Analysis of misconceptions by four tier tests in electrochemistry, case study on students of the chemistry education study program UIN Antasari Banjarmasin

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Abstract. This study aims to determine misconceptions on electrochemistry on the students of Chemistry Education Study Program UIN Antasari. The qualitative descriptive approach in this study was used to identify student misconceptions using the four-tier test. There are four (4) test levels which include: (1) multiple-choice with C2-C6 level, (2) confidence rating of the answer beliefs, (3) reasons for the answers, and (4) confidence rating of the reasoning beliefs for the answers. The three criteria used in the level of misconception consist of high, medium and low criteria. The results show that the students of the Chemistry Education Study Program of UIN Antasari experience misconception with moderate criteria on all electrochemical concepts which include the concepts of species undergoing oxidation and reduction in both Voltaic and electrolysis cells. Student's misconception about the direction of electron flow, the condition of electron flow during electrolysis, and cathodic protection of iron.

Keywords: *misconceptions*, *four tier test*, *electrochemistry*

1. Introduction

Misconception [1] is an understanding of concepts contained in the minds of students that are contrary to scientific concepts, which are influenced by students' experiences. Misconceptions can occur if students' understanding of concepts is incomplete. A level of representation is needed to get a complete understanding. Three representations that are relevant to understanding chemical concepts are: (1) macroscopic representations that describe most real phenomena and are seen in students' daily experiences when observing changes in material properties (e.g. changes in color, pH of solution, formation of gases and deposits in chemical reactions), (2) microscopic representations that provide explanations at the particle level, the material is described as consisting of atoms, molecules, ions, and also about chemical process and (3) symbolic representations that use symbols, formulas and chemical equations, as well as pictures of molecular structures, diagrams, models and animations computer to symbolize material [2].

Misconceptions that occur in students come not only from the initial conception received by students but can also come from teachers. Teachers can give new misconceptions if they are not careful in using analogies or modeling in the learning process. Brown & Clayment [3] states that analogies can build new misconceptions in students, basically analogies and modeling are often used for reasons of simplification of concepts, especially abstract concepts. Dincer [4] states that the analogy is used to inhibit the process of misconception. Teachers must be careful in giving analogies,

because if students are less able to accept the concepts given by the teacher by using analogies, then misconceptions can occur. If this misconception is not immediately followed up, the consequence is that the subsequent learning process will be less effective. Teachers must be sensitive to misconceptions that occur in students so that teachers can design effective learning processes to overcome these misconceptions. Misconceptions among students must thus be identified so that action can be taken to help students replace them with more scientific concepts [5]. One way to identify misconceptions is to use a diagnostic test instrument that is given to students after the learning process is carried out. The basic principle of diagnostic tests is that the teacher must consider the basic intuitive knowledge that students have built if they want to understand students' thinking related to the concepts of science that have been taught [6]. The method is used to determine students' understanding of concepts including concept maps, interviews, two-tiered multiple-choice diagnostic tests [5] three-tier multiple-choice [7], as well as four-tier multiple [8].

According to Caleon and Subramaniam [8], the sequence in the four-tier test is a multiple-choice question with 5 answer choices, multiple-choice answer beliefs, reasons, and reasonable beliefs. Four-tier tests can be used to identify students who understand concepts, misconceptions, errors, and students who do not know the concepts [9], [10]. The advantages of the four-tier test are it covers all the advantages in the three-tier test and can assess misconceptions and lack of knowledge accurately [11]. In this study, researchers used four-tier tests to analyze the misconceptions of students from the tertiary level (students) on electrochemistry.

Electrochemistry is classified as one of the toughest topics in chemistry for students, both at high school level [12]-[14] and university level. In general, students will find difficulty in mastering this material. One of the main reasons for this situation is because misconceptions require higher-order thinking skills that cover all three levels of representation, as previously mentioned [13], [15]. Electrochemistry is also stated as abstract material for students [16]. The movement of electrons cannot be seen, and some students have to visualize the movement of these electrons. Students must understand the movements of ions and electrons during the electrolysis process, and must be able to change the processes that occur into chemical equations and formulas [13], [15].

