

**DEVELOPMENT AND APPLICATION OF
A TWO-TIER ACID-BASE MISCONCEPTION DIAGNOSTIC
TEST BASED ON PICTORIAL TO IDENTIFYING STUDENT
MISCONCEPTIONS IN CHEMISTRY**

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Abstract

The purpose of this study was to develop a two-tier diagnostic test based on pictorial that could identify students' misconceptions of acid-base concepts. This test is called the Acid-Base Misconception Diagnostic Test (ABMDT). This study used the Development and Validation method which consisted of design, development, validation, and application. Instrument validation sheets, interview guides, and essay tests were developed to obtain the data in this study. Based on the results of the design and development stage, obtained 15 items of ABMDT were valid with the Content Validity Ratio (CVR) value for each item being one. Based on the result of the reliability test, Cronbach's Alpha value was 0.771 or in other words, the test included acceptable categories. We then used valid and reliable items to identify misconceptions among high school students who learned the concept of acid-base. The application of tests showed that many misconceptions about an acid-base concept which was identified, such as strong acids reacting with metals resulting in H₂ gas because strong acids ionized partially.

Keywords: Diagnostic test, Misconceptions, Two-tier acid-base misconception.

1. Introduction

Understanding concepts is essential in learning chemistry because good conceptual understanding will be the basis to construct more complex concepts. Many students have difficulties and misconceptions in learning chemistry [1, 2]. The main reason for this is an abstract chemical concept [3, 4]. In addition, reasons for student misconceptions include the complexity of the chemical content, the discrepancy between the scientific content presented and the level of cognitive development of the student, the inappropriate organization of educational content that does not adhere to prerequisites, and inappropriate use. Lack of analog simulation by the teacher, lack of lab work and discussion, inappropriate teaching methods, and lack of connection between three levels of learning: Sensory (macroscopic), atoms and molecules (sub microscopic), and symbolic (formulas and algorithms) [5, 6]. Many chemical concepts involve sub microscopic and symbolic representation. Most students have difficulties with sub microscopic and symbolic representation, rather than macroscopic representation [7, 8].

The misconception is students' conceptions differ from scientific conceptions [9]. The misconception is difficult to eliminate even through teaching by the teacher, and for students, these misconceptions seem more logical even though the concept is different from the scientist's conception [10]. Misconceptions can also be a problem in science education because misconceptions can obstruct students' understanding [9].

Chemical concepts are generally taught hierarchically from easy to difficult concepts, from simple to complex concepts [3]. If the student has a misconception, then the student will have difficulty understanding the next concepts. Identification of misconceptions should be done immediately for immediate remediation [11-13]. Some methods that can identify misconceptions include concept maps, interviews, drawings, and a two-tier diagnostic test [14]. Diagnostic tests can use error information to provide an accurate overview of student misconceptions [15]. A two-tier diagnostic test is a tool that can identify student misconceptions [16]. A two-tier diagnostic test was developed, the first containing answer options and the second containing reasons based on the first [17]. The advantages of the two-step diagnostic test were minimal response rates and ease of use for students and teachers [18, 19].

Previous studies have demonstrated the effectiveness of a two-tier, multiple-choice diagnostic test in identifying misconceptions in chemistry. Tan shows that a two-tier, multiple-choice diagnostic test can clarify misconceptions students have about the concept of ionizing energy [20]. Otherwise, by chemical reaction, separation, electrochemistry, and chemical bonding [21-24]. However, most of his two-step, multiple-choice diagnostic tests that were developed are descriptive.

Narrative questions have a weakness; they can make students tired of understanding the central issue of the problem [25]. To overcome these weaknesses, researchers can use metaphors. Visuals such as images, columns, tables, charts, graphs, and mindmaps can facilitate comprehension [26]. In addition, images can represent sub microscopic levels [27]. This image can also detect student misunderstandings [28]. The advantages of using pictorials are the information becomes more concrete, easier to understand, can explain a process more deeply, and can assist students in understanding scientific explanations [29]. The effectiveness

pictorial to identify misconceptions has been done by Kose and Dikmenli in identifying student misconceptions on the process of cell division [30, 31].

