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Students' Understanding of Chemical Equilibrium Lesson in Thailand

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Abstract
This research aimed to investigate the students' understanding on chemical equilibrium lessons in Thailand. In this study a diagnostic test was developed to determine students' understanding on chemical equilibrium. The result from the test showed some patterns of students' understanding and could refer to students' alternative conception effectively. The result showed that students' hold several alternative conceptions in chemical equilibrium. In addition, they hold some relevant alternative conceptions such as gas properties. The diagnostic test could help teachers to elicit students' understanding on chemical equilibrium more easily and quickly. Finally, the finding would be used to develop the appropriate lesson plan for students.

Keywords: *Alternative conception, Chemical Equilibrium, Diagnostic test*

1. Introduction

Understanding chemical equilibrium is important for studying others concepts such as acid-base behavior, solubility, and redox reaction in chemistry (Voska & Heikkinen, 2000). However, chemical equilibrium is a topic that has been accepted as being very difficult to teach and learn.

Tyson, Treagust, and Bucat (1999) argued that one cause of difficulty in understanding chemical equilibrium was the scientific vocabularies and everyday languages. Moreover, they claimed that there was the high sophisticated nature of the content of this topic between physical change and chemical change. Gorodetsky and Gussarsky (1986) argued that students did not perceive the submicroscopic behavior of the chemical system, hence, they used rote learning.

Students may come to classes with some previous cognitive conflicting conceptions (van Driel & Graber, 2002). For example, students believed that chemical reactions took place in one direction only, substances were turned to be products. On the other hand, in chemical equilibrium reactions, students were convinced that there were two opposite chemical reactions at the same time (van Driel, de Vos, Verloop, & Dekkers, 1998). Andersson (1990) reported that normally students understood that chemical reactions were complete processes while a state of chemical equilibrium reaction did not proceed to completion. Therefore, students could not differentiate between complete reactions and reversible reactions. Kousathana and Tsaparlis (2002) reported that students learned from chemical kinetics that an increase in temperature always resulted in an increase of the reaction rate. Consequently, students held the conception that increasing the temperature led to an increase in the amount of products while chemical equilibrium lessons demonstrated associating both exothermic or endothermic reactions.

A number of research studies have revealed alternative conceptions in the topic of chemical equilibrium (Akkus, Kadayifci, Atasoy, & Geban, 2003; Banerjee, 1991; Gorodetsky & Gussarsky, 1986; Gussarsky & Gorodetsky, 1990; Hackling & Garnett, 1985; Kousathana & Tsaparlis, 2002; Ozmen, 2008; Tyson et al., 1999; Voska & Heikkinen, 2000; Wheeler & Kass, 1978; Wilson, 1996). These researchers used different instruments such as interviews, multiple choice tests, open-ended

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questions, two-tier tests, or concept maps to elicit students' ideas. The results showed that students still held alternative conceptions in the topic of chemical equilibrium in every basic concept. Therefore, this research aimed to study students' alternative conceptions that found in Thai classroom. According to the result, it could showed students' understanding in chemical equilibrium lesson and referred to some difficult things behind the lesson.

2. Materials and Methods

Participants in this research were 98 students studying in grade 11 (age 17 – 18) in the 2014 academic year (November 2014 – February 2015) in three secondary schools in Surat Thani province, Thailand.

The students' scientific conceptions about chemical equilibrium were determined by the Chemical Equilibrium Test for Revealing Conceptual Change (the *CETforRCC*). The test comprises of three parts. The first part is 4 items of multiple choices used to examine students' understanding of gas properties and the basic equilibrium state. The second part is writing test used to examine students' understanding of the chemical equilibrium state. The third part is a series of six objective questions adapted from Akkus and colleagues (2003) and Bergquist and Heikkinen (1990) used to examine Le Chatelier's principle. Data analysis for the test was not only considered on the scores of each item, rather focusing on the relationship between relevant items. This analysis could help the researcher understand the pattern of students' understandings, and elicit some alternative understandings.

3. Results and Discussion

The result of the *CETforRCC* part I showed students' understanding about gas properties and the basic concept of equilibrium system. The situation as shown in Fig. 1 was presented to the students, then they were asked to answer for 4 items.

Situation

Iodine in solid state ($I_{(s)}$) can be sublimated easily to be Iodine in gas state ($I_{(g)}$). On the other hand, gas iodine can be condensed to be iodine solid.

