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Misconception of Students on Multiple Representation of Chemical Equilibrium Shift

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Abstract: This study aims to analyze students' misconceptions about shift in chemical equilibrium by using a two-tier multiple choices diagnostic test based on multiple representations. The design of this study is descriptive. The research subjects were second semester students of Chemistry Department A, B and I classes in Universitas Negeri Malang in 2018/2019 Academic Year totaling 60 students. The reliability of the diagnostic test is 0.86. The results showed that students' misconceptions of the factors affecting chemical equilibrium shifts identified 9 misconceptions with an average percentage of misconceptions below 30%. Misconceptions also often occur in students when associated with submicroscopic representation.

Key Words: misconceptions; chemical equilibrium shift; multiple representations

Abstrak: Penelitian ini bertujuan untuk menganalisis miskonsepsi mahasiswa tentang pergeseran kesetimbangan kimia dengan menggunakan tes diagnostik *two-tier multiple choice* berbasis multipel representasi. Rancangan penelitian ini adalah deskriptif. Subjek penelitian adalah mahasiswa semester 2 Jurusan Kimia kelas A, B dan I Universitas Negeri Malang Tahun Ajaran 2018/2019 yang berjumlah 60 mahasiswa. Reliabilitas tes diagnostik sebesar 0,86. Hasil penelitian menunjukkan bahwa miskonsepsi mahasiswa pada faktor-faktor yang mempengaruhi pergeseran kesetimbangan kimia teridentifikasi 9 miskonsepsi dengan rata-rata persentase miskonsepsi dibawah 30%. Miskonsepsi juga sering terjadi pada mahasiswa apabila dikaitkan dengan representasi submikroskopik.

Kata kunci: miskonsepsi; pergeseran kesetimbangan kimia; multipel representasi

INTRODUCTION

Chemical equilibrium is an important topic to study because it is necessary to comprehend other chemistry topics, including acids and bases, hydrolysis, buffers, solubility, and electrochemistry (Endur et al., 2010; Yamtanah et al., 2019). When studying chemical equilibrium, students must be familiar with a number of related concepts, including concentration, gases, moles, stoichiometry, and exothermic and endothermic reactions. In addition, the topic of chemical equilibrium necessitates knowledge of three chemical representations: macroscopic, submicroscopic, and symbolic. These three chemical representations are also known as multiple representations, which are visual explanations for chemical occurrences (Head et al., 2017). Macroscopic representations are phenomena observable by human senses including sight, smell, and touch (Li & Arshad, 2014; Lin et al., 2016; Nyachwaya & Wood, 2014). Atoms, molecules, and ions cannot be directly perceived by human senses; therefore, submicroscopic representations provide explanations at the particle level (Chandrasegaran et al., 2007; Lin et al., 2016). Symbolic representation uses chemical symbols, chemical formulas and equations, diagrams and graphs to explain chemical phenomena (Chandrasegara et al., 2007; Nyachwaya & Wood, 2014). If students are able to connect macroscopic, submicroscopic, and symbolic representations, they will have a comprehensive understanding of chemistry (Li & Arshad, 2014). Students must therefore comprehend all three representations; if they cannot make the connection between them, they will struggle to comprehend the topic and may develop misconceptions.

Misconceptions are incorrect ideas, hypotheses, or beliefs that are not based on scientific knowledge (Luxford & Bretz, 2014). According to Mondal and

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Chakraborty (2013), misconceptions are also known as prejudices and conceptual misunderstandings. Al-balushi et al. (2012) discovered that there are various misunderstandings regarding chemical concepts, including chemical equilibrium material. The concept of equilibrium state, heterogeneous equilibrium, the equilibrium constant, and the application of Le Chatelier's principle are frequently misunderstood (Akkus et al., 2012; Demirciolu et al., 2013; Hackling & Garnett, 1985; Karpudewan et al., 2015; Kousathana & Tsaparlis, 2002; Ozmen, 2008; endur et al In some prior research, it was believed that if the temperature is increased, more products will be formed (Karpudewan et al., 2015; Ozmen, 2008), and that temperature changes do not impact the direction of the equilibrium shift (Monita & Suharto, 2017; Ozmen, 2008).