The acids and bases concept has an important place in primary and secondary chemistry education. Concepts of acids and bases are interrelated. Students think that this concept is complex to learn because the student must understand macroscopic, sub microscopic, and symbolic levels so that the teacher must use suitable methods in learning about acid-base and misconceptions must be prevented [32, 33]. Students understand the explanation of acid-base, but students cannot link the acid-base concept with phenomena [10]. However, although there have been studies of two-tier diagnostic tests, there has been no development and use of a two-tier diagnostic test based on the acid-base concept pictorial. For these reasons, researchers conducted a study on developing a two-tier pictorial-based diagnostic test to identify student misconceptions about the acid-base concept.

In Brønsted-Lowry's theory, the ionization process involves the donation of protons from one water molecule to another. So one of the water molecules acts as an acid and other acts as a base [33]. As a result, the hydronium ion H_3O^+ (acid conjugate) and the hydroxide ion OH^- (basic conjugate) are produced. This reaction is reversible and in the reverse reaction, H_3O^+ donates a proton to OH^- . The opposite reaction tells a lot more than the correct one. Equilibrium is further to the left. Figure 1 shows that acid (2) and base (1) are much stronger than acid (1) and base (2) [9].

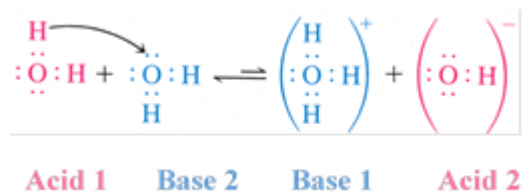
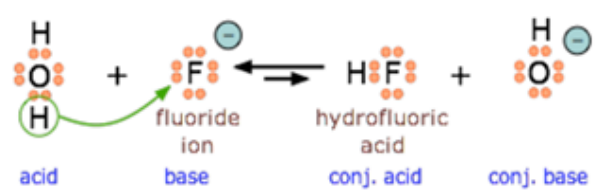


Fig. 1. The ionization process.

Lewis acids and Lewis bases are a generalization of the concept of being an acid or a base. A Lewis base is a substance that can donate an electron pair, and a Lewis acid is a substance that can accept an electron pair [32]. Figure 2 shows that all Lewis acid-base reactions lead to the formation of coordinate covalent bonds (both electrons come from the same species). Lewis acid-base reactions differ from redox reactions in that there is no physical transfer of one or more electrons from the donor to the acceptor and Fig. 3 shows simple acid-base neutralization [33].



F^- acts as Lewis Base.

Fig. 2. Lewis acid-base reaction.

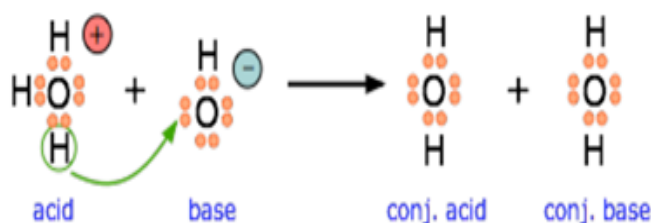


Fig. 3. Simple acid-base neutralization.

2. Method

This study used Development and Validation method to design the item test through the validation process [34]. The validation test involved five chemistry education experts and the reliability test involved 70 students. After the items were valid and reliable, then the item test was applied to 38 students who had studied the acid-base concept. Research stages had four stages. (1) Design phase, (2) Development phase, (3) Verification phase, (4) Application phase. The design phase began with defining the target concept based on the acid-base concept. The development stage adapted the development stage of the two-tier diagnostic test from Chandrasegaran and Treagust there were (a) the determination of concept content, (b) the data collection stage of student misconception, and (c) the development stage. In the first stage, determined target concept and then this target concept is developed into concept maps. In the next stage, the data collection of misconceptions through literature review and interview. The researcher did interviews to complement and confirm the findings of misconceptions from pre-existing studies. The validation phase consisted of content validity and reliability tests [21, 35]. Five experts were involved in content effectiveness testing. The content validity test resulted in a CVR value [36]. 70 students participated in the reliability test and gave Cronbach alpha scores.

In the application stage, the test that had been valid and reliable, which contained seven target concepts and 15 valid items applied to 38 students. The researcher took seven items that represented each target concept with the highest misconception proportions. Based on the determinations key made from the results of an analysis of the pattern of student responses at the previous test, the researcher determined the type and number of misconceptions.