If some of $I_{(s)}$ were put into a close container, there will be the phenomenon of sublimation and condensation. When the system are maintain at the steady temperature and pressure for a time period, it will reach equilibrium. The equation shown this phenomenon below

$$I(s) \rightleftharpoons I(g)$$

If we do an experiment of this phenomenon, at the beginning we should see as the Figure 1 below.

Fig. 1 The situation presenting in the *CETforRCC* part I.

The result for the first part of the *CETforRCC* showed that students hold some alternative conceptions.

When the students were asked about the changes would be observed in the container after leaving the system for a while, 23.5% of students understood correctly that iodine gas would spread out all over the container. While the most of students hold alternative conception that gas would level up like liquid do. 49.0% of students thought that iodine gas will fill the container, but 27.5% of students were unsure it could fill the container.

It is interesting that the result showed most of students did not know about the volume of gas in the closed container. The students were asked to answer what is the volume of gas in the new container, if 500 cm^3 of iodine gas are transferred to 1,000 cm^3 container. It was found that 19.4% of students answered correctly. Students of 25.5% thought that the gas fill half of the container, and there are 500 cm^3 and 55.1% thought that the gas fill full the container but there are 500 cm^3.

According to the test showed other results about the basic understanding of equilibrium system as shown in Table 1. It was found that 50.0% of students understood about the continuous changes in the system. The rest of students believed that the system would cease after the observable phenomenon stop. In addition, students only 17.0% understood about simultaneously change. The students 63.8% thought that the phenomena would change as pendulum, and 50.0% of students thought that there is no change when the system reach equilibrium.

Table 1: Percentage of students' conceptions of the Quantifications of dynamic equilibrium

Topic	Students' Conceptions	Percentage of Students' Conceptions
Quantifications of dynamic equilibrium	Complete reaction	19.1
	Reverse reaction, but ceased	30.9
	Continuous change*	50.0
	Change process as pendulum	63.8
	Simultaneously change process*	17.0
	No change at equilibrium	50.0

In the *CETforRCC* part II, the situation as shown in Fig. 2 was presented to the students, then they were asked to depict the phenomenon in microscopic level. The results showed that 23.5% of students represented correctly about the amount of substances

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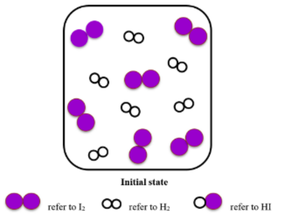
in the system. The following alternative conceptions were found: 38.8% of students represented only 6 mol of HI, 6.1% of students represented only 12 mol of HI, 4.1% represented 6 mol for each of H_2, I_2, and HI. The rest of the 27.6% of students represented different forms, and some of them could not represent the molecules in the system. Students' drawing examples is shown as in Fig. 3.

Situation
If H_2 and I_2 were added to the close container at the proper condition, there will be reaction and give the product that is HI.
When the system reach equilibrium state can be show as chemical equation as follow:
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$; the forward reaction is exothermic reaction.
In a closed glass container at the initial state, there are 6 mol of H_2 and 6 mol of I_2 as figure below



After the container was maintained at the steady temperature and pressure for a time period, then the system reach equilibrium. At equilibrium 6 mol of HI are found.

Fig. 2 The situation presenting in the *CETforRCC* part II.

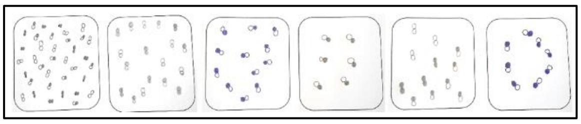


Fig. 3 Example of students' depiction.

Regarding students' conceptions about the re-established equilibrium, part III of the *CETforRCC* showed students' understanding about Le Chatelier's principle.

The students were proposed the situation of a reaction between hydrogen gas and iodine gas, which reacted to form hydrogen iodide at constant conditions. When the system reached equilibrium, some iodine was added to the system. The students were asked to predict the re-established equilibrium. The test comprised of six questions in a series from item 11 to item 16.

Item 11 was about the shift of re-establish equilibrium. It was found that 48.6% of students answered correctly that the new equilibrium would shift to the right; while 24.3% of students thought that it would shift to the left, and 27.1% of students thought that there was no change at the equilibrium.

Item 12 was about what should be the amount of product. As many as 51.4% of students picked the correct answer that the product increased; while 34.8% of students answered that the product was constant and 13.8% of students answered that the amount of product decreased.