Interviews, open-ended questions, multiple choice tests, multiple tier tests (two-tier, three-tier, and four-tier tests), and other assessments such as concept maps have been used to identify student misconceptions (Gurel et al., 2015). Several studies have employed multiple-tiered tests, as well as a two-tiered diagnostic instrument, to identify misconceptions. Karpudewan et al. (2015) and Ozmen (2008) have employed two-tier diagnostic tests to identify misconceptions about chemical equilibrium. The application of Le Chatelier's principle to factors affecting chemical equilibrium changes was one of the subtopics explored. The disadvantage of the two-tier diagnostic test used to analyze misconceptions in previous studies is that diagnostic tests typically only involve chemical representations in symbolic representations, thereby unbalancing the use of all three representations (macroscopic, submicroscopic, and symbolic). In fact, knowing the chemistry of submicroscopic representations is crucial for explaining chemical phenomena (Hoe & Subramaniam, 2016). In this study, it is anticipated that more comprehensive misconceptions concerning shifting equilibrium would be uncovered. The goal of this study is to examine students' misconceptions about chemical equilibrium shifts using a two-tier multiple-choice diagnostic exam based on different representations.

METHOD

This research employed a descriptive approach. This research approach intends to describe the outcomes of an analysis of student misunderstandings. The research participants were 60 second-semester students majoring in Chemistry classes A, B, and I at State University of Malang during the 2018-2019 academic year who had studied chemical equilibrium and one of the subtopics studied, namely factors that influence the shift of chemical equilibrium. The research instrument employed was a two-tier diagnostic exam based on multiple representations tested with five questions per concept in the same context. There were 15 questions on the diagnostic examination, which were separated into three subsections: the influence of temperature changes, the effect of pressure/volume changes, and the effect of concentration changes. Three chemistry professors from the State University of Malang have confirmed the diagnostic exam questions. The validity of the items was assessed using the SPSS Statistics 22 program via Bivariate Pearson correlation analysis, yielding a validity range of 0.345-0.675, and their reliability was calculated using the Cronbach Alpha method, yielding a coefficient value of 0.86. Determination of student misconceptions on the two-tier diagnostic test, based on student answer patterns that are classified into the study's criteria (Yamtinah et al., 2019) and analyzed through five questions in one idea. Table 1 lists the categories of student answer patterns. The assessed and described misunderstandings are held by at least 20 percent of the student population. If 20% or more of students answer two-tier diagnostic exam questions incorrectly, misconceptions are said to exist (Peterson et al., 1989).

Table 1. Criteria for Two-Tier Diagnostic Test Answer Patterns

Students Answer		Comprehension Level Category
First Tier	**Second Tier**	
Correct	Correct	Understand
Correct	Incorrect	Misconception
Incorrect	Correct	Misconception
Incorrect/No Answer	**Incorrect/No Answer**	Do not understand

(Yamtinah et al., 2019)

RESULTS

The results of the misconception analysis show that the average percentage of misconceptions that occur in the sub-topic of factors that affect the shifting of chemical equilibrium is below 30%. This is shown in Table 2.

Table 2 shows that the largest percentage of student misconceptions is on the concept of the effect of temperature changes and the concept of the effect of changes in concentration on equilibrium, which is 26.7%.

DISCUSSION

Effect of Temperature Change

Students have four misconceptions regarding the influence of temperature fluctuations on equilibrium shifts. The first mistake occurs when students do not comprehend that if the temperature is increased, the reaction system receives a specific quantity of energy. Obviously, the reaction that will take place will require energy. The rise in temperature will therefore move the equilibrium toward an endothermic process. The investigation of Karpudewan et al. (2015) and Andriani also uncovered misconceptions around this (2016). This misunderstanding may be due to the fact that pupils do not pay close attention to the submicroscopic image and its description on the question, but rather rely on memorization.

The second misunderstanding comes when students fail to comprehend that if the temperature is dropped, energy is liberated from the reaction system. Naturally, all possible reactions are those that release energy. Consequently, a temperature decrease will move the equilibrium towards an exothermic process. In addition to not comprehending the submicroscopic image adequately, pupils may just memorize rules, principles, and concepts, which can lead to a misunderstanding of the opposite nature. According to Romine et al. (2016), memorization of rules, ideas, and concepts results in misunderstandings.

