First-year university students’ understanding of chemical equilibrium

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Abstract. This study analyzed the understanding of first-year students on the concept of chemical equilibrium. It involved 30 first-year students in the faculty of mathematics and natural sciences of Universitas Negeri Padang. The students’ understanding was explored using a conceptual test. The result shows that generally, students have misconceptions about the concept of chemical equilibrium especially when the reaction reaches equilibrium as reported by many studies. The results of this study have implications for the lecturers in planning the general chemistry learning process, especially on the chemical equilibrium topic.

1. Introduction
Chemical equilibrium has become the focus of research on chemistry learning since 1960 [1–4]. Because this is an essential topic and is the basis for mastering acid-base, pH of solution, solubility and Ksp, electrochemistry, etc. If the previous concept is deficient or wrong, students will construct inaccurate new knowledge[5]. It means that students who don’t understand chemical equilibrium become difficult to make connection to those topics. In the other hand, there are many abstract concepts within this topic. The language used in this topic has a different meaning from daily language[6]. For example, when equilibrium is reached, the concentration of the substance involved in the reaction is constant but sub-microscopically there is always a change both towards the product and backwards the reactant. Students assumed that all species at equilibrium had the same concentration[4]. Of course, student prior knowledge about “equilibrium” was all things are equal. It would lead some misconceptions[7-10]. Besides, to construct the full understanding of this concept, students must be able to associate the three level of chemical representation: macroscopic, sub-microscopic, and symbolic[11,12]. This is one way to gain the deeper understanding[11]. But, not all of teachers explained the chemical phenomena across these representation levels.

In high school curriculum of 2013 in Indonesia, this topic was studied in class XI and then repeated in preparation for national exams and college entrance exams. Such repetitions should make students understand chemical equilibrium well. However, the results of the studies indicated that there were still many students who fail to understand this topic [1,7,8]. It’s important to know students’ knowledge about this topic so that a new learning media may be developed. This study aims to analysed the understanding of first-year students on the chemical equilibrium concept.

2. Methods
This study was conducted on first-year students at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang in the January-June 2018 semester. The samples in this study were 30
students who took general chemistry courses. The sampling technique uses purposive sampling. The instrument in this study used conceptual test which have been made by Bergquist and Keikkinen [3]. The concepts analysed in this study are:

2.1. Stoichiometry of equilibrium reaction
Common mistakes made by students regarding equilibrium reaction stoichiometry are students confused about distinguishing concentration with moles and not using volume to determine concentration. Then the mole ratio applies when the equilibrium state is reached. Furthermore, the students’ confusion is the amount of substance when equilibrium is the same.

2.2. The process occludes when equilibrium is disturbed
Students are used to memorizing Le Chatelier's principle without knowing the real concept when an equilibrium is interrupted and shifted.

3. Result and Discussion

3.1. Students’ understanding when the system reaching equilibrium
Students' answers on the test will be discussed here. The first group of questions identified students' knowledge of the number of moles and the concentration of substances at the beginning, reaction, and reaching equilibrium. The question was about the amount of substances present in equilibrium in a time that is not familiar to students. Usually, students were only asked to equilibrium problems without being given time information. It requires properly understanding that when equilibrium has been reached, the concentration of substances involved in the reaction will always constant. The first group of questions was the question of the equilibrium reaction of H₂(g) + I₂(g) ⇌ 2HI (g). Students were requested to determine the concentration of H₂, I₂and HI when in equilibrium state. Based on the results, only 67% of students answered correctly the concentration of H₂ and I₂ when equilibrium was reached. 20% of students answered the concentration of H₂ and I₂ in units of moles. Although the value was correct, students ignored the volume of the container so that the substance concentration could be expressed with moles. There were many students who did not understand the concentration concept. Meanwhile, for HI concentration, only 60% of students gave the correct answer. The same misconception appeared; students confused whether mole was a unit of concentration. In the next question students were asked to determine the number of moles I₂ and HI before the reaction occurs. The results were so surprising. Only 47% of students answered the correct number of moles I₂ and 27% for the number of moles HI. 40% of students gave answers by assuming that the number of moles I₂ when the reaction was equal to the moles of I₂ before reacting. 30% of students consider that the number of moles of HI when equilibrium reached was equal to the number of HI before reacting. 20% of students considered that the initial amount of HI was determined by reducing the amount of HI when equilibrium reached by reactant moles. This implied chemical reactions and stoichiometry had not been understood. Whereas, students should know when the reaction had not occurred, the product had not been formed, so the answer to the number of HI moles at the beginning of the experiment is 0.