However, when the students' answers of both items were analyzed together, it was found that only 31.6% of students understood the movement of the equilibrium state and the quantity of substances at equilibrium. The analysis of answers of both questions is shown in Table 2.

Table 2: Students' answers for Item 11 and Item 12.

Item11 / Item12	1) shift to left	2) shift to right	3) not shift	**Total**
(1increased	9.2	**31.6***	10.2	51.0*
(2decreased	2.0	6.1	6.1	14.3
(3stayed the same	13.3	10.2	11.2	34.7
Total	24.5	48.0*	27.6	

According to Table 2, the groups of students who held alternative conceptions such as:

Group 1: Students lacked understanding of the relationship between shifting to the right/left and increasing/decreasing the amounts of substances, with 9.2% of students answering 1-1 (shift to the left – the product increases) and 6.1% of students answering 2-2 (shift to the right – the product decreases).

Group 2: Students chose the direction of reaction as moving to the left or the right, but they thought the concentration of substances was constant. These were 13.3% of students who answered 1-3 (shift to the left – the product is constant) and 10.2% who answered 2-3 (shift to the right – the product is constant).

Group 3: Students answered that the equilibrium did not shift, but the amount of substance changed. 10.2% answered 3-1 (no shift – the product increases) and 6.1% answered 3-2 (no shift – the product decreases).

It can be deduced that group 2 and group 3 students did not understand the relationships between the equilibrium shift and the quantity of the substance.

Group 4: Students believed that no change occurred at the re-established equilibrium compared to the previous state. Only 11.2% of students answered 3-3 (no shift – the product is constant).

Group 5: 2.0% of students answered 1-2 (shift to the left – the product increases). These students understood the relationship between the shift and the

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change in the quantity of substance, but they erred in the direction in which the equilibrium shifted.

In items 13, 14, and 15, students were asked to predict the concentration of the substances in the system at the re-established state. The results are shown in Table 3. Considering students' answers to each item, the percentage of students who predicted changes of I_2, H_2, and HI was 44.3%, 13.6% and 34.8% respectively. However, when considering answers of all the three items, it was found that only 6.1% of students answered all the items correctly. The results of the analysis are illustrated in Table 4.

Table 3: Students' answers for Item 13 Item 14 and Item 15

Choices	Percentage of students who predicted the concentration of the substance in the system		
	Item 13 I_2	**Item 14 H_2**	**Item 15 HI**
1) increased, then decreased	44.3*	16.2	19.5
2) decreased, then increased	20.2	27.6	15.5
(3stayed the same	11.0	27.1	15.5
(4increased merely	11.0	15.7	34.8*
(5decreased merely	13.6	13.3*	14.8

Table 4: Relationship of students' answers between item 13 item 14 and item 15

Percentage of students' answers for Item 13, Item 14 and Item 15									
Ans.	**%**	**Ans.**	**%**	**Ans.**	**%**	**Ans.**	**%**	**Ans.**	**%**
1-1-1	2.0	2-1-1		3-1-1		4-1-1		5-1-1	
1-1-2	1.0	2-1-2		3-1-2	1.0	4-1-2		5-1-2	
1-1-3		2-1-3	2.0	3-1-3		4-1-3		5-1-3	
1-1-4	2.0	2-1-4	5.1	3-1-4		4-1-4		5-1-4	
1-1-5	2.0	2-1-5		3-1-5	1.0	4-1-5		5-1-5	
1-2-1	7.1	2-2-1	1.0	3-2-1		4-2-1		5-2-1	2.0
1-2-2		2-2-2	1.0	3-2-2		4-2-2		5-2-2	1.0
1-2-3	3.1	2-2-3	2.0	3-2-3	1.0	4-2-3		5-2-3	
1-2-4	3.1	2-2-4	1.0	3-2-4	1.0	4-2-4		5-2-4	1.0
1-2-5	2.0	2-2-5	2.0	3-2-5		4-2-5		5-2-5	
1-3-1		2-3-1		3-3-1	1.0	4-3-1		5-3-1	2.0
1-3-2	4.1	2-3-2	1.0	3-3-2		4-3-2	1.0	5-3-2	1.0
1-3-3	1.0	2-3-3	2.0	3-3-3		4-3-3	1.0	5-3-3	
1-3-4	3.1	2-3-4		3-3-4	3.1	4-3-4	2.0	5-3-4	1.0
1-3-5	1.0	2-3-5		3-3-5	1.0	4-3-5	1.0	5-3-5	
1-4-1	1.0	2-4-1		3-4-1		4-4-1	1.0	5-4-1	
1-4-2		2-4-2		3-4-2	1.0	4-4-2		5-4-2	3.1
1-4-3		2-4-3		3-4-3		4-4-3	1.0	5-4-3	
1-4-4	2.0	2-4-4	1.0	3-4-4		4-4-4	1.0	5-4-4	
1-4-5		2-4-5	1.0	3-4-5		4-4-5	2.0	5-4-5	1.0
1-5-1	2.0	2-5-1		3-5-1		4-5-1		5-5-1	
1-5-2		2-5-2		3-5-2		4-5-2		5-5-2	
1-5-3	1.0	2-5-3		3-5-3		4-5-3		5-5-3	1.0
1-5-4	**6.1***	2-5-4	1	3-5-4	1.0	4-5-4		5-5-4	
1-5-5	1.0	2-5-5		3-5-5		4-5-5		5-5-5	