Students commit misconceptions three and four because they believe that a change in temperature in

Table 2. Misconceptions and Percentage of Students with Misconceptions

No	Misconception	Number of Students with Misconceptions	Percentage of students with misconceptions
Factors Affecting the Shift Equilibrium			
Effect of Temperature Change on Equilibrium			
1.	An increase in temperature shifts the equilibrium toward an exothermic reaction	13	21,7
2.	A decrease in temperature shifts the equilibrium toward an endothermic reaction	16	26,7
3.	An increase in temperature does not shift the equilibrium so that the number of molecules of reactants and products remains fixed	12	20,0
4.	A decrease in temperature does not shift the equilibrium so that the number of molecules of reactants and products remains fixed	12	20,0
Effect of Pressure/Volume Changes on Equilibrium			
5.	Increasing the load (increasing the pressure) reduces the volume of the gas, thus shifting the equilibrium to a larger number of molecules.	14	23,3
6.	Reducing the load (pressure is reduced) increases the volume of the gas, thus shifting the equilibrium to a smaller number of molecules	15	25,0
Effect of Concentration Change on Equilibrium			
7.	The addition of H2 gas in the equilibrium reaction $2NO(g) + Cl2(g) \rightleftharpoons 2NOCl(g)$ will shift the equilibrium towards the products	15	25,0
8.	The addition of H2 gas in the equilibrium reaction $PCl5(g) \rightleftharpoons PCl3(g) + Cl2(g)$ will shift the equilibrium towards the reactants	16	26,7
9.	The addition of H2 gas will increase the concentration of Cl2 gas	15	25,0

an equilibrium system will not influence equilibrium, regardless of whether the reaction is exothermic or endothermic. This demonstrates that students do not comprehend that temperature is one of the factors that can induce an equilibrium shift. Ozmen (2007), Monita & Suharto (2017), and Demirciolu et al. (2017) all discovered similar misunderstandings (2013).

Effect of Pressure / Volume Change

There are two misconceptions that occur in the influence factor of pressure / volume changes on equilibrium shifts experienced by students. The first and second misconceptions occur because students do not understand Avogadro's law regarding the relationship between the volume-amount of gas, which states that at constant temperature and pressure, the volume of a gas is directly proportional to the number of moles of gas. Mathematically, the equation is given:

$$V = \left(\frac{RT}{P}\right) n \text{, by } \left(\frac{RT}{P}\right) \text{constant}$$

Therefore, if in equilibrium there is a decrease in the volume of gas (volume is reduced), the equilibrium will shift to a smaller number of molecules. Conversely, if in equilibrium there is an increase in gas volume (volume is enlarged) then the equilibrium will shift to a larger number of molecules. Similar misconceptions were also found in the research of Andriani (2016), Susanti (2016), Monita & Suharto (2017), and Umam et al (2015). These two misconceptions may occur because students only memorize the concept of the relationship between pressure and volume without understanding its relation to the number of molecules. According to Romine et al (2016), students who understand concepts, rules and principles by rote will cause many misconceptions. In addition, students' ability to connect understanding between symbolic representation to submicroscopic representation is still low. If the ability regarding the relationship between the three levels of representation is low, it is likely to cause difficulties in understanding the concept, causing misconceptions (Gilbert, 2009; Gkitzia et al., 2011; Muchtar & Herizal, 2012).

Pengaruh Perubahan Konsentrasi

There are three misconceptions that occur in the factor of the effect of concentration changes on equilibrium shifts experienced by students. The first misconception occurs because students do not understand that the addition of gas that reacts with reactants or products in equilibrium will change the concentration of reactants or products. This will cause a shift in equilibrium towards the direction that will cause an increase in the concentration of the substance. Therefore, when adding H2 gas in the equilibrium reaction: 2NO(g) + Cl2(g) ⇌ 2NOCl(g), then a reaction occurs between H2 gas and Cl2 gas with the reaction H2(g) + Cl2(g) ⇌ 2HCl(g) causing the concentration of Cl2 gas to decrease. The reduction in Cl2 gas concentration causes a change in the Kc price. The equilibrium constant price for the NOCl formation reaction is:

$$Kc = \frac{[NOCl]^2}{[NO]^2[Cl_2]}$$

The value of the equilibrium constant will be fixed if the reaction takes place at a fixed temperature. so, when the concentration of Cl2 decreases it will cause a shift in equilibrium to the left so that the price of the equilibrium constant remains.

