Students’ misconceptions on solubility equilibrium

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Abstract. This study investigated the students' misconceptions of the solubility equilibrium. The participants of the study consisted of 164 students who were in the science class of second year high school. Instrument used is two-tier diagnostic test consisting of 15 items. Responses were marked and coded into four categories: understanding, misconception, understand little without misconception, and not understanding. Semi-structured interviews were carried out with 45 students according to their written responses which reflected different perspectives, to obtain a more elaborated source of data. Data collected from multiple methods were analyzed qualitatively and quantitatively. Based on the data analysis showed that the students misconceptions in all areas in solubility equilibrium. They had more misconceptions such as in the relation of solubility and solubility product, common-ion effect and pH in solubility, and precipitation concept.

1. Introduction
Chemistry is one of the most important branches of science; it reviews the composition, structure and nature, transformation, dynamics, and energetics of matter. Chemical learning often combines abstract concepts, which become the next center of learning in chemistry and other sciences [1][2]. Chemistry is often considered as a difficult subject because it discusses complex material structures and requires intellectual understanding. The difficulty in studying chemistry can be seen from the characteristics of chemical subjects that include three levels of thinking, such as: macroscopic, sub-microscopic, and representational level [3]. The macroscopic level is a phenomenon that can be seen, touched, and smelled. The sub-micro level is what can’t be observed visually. The representational level is a sub-micro representation into a symbol, formula, equation, molarity, mathematical manipulation, and graph. Each level of thought is complementary.

Chemistry learning in high school emphasizes mathematical calculations (representational level) rather than conceptual learning (macroscopic and sub-microscopic level). The presence of imbalance at the macroscopic, sub-microscopic, and representational level can cause students to have difficulty in understanding the concept of chemistry as a whole even in the most basic concepts. If the student does not understand certain basic concepts, then he will have difficulty in understanding more complex concepts and can lead to an understanding which is beyond the concept itself or misconception. Misconception is part of a larger knowledge system that involves many interrelated concepts that students use to make sense of their experiences [4]. Misconceptions can occur due to the limitations of students in constructing or building an understanding of a concept they receive during the learning process. Generally, there are five factors that can cause misconceptions, such as: students, teachers, textbooks, contexts, and teaching methods. Misconceptions that continuously occur in students will
result in decreased their achievement. The results of previous research indicated that misconceptions of students in studying chemistry included basic concepts of chemistry [5], chemical bonding [1][6], chemical equilibrium [7][8], mole concepts [9], and nuclear chemistry [10].

One of the chemicals considered as difficult by students is solubility equilibrium. Solubility equilibrium materials have basic abstract, mathematical calculations, and complex concept that can cause misconceptions, and they are interconnected with one another. Students had more problems in understanding the areas such as dynamic nature of the solubility equilibrium, common-ion effect, selective precipitation, solving the problems of solubility product, understanding and interpreting graphs related to the solubility equilibrium concept [11]. Although chemistry students can solve various calculation problems on solubility equilibrium, for example solubility and solubility product calculation (K_{sp}), it does not guarantee that the student can understand the concepts in the material [12].

Misconceptions can be identified by diagnostic tests. Two-tier multiple choice diagnostic test is an effective diagnostic instrument for identifying student misconceptions [13]. The use of a two-tier diagnostic instrument at the beginning or end of teaching of a particular subject may help science teachers to get a better picture of students’ understanding and the presence of misconceptions in a particular part of the topic being taught [14]. The two-tier multiple choice diagnostic test is one of the diagnostic tests which is a matter of two-tier problems. The first level consists of questions with five answer options, while the second level consists of five reason options that refer to the answer at the first level [14]. Students are considered master if they can answer both items correctly. Conceptual understanding can be divided into four categories: understand, misconception, understand little without misconception, and not understand [15][7]. This grouping is based on possible responses from students’ answers using two-tiered questions. Based on the above description, the researcher wants to identify the misconception of high school students on the concept of solubility equilibrium by using Two-Tier diagnostic test.

2. Method
The subjects of the study were 164 eleventh grade of High School science program students in three school categories: high, medium, and low. The research was conducted in school year 2016/2017. The research was a descriptive study. Data collection techniques used tests, interviews, and document studies. The test instrument used two-tier diagnostic instrument consisted of 15 question items. Responses were marked and coded into four categories[7][15]:

| No | Patterns of Students’ Answers                              | Category of Understanding                  |
|----|-------------------------------------------------------------|--------------------------------------------|
| 1. | The main answer is correct – the reason is correct          | Understand                                 |
| 2. | The main answer is correct – the reason is incorrect        | Misconception                              |
| 3. | The main answer is incorrect – the reason is correct        | Misconception                              |
| 4. | The main answer is incorrect – the reason is incorrect      | Not understand                             |
| 5. | The main answer is incorrect – the reason is not answered   | Not understand                             |
|    | The main answer is correct – the reason is not answered     | Understand little without misconception     |
| 6. | The main answer and reason are not answered                 | Not understand                             |