Notice
The three series of numbers refer to the answers for items 13, 14 and 15 respectively.
1 = increase and then decrease, 2 = decrease and then increase,
3 = be constant, 4 = merely increase, 5 = merely decrease

Table 4 showed that only 6.1% of students answered correctly all the three items. The other students had incorrect answers. According to the pattern of students' answers, their alternative understanding of Le Chatelier's principle can be determined. If the students do not understand Le Chatelier's principle, there answers may be not relative each other, which could be interpreted as certain group of alternative conceptions below:

Group 1: the students who have two of the three correct answers could hold some alternative conceptions. For example, answering correctly items 13 and 15 as 1-4 may be indicated that the students lack of understanding of the amount of another reactant when one reactant is added. In this study, 10.2% of students answered for 1-1-4 (2.0%), 1-2-4 (3.1%), 1-3-4 (3.1%), and 1-4-4 (2.0%). Another group students who correctly answered items 14 and 15 as 5-4 may be indicated that the students lacked understanding of the amount of the reactants that were added. In this study, 2.0% of students answered in this manner. A student who answered 3-5-4 may demonstrated an interesting alternative conception. They thought that the amount of iodine, which was added to the system, would all turn to product. Therefore, iodine at the re-established equilibrium is in the same amount as before. The students who chose 1-3-4 may held the same alternative conception.

Group 2: students answered the questions 14 and 15 as 3-3. The students understood that adding the substance to the reaction did not affect changes in the quantity of reactants and products. There were 4% of students in this group, answering 1-3-3 (1.0%), 2-3-3 (2.0%), and 4-3-3 (1.0%).

Group 3: students answered the questions 14 and 15 as 3-4. The students understood that when adding the reactants to the system, it would produce a greater number of products. 9.2% of the students may understood that when adding iodine to the system, hydrogen was constant, but HI increased. Among these students: 3.1% of students answering that the quantity of iodine was constant; 3.1% of students answering that the quantity of iodine increased and then decreased; 2.0% of students answering that the quantity of iodine merely increased; and 1.0% answering that the quantity of iodine merely decreased.

Group 4: students answered the questions as the concept of a pendulum.

4.1) the group of students who answered the questions 13 and 15 as 2-1 was a total of 1.0% of students. They thought that when adding iodine to the system, hydrogen decreased and then increased, while HI increased and then decreased. The students may believe that as the case of the pendulum, the reactants became the product and the product reversed to form the reactants. In this group, 7 students who answered as 1-2-1 were the students whose understanding involved the change of the quantity of iodine.

4.2) the group of students who answered the questions 13 and 15 as 2-4 was a total of six students. Students understood that adding the reactants was a way to increase the products. The increased products would actually become the reactants again and then it made H_2 increase (but it did not decrease a number of products). The students of this group answered as 1-4-4 such that I_2 increased and then decreased, H_2 decreased and then increased, and HI increased only as suggested by 3.1% of the students. The students thought that when iodine increased, it would react with hydrogen and then hydrogen decreased, so it would produce products and the products somehow reversed to be reactants again and then the quantity of H_2 increased more. Thus, this was the misunderstanding as the pendulum, but the rest of them misunderstood the quantity of iodine.