The second misconception also occurs the same as the first misconception, namely students do not understand that the addition of gas that reacts with reactants or products in equilibrium will change the concentration of reactants or products. This will cause a shift in equilibrium towards the direction that will cause an increase in the concentration of the substance. Therefore, upon the addition of H2 gas in the equilibrium reaction: PCl5(g) ⇌ PCl3(g) + Cl2(g), then a reaction occurs between H2 gas and Cl2 gas with the reaction: H2(g) + Cl2(g) ⇌ 2HCl(g), causing the concentration of Cl2 gas to decrease. The reduction in Cl2 gas concentration causes a change in the Kc price. The equilibrium constant price for the PCl5 dissociation reaction is:

$$Kc = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

The value of the equilibrium constant will be fixed if the reaction takes place at a fixed temperature. so, when the concentration of Cl2 decreases it will cause a shift in equilibrium to the right so that the price of the equilibrium constant remains.

The third misconception also occurs because students do not understand that the addition of H2 gas, for example in the reaction 2NO (g) + Cl2 (g) ⇌ 2NOCl (g) will cause a change in gas concentration at equilibrium. When the added H2 gas in equilibrium reacts with Cl2, the reaction will occur: H2(g) + Cl2(g) ⇌ 2HCl(g), this will cause the concentration of Cl2 gas to decrease so that it will shift the existing equilibrium.

The three misconceptions above may occur because students only memorize Le Chatelier's principle, without understanding it properly, because based on the analysis of the problems given it can be seen that students only memorize that if there is an addition of a substance (H2) then reacts with a substance that is in equilibrium (Cl2) then the equilibrium will shift in the opposite direction so if the addition of H2 that reacts with Cl2 is in the reactant position then the equilibrium will shift towards the product. Conversely, if the addition of H2 that reacts with Cl2 is in the product position, the equilibrium will shift towards the reactants.

CONCLUSIONS

Based on the results of this study, it can be concluded that the misconceptions of students identified in the factors that affect the shift in chemical equilibrium are (1) an increase in temperature shifts the equilibrium towards an exothermic reaction, (2) a decrease in temperature shifts the equilibrium towards an endothermic reaction, (3) an increase in temperature does not shift the equilibrium so that the number of reactant and product molecules remains, (4) a decrease in temperature does not shift the equilibrium so that the number of reactant and product molecules remains, (5) the addition of load (pressure is enlarged) reduces the volume of gas, thus shifting the equilibrium to a greater number of molecules, (6) the reduction of the load (pressure is reduced) increases the volume of gas, thus shifting the equilibrium to a smaller number of molecules, (7) the addition of H2 gas in the equilibrium reaction 2NO (g) + Cl2 (g) $\rightleftharpoons$ 2NOCl (g) will shift the equilibrium towards the products, (8) the addition of H2 gas in the equilibrium reaction PCl5 (g) $\rightleftharpoons$ PCl3 (g) + Cl2 (g) will shift the equilibrium towards the reactants, (9) the addition of H2 gas will increase the concentration of Cl2 gas. The misconceptions experienced by students and college students are likely due to students and college students memorizing more concepts about the application of Le Chatelier's principle and not understanding multiple representations, especially submicroscopic representations in the problem.

This study only examines the analysis of student misconceptions about the factors that affect the shift in equilibrium including the effect of changes in temperature, pressure/volume, and concentration. Therefore, it needs to be developed in other chemical equilibrium sub-topics such as the equilibrium state, the chemical equilibrium constant and so on. In addition, research needs to be done to reduce students' misconceptions about the factors that affect equilibrium shifts. This research shows that students often experience misconceptions in problems involving submicroscopic representations, so that in learning lecturers can add applications or animations that can show the relationship between the three levels of representation so that it can improve students' abilities at the submicroscopic level.

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