3. Results and Discussion

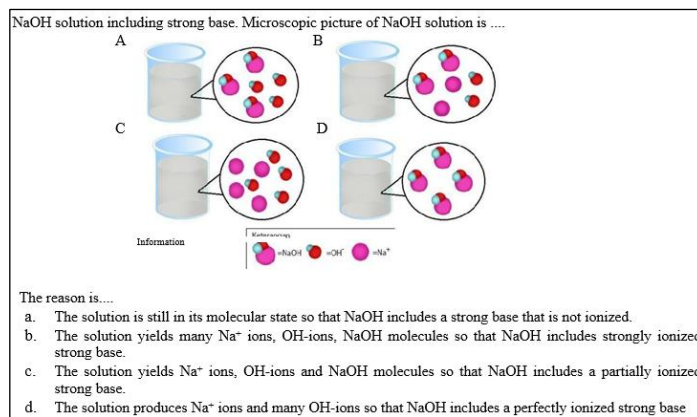
3.1. Results

The result of the validation stage was the validity value and reliability value, the outcome of the application phase was the type and number of student misconceptions. Based on the first stage, then got seven concept labels and 15 items about the acid-base concept. The concept label, item number, and CVR value of the items showed in Table 1.

Based on Table 1, each item represented almost a concept label. The CVR value of all items was one, which showed that all items were valid. This was one of the fifteen valid items shown in Fig. 4.

Table 1. Content validity test results of instrument on basic acid concept.

No.	Concept Label	Item number	CVR value
1.	Ionization of Strong Acid	1	1
		2	1
2.	Strong Acid Reaction with Metals	3	1
		4	1
3.	Ionization of Weak Acid	5	1
		6	1
4.	Strong Base Ionization	7	1
		8	1
5.	Electrical Conductivity of Acid-Base	9	1
		10	1
6.	Weak Base Ionization	11	1
		12	1
7.	Neutralization	13	1
		14	1
		15	1

**Fig. 4. One of fifteen items that were successfully assembled and validated.**

The fifteen items that had valid were then tested the reliability. The item that had been revised and accepted was tested on 70 students. The reliability test results for 15 items were Cronbach's Alpha value of 0.771. This meant that all items had a good reliability index, so all items developed were valid and reliable.

To minimize error when identifying misconceptions, before applying the items test, the item was selected based on the largest percentage of misconceptions, so that the data were more accurate. Seven items that had been selected with numbers 1, 3, 5, 8, 9, 12, and 13 were changed to numbers 1,2,3,4,5,6,7. After selecting items, the reliability item was tested again. The Cronbach's Alpha value of seven items was 0.736 with the category "acceptable" because of the value of $\alpha \geq 0.7$.

Based on the reliability test results, the seven items selected are also key in determining the type and number of misunderstandings in response to student

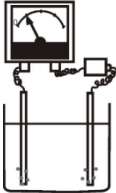
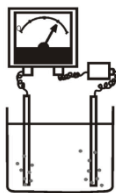
responses. An identification key was created based on the item's characteristics. In a two-stage multiple choice, the first stage consisted of 4 responses and the second stage consisted of 4 reasons, yielding 16 possible responses with the response patterns in Table 2.

Table 2. Student response patterns.

I II	A	B	C	D
1	A.1	B.1	C.1	D.1
2	A.2	B.2	C.2	D.2
3	A.3	B.3	C.3	D.3
4	A.4	B.4	C.4	D.4

Determinations are key used to identify misconceptions based on students' responses. With the determination key, it could easily classify students' conceptions as misconceptions, or not understanding. This was appropriate with other researchers on the benefits of a two-tier multiple-choice test as a tool for diagnosing students' misconceptions [15, 16]. The determination key of item number 3 about the electrical conductivity of the acid-base concept is shown in Table 3.

Table 3. Determination key of item No. 3, response patterns and student misconceptions.