This misunderstanding was shown by the students' sub-microscopic representation of this reaction. For example, student 24 assumed that at the beginning of the reaction HI has been formed. His representation can be seen in Figure 1. However, when equilibrium was formed the number of reactants increased as well as the number of products.
Figure 1. Sub-microscopic representation made by student 24 when expressing the symbolic level of molecules (a) before reaction, and after reach an (b) equilibrium

Student 17 illustrated that the number of reactants decreased but this student assumed that when equilibrium was formed the amount of all the substances involved in the reaction are the same.

Figure 2. Sub-microscopic representation made by student 17 when expressing the symbolic level of molecules (a) before reaction, and after reach an (b) equilibrium

Students 27 still assumed that the equilibrium reaction and complete reaction are the same. In the picture, when equilibrium was achieved there was only a product without H$_2$ and I$_2$.

Figure 3. Sub-microscopic representation made by student 27 when expressing the symbolic level of molecules (a) before reaction, and after reach an (b) equilibrium
3.2. Students’ understanding when an equilibrium was upset

The second group of questions tests students’ understanding of the concentration of substances when equilibrium was disturbed. The results of this study indicated that students have low understanding about the changes that occur when a concentration of equilibrium system was increased. Only 7% of students gave the correct answer to this problem. Many students answered wrongly about the number of \(2\) after the equilibrium was disturbed and then reached again. Some students answered the moles of \(I_2\) at the new equilibrium was the result of moles from the initial equilibrium plus moles \(I_2\) added. Students do not understand Le Chatelier's principles in depth. One of the causes was due to students’ lack of understanding of the chemical reaction and stoichiometry so that the process occurred when an equilibrium was disturbed equilibrium was not clearly understood. The next question was about the concentration of substances involved in the reaction when new equilibrium had been reached. In this case, the amount of \(I_2\) was added to the equilibrium system so that there was a shift in equilibrium towards the product. Students were asked to compare qualitatively the concentrations of \(H_2, I_2,\) and \(HI\) when equilibrium was disturbed and when new equilibrium was reached. Only 3% of students answered correctly about concentration \(I_2\). However, for \(H_2\) concentration 50% of students answered correctly, and 53% of students were correct in determining the concentration of \(HI\). This misunderstanding was shown by the student's image in representing the initial equilibrium state with a new equilibrium.

![Sub-microscopic representation](image1)

**Figure 4.** Sub-microscopic representation made by student 3 when expressing the symbolic level of molecules (a) equilibrium, and that (b) after addition of \(I_2\)

Student 3 response showed that she did not understand the shift in equilibrium. At the new equilibrium, it seems that there was no more \(I_2\). Unlike student 3, student 11 considered that \(H_2\) is no longer there when new equilibrium is formed.

![Sub-microscopic representation](image2)

**Figure 5.** Sub-microscopic representation made by student 11 when expressing the symbolic level of molecules (a) equilibrium, and that (b) after addition of \(I_2\)
Students 21 provided answers that were further from the concept of equilibrium. From its sub-microscopic representation, this student did not understand the concept of substances involved in the equilibrium system. He still thought that this reaction was a complete reaction so that only the products formed at equilibrium. With the addition of I\(_2\) he considered that HI was formed more and more. Whereas at the equilibrium he wrote H\(_2\) no longer exists.

![Figure 6](image)

**Figure 6.** Sub-microscopic representation made by student 21 when expressing the symbolic level of molecules (a) equilibrium, and that (b) after addition of I\(_2\)

Student 10 showed a picture when new equilibrium is formed the number of HI increases and the number of reactants decreases. However, the amount of H\(_2\) and I\(_2\) was the same when new equilibrium was formed. This showed that this student had not understood the effect of the addition of I\(_2\) making the equilibrium disrupted.

![Figure 7](image)

**Figure 7.** Sub-microscopic representation made by student 10 when expressing the symbolic level of molecules (a) equilibrium, and that (b) after addition of I\(_2\)

4. Conclusion

Based on the results of this study, it can be seen that students have poor understanding to the concepts of chemical equilibrium. Concepts of concentration and stoichiometry were needed to master how a system reach equilibrium. Meanwhile, the in comprehension of these concepts resulted in ongoing misunderstanding in equilibrium reactions. Furthermore, most of students assumed in the equilibrium the species had the same amount. Students also had poor understanding to predict the effect of concentration change of I\(_2\) to the equilibrium. Therefore, in chemistry learning in high school, a deep emphasis is needed on stoichiometric and concentration concepts. This result has implications for the lecturers in planning the general chemistry learning process, especially on the chemical equilibrium topic.
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