Group 5: 2.0% of students tended to apply the principle of Le Chatelier to the language and answered the questions 14 and 15 as 1-2. In the meantime, 5.1% of students thought the concentrations of hydrogen increased and then decreased, but HI decreased and increased and answered the questions 13 and 15 as 1-2 and 1.0% of students thought that while the concentration of iodine increased and then decreased, the concentrations of HI decreased and increased and answered the questions as 1-1-2. Thus, the students applied the principle of Le Chatelier and they really misunderstood that "when the reactants 'increased and then decreased', then the product must 'decrease and then increase'". Despite the fact that if the students thought as the Le Chatelier principle, but they misunderstood the concept of pendulum, they would actually have thought that the reactants 'increased and then decreased', and it meant that the reactants became more products, so the students were supposed to answer that the products 'increased and then decreased'.

The researcher interviewed the students by providing one type of reactants and product such asThe " : reaction A⇌ B has reached the state of equilibrium, then the system is disturbed by adding A to the reaction. The students were asked to answer the question that how would the reactants affect the concentrations of substances." The group of students who understood the principle would have answered that A increassed and then decreased while B merely increased. The group of students who misunderstood eq ke a pendulumilibrium as li(Groups 2, 3, and 4 (would have answered that both of A and B increased and then decreased. The group of students who did not understand the principle of Le Chatelier (Group 5) showed their misunderstanding of language even though the researcher guided the answer of A by:

Researcher: I told you that the concentration of A increases and then decreases, what will happen to B?
Student: B will decrease and then increase.
Researcher: Can you explain more why it should be like that?
Student: It just changed in the opposite way.

Moreover, the rest of the students showed their other misunderstanding in many patterns, so the teacher could take this test to analyze the students' misunderstandings because it was quite easy to check the answer, it could comprehend the students' thoughts, and it could check whether the students understood Le Chatelier's principle, or not. If not, the students would have the answers that were not related such as a number of students who answered 2-2-2, 4-4-4, 5-5-5, or 2-5-5, 3-4-4.

The last question of the *CETforRCC* was item 16 that determined students' prediction of the amount of I_2.

Table 5: Students' answers for Item 13 and Item 16

Item16 \ Item13	1)increase, decrease	2)decrease, increase	3)constant	4)increase	5)decrease	**Total**
(1more than 0.080	5.1	8.2	1.0	2.0	0.0	16.3
(2equal 0.080	7.1	3.1	1.0	1.0	0.0	12.2
(3equal 0.060	5.1	0.0	4.1	2.0	4.1	15.3
(4less than 0.060	11.2	6.1	3.1	3.1	4.1	27.6
(5between 0.080-0.060	**13.3***	2.0	1.0	1.0	2.0	19.4*
(6equal 0	3.1	1.0	1.0	1.0	3.1	9.2
Total	44.9*	20.4	11.2	10.2	13.3	

According to Table 5, if we consider the percentage of students answering each question separately, there were 44.9% of students who answered correctly for item 13, and there were 19.4 % of students who answered correctly for item 16. However, when finding the relation of the answers between both items, only 13.3% of students showed sound understanding about the amount of iodine. The rest of the students displayed alternative conceptions in a variety of ways as shown below:

Group 1: students understood Le Chatelier's principle, but they had alternative conceptions about the amount of iodine. For example: 5.1% of students who answered for item 13 that "increase then decrease", and answered for item 16 that "is equal to

0.060"; and 11.2% of students who answered for item 13 that "increase then decrease", and answered for item 16 that "less than 0.060".

Group 2: students predicted based on Le Chatelier's principle that "when the system is disturbed, it will adjust to reduce the disturbance", therefore, the amount of iodine should be reduced. For example: students who answered for item 13 that "iodine merely decreased", they may have understood about Le Chatelier's principle too, but they did not realize about the added amount of iodine in the system.

4. Conclusions

The finding showed that students hold several alternative conception in chemical equilibrium similar to previous research. However, the diagnostic test which was developed in this research can be used to elicit students' understanding effectively. Teachers can see pattern of students' ideas. Therefore, it would help teachers to help students remedy their alternative conception. In teaching process, it was supposed to examine basic knowledge before the class and help students to develop the basic knowledge. A study about children's conceptions in Thailand has been going on not for long, so, several basic alternative conceptions could be found even though they are secondary school students. In addition, teachers were supposed to survey students' concepts before teaching each lesson to help students realize whether they had alternative conceptions or not. It would actually stimulate students to set their study goals and try to study.

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