledge in this study were identified from interviews with chemistry teachers (can be seen in Table 2). Four chemistry teachers revealed the troublesome knowledge of chemical reactions consisting of the complexity of possible reactions, the complexity of the particles involved, the complexity of applying Lavoisier's Law, and the language used.

| Teacher | Troublesome Knowledge |
|---------|----------------------|
| Teacher 1 | The complexity of the reactions that occur, the language used, the complexity of the particles involved |
| Teacher 2 | The complexity of reactions that may occur |
| Teacher 3 | the complexity of applying Lavoisier's Law, the language used |
| Teacher 4 | The language used |

The first teacher revealed that when the teacher gives an example of a simple chemical reaction, students can understand it. But when the teacher gives examples of more complex chemical reactions, students experience difficulties. Besides, the complexity of the particles involved in chemical reactions also causes students to experience troublesome knowledge. For example, when given training to balance simple reaction equations such as Fe + HCl → FeCl₂ + H₂, students can complete it. However, when the particles involved in the reaction are more complex, such as Cu + HNO₃ → Cu (NO₃)₂ + NO + H₂O, students experience difficulties.

Furthermore, the second teacher said that when a chemical reaction involves large compounds, for example, K₂Cr₂O₇ is reacted with other reactions, students are confused to determine the results of the reaction that occurs. However, the second teacher revealed that the language used does not have the potential to be troublesome knowledge for students in studying chemical reactions. According to the third teacher, troublesome knowledge in chemical reactions is the complexity of applying Lavoisier's law. Students have difficulty in equalizing product and yield coefficients involved in chemical reactions.

In addition to the three things above, the fourth teacher revealed the language used could potentially become troublesome knowledge for students when studying chemical reactions. The number of compounds that are not yet known to students who use scientific language is a difficulty for students when they have to change it into a chemical formula or from a chemical formula into the name of the compound. The four things above can cause students to experience misconceptions when studying chemical reactions. Therefore, research on troublesome knowledge can be useful for teachers to determine strategies, media, and appropriate teaching materials. Inappropriate learning strategies can cause discrepancies between what the teacher teaches and what students learn [18].

4. Conclusion

Concepts that are following scientific concepts (the appropriate concept) in chemical reactions are an atomic reorganization, bond breaking and reformation, and changes in physical or chemical properties.
While misconceptions consist of molecules and compounds formed from cations and molecules, polyatomic ions decompose into smaller particles, mistaken in writing ion charges and chemical formulas of a compound, cations will bind to positively charged atoms and anions will bind to charged atoms negative, products aqueous or solids (precipitations) are present as ions, and ionic compounds in solids are present in molecular form.

Meanwhile, threshold concepts for chemical reactions are a concept of mixtures, physical and chemical properties, material changes, concepts of protons and electrons, electron configurations, chemical bonds, inter-molecular forces, attractive forces between charges, compound nomenclature, chemical formulas, and Lavoisier’s laws. Whereas troublesome knowledge consists of the complexity of possible reactions, the complexity of particles involved, the complexity of applying Lavoisier’s Law, and the language used.

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