Some research on misconceptions on electrochemistry have been done at the secondary school and university level with research instruments in the form of open-ended tests and interviews, where the results of the study show that (1) students have misconceptions in identifying anodes and cathodes, analyzing reactions in liquid compounds and aqueous solution, and write down chemical equations [17]. Weak basic knowledge in electrochemistry, language barriers and the application of rote learning are identified as factors that contribute to students' misconceptions in electrochemical learning [17]. (2) Students in tertiary institutions have misconceptions about the electrolyte equation in electrochemical cells [18], and this misconception occurs as a result of the wrong impression given from drawings and statements and instructions/explanations that are not correct. (3) Students experience misconceptions in oxidation and reduction reactions as well as electrochemistry and electrolysis cells, but it also occurs with respect to current flow in electrolyte solutions and salt bridges which includes the idea that (i) electrons move through electrolytes and salt bridges, are carried out or transferred by cations and anions; (ii) protons move through electrolytes and salt bridges, even in neutral and basic solutions; and (iii) the movement of ions in solution does not form an electric current [19], [20]. Based on this background, the misconception research conducted was aimed at students, especially students of the Chemistry Education Study Program on electrochemistry using the four-tier test. The formulation of the issues raised for observation and discussion are what misconceptions can be identified by the four-tier test of electrochemistry in students of the Chemistry Education Study Program.

2. Research method

The qualitative descriptive approach in this study was used to identify students' misconceptions by using misconception tests and concepts that were understood with four tier test. Stages of research are conducted: (1) conducting studies to find misconceptions that often occur in special electrochemisty,

(2) designing test instruments developed by researchers by referring to four levels in each question which includes: the first stage show multiple choice test with a C2-C6 level about voltaic cell and electrolysis concept that can be seen in Table 3, second stage are confident rating for the respondent's answer confidence, third stage; the reasons for the answers in the first stage, and the fourth stage; confident rating which is the conviction of the reason for the answer in the third stage. (3) validating the instruments conducted by chemistry lecturers, (4) testing the instruments to students of the Chemistry Education Study Program of UIN Antasari, and (5) analyzing students' misconceptions with four tier test developed [11] by calculating percentages and following 16 types of answer patterns of predetermined results on Table 1.

Table 1. Criteria for answer patterns results *four tier test.*

No	*Tier 1*	*Tier 2*	*Tier 3*	*Tier 4*	Conclusion
1	True	Sure	True	Sure	Understanding Concept
2	True	Sure	True	Not sure	Not understand concept
3	True	Not sure	True	Sure	Not understand concept
4	True	Not sure	True	Not sure	Not understand concept
5	True	Sure	False	Sure	False positive
6	True	Sure	False	Not sure	Not understand concept
7	True	Not sure	False	Sure	Not understand concept
8	True	Not sure	False	Not sure	Not understand concept
9	False	Sure	True	Sure	False negative
10	False	Sure	True	Not sure	Not understand concept
11	False	Not sure	True	Sure	Not understand concept
12	False	Not sure	True	Not sure	Not understand concept
13	False	Sure	False	Sure	Misconception
14	False	Sure	False	Sure	Not understand concept
15	False	not sure	False	Sure	Not understand concept
16	False	Not sure	False	Not sure	Not understand concept

After determine using Kaltakci criteria, it is calculated using this formula [11].

$$\% = \frac{\Sigma\ Student\ with\ Misconception}{\Sigma\ sample}\ x\ 100\%$$

Then, using three misconception criteria based on the amount of percentage consisting of low, medium and high Kurniawan and Suhandi on [21] following Table 2.

Table 2. Criteria for answer patterns results *four tier test.*

Percentage of Misconception	Category
0 < misconception ≤ 30	Low
30 < misconception ≤ 70	Medium
70 < misconception ≤ 100	High

3. Results and Discussion

Misconception analysis was conducted on the answers of Chemistry Education students with a four-tier electrochemistry test. The question was developed into 23 items representing 12 concepts in electrochemistry. The results of the analysis are shown in Table 3.

Table 3. Percentage of misconceptions of UIN Antasari chemistry students.

No.	Concepts	Question Number	Percentage	Category
1	Spontaneous and non-spontaneous nature of redox reactions	1	46.67	Medium
2	Characteristic of a spontaneous redox reaction	2 and 3	43.33	Medium
3	Voltaic or Galvani cells and their functions	4,5,6, and 7	46.67	Medium
4	Cell potential based on standard potential data	8	46.67	Medium
5	Cell potential through the Nernst equation	9 and 10	40.00	Medium
6	The principle of the work of Voltaic cells in everyday life	11	33.33	Medium
7	Factors affecting corrosion	12 and 13	46.67	Medium
8	Corrosion prevention	14 and 15	50.00	Medium
9	Electrolysis and function of its parts	16	60.00	Medium
10	Reaction at anode and cathode on electrolysis	17,18,19, and 20	31.11	Medium
11	Faraday's Law in the calculation of electrolysis cells	21,22, and 23	17.78	Low
	Average		**42.02**	**Medium**

Based on the Table 1, the results of the misconception analysis of Chemistry Education students in electrochemistry are in the medium category, with a percentage of 42.02%. The highest misconception occurs in electrolysis concepts and its parts with a percentage of 60% while the lowest misconception occurred in the concept of Faraday's Law in the calculation of electrolysis cells with a percentage of 17.78%.