No.	Question	Response Patterns	Student misconceptions
3	<p>This is the test result of the electrical conductivity of 1 M CH_3COOH solution (Fig. T-1) and 1 M KOH (Fig. T-2) using an inert electrode.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Fig. T1</p> </div> <div style="text-align: center;">  <p>Fig. T2</p> </div> </div> <p>The conclusion from this experiment is that in the same molarity, CH_3COOH and KOH produce different electrical conductivity. This is caused by</p> <p>A. $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$ $\text{KOH}(\text{aq}) \rightleftharpoons \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})$</p> <p>B. $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$ $\text{KOH}(\text{aq}) \rightarrow \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})$</p>	<p>A.1</p> <p>A.2</p>	<p>At the same molarity, CH_3COOH is more electrically conductive than KOH because CH_3COOH partially ionizes in water to produce several ions, whereas KOH is fully ionized to produce many ions. lower. The reaction formula is: $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$ $\text{KOH}(\text{aq}) \rightleftharpoons \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})$</p> <p>At the same molarity, CH_3COOH is less conductive than KOH. This is because KOH is completely ionized and produces many ions, whereas CH_3COOH is not ionized in water. The formula for the ionization reaction is: $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$ $\text{KOH}(\text{aq}) \rightleftharpoons \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})$</p>

No.	Question	Response Patterns	Student misconceptions
	C. $\text{CH}_3\text{COOH} (\text{l}) \rightarrow \text{CH}_3\text{COOH} (\text{aq})$ $\text{KOH} (\text{s}) \rightarrow \text{KOH} (\text{aq})$		
	D. $\text{CH}_3\text{COOH} (\text{aq}) \rightarrow \text{CH}_3\text{COO}^- (\text{aq}) + \text{H}^+ (\text{aq})$ $\text{KOH} (\text{l}) \rightarrow \text{KOH} (\text{aq})$		
	The reason is...	A.3	In the same molarity, KOH had greater electrical conductivity than CH_3COOH . This is because, in water, KOH was not ionized while CH_3COOH is perfectly ionized to produce many ions. The formula for the ionization reaction is: $\text{CH}_3\text{COOH} (\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^- (\text{aq}) + \text{H}^+ (\text{aq})$ $\text{KOH} (\text{aq}) \rightleftharpoons \text{K}^+ (\text{aq}) + \text{OH}^- (\text{aq})$
	1. In water, CH_3COOH is partially ionized to produce several ions, while KOH is fully ionized to produce many ions.		
	2. In water, CH_3COOH was not ionized, but KOH was completely ionized, producing many ions.		
	3. In water, KOH was not ionized, but CH_3COOH is fully ionized to produce many ions.		
	4. In water, CH_3COOH is partially ionized to produce some ions, while KOH is completely dissociated to produce many ions.		
		A.4	At the same molarity, CH_3COOH is partially ionized in water to produce some ions, whereas KOH is completely dissociated to produce many ions, so CH_3COOH has a lower electrical conductivity than KOH became. The formula for the ionization reaction is: $\text{CH}_3\text{COOH} (\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^- (\text{aq}) + \text{H}^+ (\text{aq})$ $\text{KOH} (\text{aq}) \rightleftharpoons \text{K}^+ (\text{aq}) + \text{OH}^- (\text{aq})$
		B.1	At the same molarity, CH_3COOH is partially ionized in water to produce some ions, whereas KOH is fully ionized to produce many ions, so CH_3COOH has a lower electrical conductivity than KOH became. The reaction formula is as follows: $\text{CH}_3\text{COOH} (\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^- (\text{aq}) + \text{H}^+ (\text{aq})$ $\text{KOH} (\text{aq}) \rightarrow \text{K}^+ (\text{aq}) + \text{OH}^- (\text{aq})$
		B.2	At the same molarity, CH_3COOH is less