Based on these categories, learners misconceptions and how many learners (percentage) are experiencing misconceptions can be determined on the test items. The percentage of each item can be calculated in:

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\% = \frac{\text{the number of the patterns of students’ answers in each category}}{\text{the number of students}} \times 100\%
\]
Semi-structured interviews were conducted to 45 students according to their written responses which reflected different perspectives, to obtain more elaborated source of data. The data obtained from the results of test and interview were analyzed. Data analysis was aimed to give meaning to the data that has been collected from the research. Descriptive analysis techniques were used to determine the types of misconception experienced by students on solubility equilibrium.

3. Result and Discussion

Misconceptions on Solubility Equilibrium

3.1. Difficulty of Soluble Salt Equilibrium

There were 37.80% of students in misconception group. Most students who had misconceptions ignored the law of charge neutrality in solution to the concept of soluble salt equilibrium. It was in accordance with a statement that the amount of ions in the over saturated solution was greater than the saturated solution without regarded to the law of neutrality [16]. The correct concept was that the amount of charge of ions from the ionized salt must be zero, so that the solution is neutral. In addition, some students who had misconceptions ignored the difficulty of soluble salt phases in equilibrium reactions. The correct concept was that in equilibrium reaction for solution with soluble salt had a solid phase (s) and the ions had aqueous phase (aq).

Another misconception was that when the concentration of produced equilibrium ion was equal to the salt concentration had by 27.44% of students. They assumed that equilibrium mean between the salt and ions in the same rate so that it had the same concentration. This misconception corresponded to the result which stated that the resulting ion concentration was equal to the salt concentration at equilibrium [16]. The correct concept was that the equilibrium, concentration of the ions and concentration of salt (salt solubility) could be determined by the mole ratio of the equilibrium system.

3.2. The Concept of Solubility

This study revealed that few students had misconceptions on the concept of solubility. There were 29.27% of students in misconception group. Students experiencing misconceptions assumed that the solubility value was calculated from mole of salt under saturation conditions. The correct concept of solubility was the number of salt moles dissolved in a liter of solvent and yielded a saturated solution. Thus, the solubility value could be calculated from the molarity of the salt under saturation [17].

Other misconceptions found was about the relationship of $K_{sp}$ value with solubility. The researcher gave a question about the most soluble salt with different number of ions based on the given $K_{sp}$ value. There were 85.37% in misconception group. The number of students experiencing misconception was quite large. Most students assumed that a large salt solubility had a large $K_{sp}$ value regardless of the amount of ions in the salt. The correct concept was that in the salt which had the same number of ions, the greater the $K_{sp}$ value the greater the solubility. However, if the salt had a different amount of ions, the solubility of each salt must be first calculated.

3.3. The Concept of Common Ion-Effect

Concerning this concept, there were 44.52% of students assumed that the solubility of soluble salt would increase if the equilibrium system shifted toward the reactant (the soluble salt). In this concept students understood about the concept of equilibrium was the addition of ion names on the equilibrium salt soluble would cause the ion concentration increased so that the equilibrium shifted toward the salt (reactants). However, students could not understand that if the reaction shifted toward the salt then the salt solubility would decrease. The correct concept was that if the same ion-containing compound was added to the soluble salt-soluble equilibrium, it would cause the concentration of soluble salt-soluble ions to increase and the system shifted to the left (salt formation). This caused less salt to dissolve in a solution containing the same ion.
3.4. The Concept of Precipitation
There were 71.95% students experiencing misconceptions assumed that saturated solution occurred when the product concentration was less than $K_{sp}$. The correct concept was that the saturated solution occurred when the product ion concentration was greater than $K_{sp}$ while the unsaturated solution occurred when the product concentration product was smaller than $K_{sp}$.

3.5. The Relation of Solubility and pH Concept
There were 68.29% of students assumed that the hydroxide ions used to calculate the $K_{sp}$ value of the base solution were from the negative antilog of pH. The correct concept was it used to calculate the $K_{sp}$ value of an alkaline solution and to be noted in particular OH concentration.

4. Conclusions
Based on the description of results and discussion of the present research of misconception of high school students on solubility equilibrium it can be concluded that there are misconceptions in all areas in solubility equilibrium. They had more misconceptions such as in relation of solubility and solubility product, common-ion effect and pH in solubility, and precipitation concept. Teachers should pay attention to sub-materials that often lead to misconception when they are teaching solubility equilibrium in order improve their understanding.

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