The concept of spontaneous and non-spontaneous nature of the oxidation-reduction reaction is measured through item 1, with a percentage of misconceptions of 46.67%. In question no. 1, the experimental data were given about the insistence of Zn, Pb, Cu, and Fe with $ZnSO_4$ solution; $Pb(NO_3)_2$; $CuSO_4$; $FeSO_4$ where the reaction takes place spontaneously in the reaction $Zn(s) + Pb^{2+}(aq) \rightarrow Zn^{2+}(aq) + Pb(s)$. It is because the left voltaic series is more reactive and will push the right side. However, students answer choices with reactions involving Zn^{2+} undergoing a reduction. The reason for the answer is because Zn has the strongest oxidation power. It is not under the existing theory, that Zn is the strongest reduction among these metals so that the reduction power is Zn> Fe> Pb> Cu [22].

The concept of spontaneous oxidation-reduction reaction characteristics was developed in questions no. 2 and 3, with an average percentage of misconceptions of 43.33%. Misconceptions on this concept occur because they do not understand the problem well about reducing and oxidizing, which is related to problem number 1. For example, in problem number 2, students misunderstand the reduction power because the answer shows the metal which has an increased reduction power. Because of the sign of a decrease in oxidation number because it can force metal ions in solution. Students' understanding of the reducing power of a substance means that the substance is reduced. When a substance has high reduced power, then the substance will easy reduce other substances so that the substance itself oxidizes [19], [20].

Problems no. 4, 5, 6 and 7 test the understanding of the concept of reactions in Voltaic or Galvani cells and the functions of each part. In this concept also tests students' understanding of writing cell notation on Voltaic cells. For example, the flow of electrons in Voltaic cells using copper and lead electrodes is from Pb to Cu because electrons flow from the anode to the cathode. Whereas, most students answer that electrons flow from Pb to Cu^{2+} because there is an electron handover from Pb metal to Cu^{2+} ions. According to Garnett and Treagust [19], electrons from the oxidation reaction at the anode flow into the cathode. Electron flow occurs in metals instead of electrolyte solutions, whereas students' understanding of electrons flows from metal to electrolyte solution.

The concept of cell potential based on standard potential data is tested through question no 8. Reactions can take place spontaneously if they have a positive value potential reaction [22], so the reaction that can take place is $Mn(s) + 2Ag^{+}(aq) \rightarrow Mn^{2+}(aq) + 2Ag(s)$. Students are still not right for determining the reaction that takes place spontaneously. This is also supported by the reason that students still think that a spontaneous reaction can take place if it has a negative potential standard value.

Factors affecting corrosion were developed in questions no. 12 and 13. In this concept, Tadris Chemistry students experienced a misconception of 46.67%. Factors that influence the occurrence of corrosion are the presence of water vapor, oxygen, and acid vapor. Carbon dioxide does not affect the reaction because carbon dioxide does not cause oxygen to be reduced in the iron surface and does not cause iron to oxidize. While students are more likely to answer the acid vapor around the iron does not affect the occurrence of corrosion. Because acid vapor around the metal only causes a reaction at the cathode, namely $O_2 + 4H^{+} + 4e^{-} \rightarrow 2H_2O$, while the reaction at the anode remains.

For the concept of corrosion prevention can be seen from the answers of students in questions no. 14 and 15. In this concept, students experience a fairly high misconception, which is as much as 50%. One of the corrosion prevention in the problem is about cathodic protection with zinc metal. Zinc metal is more easily oxidized than ferrous metal, because the electrode potential value of the zinc metal is more negative than the electrode potential value of the ferrous metal, so the zinc metal is a strong reducing agent. This causes zinc to undergo oxidation, whereas iron undergoes reduction. Students consider ferrous metal to be more easily oxidized because it has a more negative potential value than zinc metal.

The last discussion was on question no 16, namely the concept of electrolysis and its parts. In this concept, students experience the highest misconception, which is around 60%. In electrolysis cells, there is a change in electrical energy into chemicals. In electrolysis cells, the cathode functions as an electrode where the reduction occurs because positive ions will tend to be attracted to the cathode [17]. Students assume that the cathode functions as an electrode where oxidation occurs because negative ions will tend to be attracted to the anode.

4. Conclusion

Based on the results of the analysis, it was found that Chemistry Education students experienced misconceptions on all electrochemical concepts with different numbers of percentages with most of the medium criteria. Students still do not understand the concept of species undergoing oxidation and reduction in Voltaic cells or electrolysis. Students do not understand that electrons were resulting from oxidation reactions at the anode flow into the cathode. Electron flow occurs in metals instead of electrolyte solutions, whereas students' understanding of electrons flows from metal to electrolyte solution. Additionally, students also did not understand well about cathodic protection in iron. Some of these misconceptions need to be done by educators to reduce and prevent these misconceptions.

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