No.	Question	Response Patterns	Student misconceptions
			<p>conductive than KOH. This is because KOH is completely ionized and produces many ions, whereas CH₃COOH is not ionized in water. The formula for the ionization reaction is:</p> $\text{CH}_3\text{COOH (aq)} \rightleftharpoons \text{CH}_3\text{COO}^- \text{ (aq)} + \text{H}^+ \text{ (aq)}$ $\text{KOH (aq)} \rightarrow \text{K}^+ \text{ (aq)} + \text{OH}^- \text{ (aq)}$
		B.3	<p>At the same molarity, KOH had greater electrical conductivity than CH₃COOH. This is because, in water, KOH was not ionized while CH₃COOH is perfectly ionized to produce many ions. The equation for the ionization reaction was:</p> $\text{CH}_3\text{COOH (aq)} \rightleftharpoons \text{CH}_3\text{COO}^- \text{ (aq)} + \text{H}^+ \text{ (aq)}$ $\text{KOH (aq)} \rightarrow \text{K}^+ \text{ (aq)} + \text{OH}^- \text{ (aq)}$
		B.4	Answer Key
		C.1	<p>At the same molarity, CH₃COOH is partially ionized in water to produce some ions, whereas KOH is fully ionized to produce many ions, so CH₃COOH has a lower electrical conductivity than KOH became. The reaction formula is as follows.</p> $\text{CH}_3\text{COOH (l)} \rightarrow \text{CH}_3\text{COOH (aq)}$ $\text{KOH (s)} \rightarrow \text{KOH (aq)}$
		C.2	<p>At the same molarity, CH₃COOH is less conductive than KOH. This is because KOH is completely ionized and produces many ions, whereas CH₃COOH is not ionized in water. The formula for the ionization reaction is:</p> $\text{CH}_3\text{COOH (l)} \rightarrow \text{CH}_3\text{COOH (aq)}$ $\text{KOH (s)} \rightarrow \text{KOH (aq)}$
		C.3	<p>In the same molarity, KOH had greater electrical conductivity than CH₃COOH. This is because, in water, KOH was not ionized while CH₃COOH is perfectly ionized to produce many ions. The equation for the ionization reaction was:</p> $\text{CH}_3\text{COOH (l)} \rightarrow \text{CH}_3\text{COOH (aq)}$ $\text{KOH (s)} \rightarrow \text{KOH (aq)}$
		C.4	<p>In the same molarity, CH₃COOH had less electrical conductivity than KOH. This is because, in water, CH₃COOH is partially ionized to produce a few ions while KOH is perfectly dissociated to produce many ions. The equation for the ionization reaction</p>

No.	Question	Response Patterns	Student misconceptions
			was: $\text{CH}_3\text{COOH (l)} \rightarrow \text{CH}_3\text{COOH (aq)}$ $\text{KOH (s)} \rightarrow \text{KOH (aq)}$
		D.1	At the same molarity, CH_3COOH is partially ionized in water to produce some ions, whereas KOH is fully ionized to produce many ions, so CH_3COOH has a lower electrical conductivity than KOH became. The reaction formula is as follows. $\text{CH}_3\text{COOH (aq)} \rightarrow \text{CH}_3\text{COO}^- \text{(aq)} + \text{H}^+ \text{(aq)}$ $\text{KOH (l)} \rightarrow \text{KOH (aq)}$
		D.2	At the same molarity, CH_3COOH is less conductive than KOH . This is because KOH is completely ionized and produces many ions, whereas CH_3COOH is not ionized in water. The formula for the ionization reaction is: $\text{CH}_3\text{COOH (aq)} \rightarrow \text{CH}_3\text{COO}^- \text{(aq)} + \text{H}^+ \text{(aq)}$ $\text{KOH (l)} \rightarrow \text{KOH (aq)}$
		D.3	At the same molarity, KOH had a greater electrical conductivity than CH_3COOH because CH_3COOH was completely ionized and produced many ions while KOH was not ionized in water. The formula for the ionization reaction is: $\text{CH}_3\text{COOH (aq)} \rightarrow \text{CH}_3\text{COO}^- \text{(aq)} + \text{H}^+ \text{(aq)}$ $\text{KOH (l)} \rightarrow \text{KOH (aq)}$
		D.4	At the same molarity, CH_3COOH is partially ionized in water to produce some ions, whereas KOH is completely dissociated to produce many ions, so CH_3COOH has a lower electrical conductivity than KOH became. The formula for the ionization reaction is: $\text{CH}_3\text{COOH (aq)} \rightarrow \text{CH}_3\text{COO}^- \text{(aq)} + \text{H}^+ \text{(aq)}$ $\text{KOH (l)} \rightarrow \text{KOH (aq)}$

According to Tan, a misconception was considered serious and common if it was found in at least 10% of the student sample. Besides that, if the first and second-tier were related, so it could be a misconception, and if the first and second-tier were unrelated, so it could be a significant error [15]. Thus, if the answer choices were chosen by more than 10% of students but between the first and second tiers there was an unrelated, then the answer choices were not a misconception but a significant error.

In the application stage, two-tier diagnostic tests that had been developed were used to identify student misconceptions. Seven valid and reliable items were applied to 38 students. Based on application test results and calculation of misconceptions rates for identification keys in Table 3, there was a misconception for each target

concept. There were examples of item number 3 to identify misconceptions about the electrical conductivity of the acid-base concept. From item 3, we get the student performance percentages and categories as shown in Table 4.

Table 4. Student answer for item No. 3 on electrical conductivity properties of acid-base.

Pattern	Percent	Category
A.1	12.06	Misconceptions
A.2	1.59	Do not understand
A.3	2.22	Do not understand
A.4	1.90	Do not understand
B.1	32.38	Misconceptions
B.2	13.33	Misconceptions
B.3	7.30	Do not understand
B.4	9.21	Understand
C.1	3.81	Do not understand
C.2	1.59	Do not understand
C.3	1.59	Do not understand
C.4	2.86	Do not understand
D.1	1.90	Do not understand
D.2	2.33	Do not understand
D.3	3.60	Do not understand
D.4	2.33	Do not understand

The result of the application test on item number 3 showed the pattern of response: A.1, A.2, A.3, A.4, B.1, B.2, B.3, B.4, C.1, C.2, C.3, C.4, D.1, D.2, D.3 and D.4. Based on table 4, many students chose B.4 (9,21%), which showed some students already understand about electrical conductivity properties of the acid-base concept. While the percentage for the category did not understand was 33,02%, and the misconception was 57,77%. A comparison of student conceptions was shown in Fig. 5.

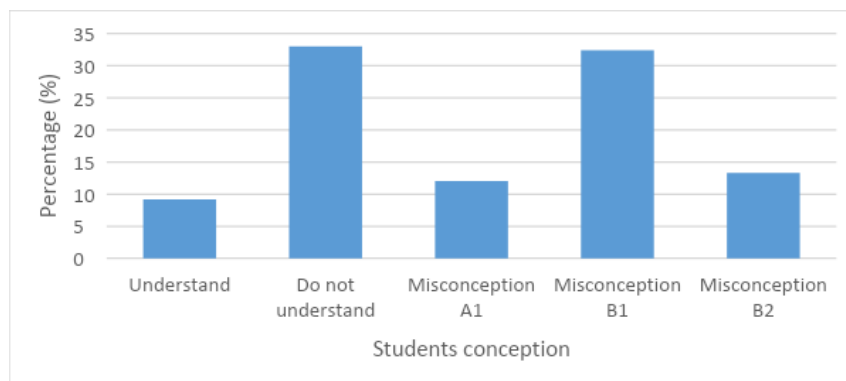


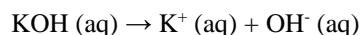
Fig. 5. Comparison of student conception for item Number 3.

The student answers that were said to be misconceptions were A.1, B.1, and B.2. The misconceptions shown by pattern A.1 were chosen by 12,06% of students. The misconception is the same molarity, CH_3COOH is partially ionized in water to produce some ions, whereas KOH is fully ionized to produce many ions, so

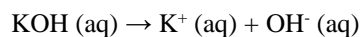
CH_3COOH is more electrochemical than KOH and less conductive. The reaction formula is as follows:



Then the misconceptions shown by pattern B.1 were chosen by 32,38% of students. The misconceptions were in the same molarity: CH_3COOH partially ionizes in water to produce some ions, whereas KOH fully ionizes to produce many ions, so CH_3COOH is more electrically conductive than KOH . The conductivity was low. The reaction formula is as follows:



The last misconceptions shown by pattern B.2 were chosen by 13,33% of students. The misconception is the same molarity, KOH ionizes completely and produces many ions, whereas CH_3COOH was not ionized in water, so CH_3COOH was less conductive than KOH . The formula for the ionization reaction is:



Overall, Fig. 6 shows the percentage of misconceptions found in the acid-base concept. The highest percentage of students had misconceptions about the concept of neutralization and the smallest percentage of students had misconceptions about strong acid reactions with metals concept.

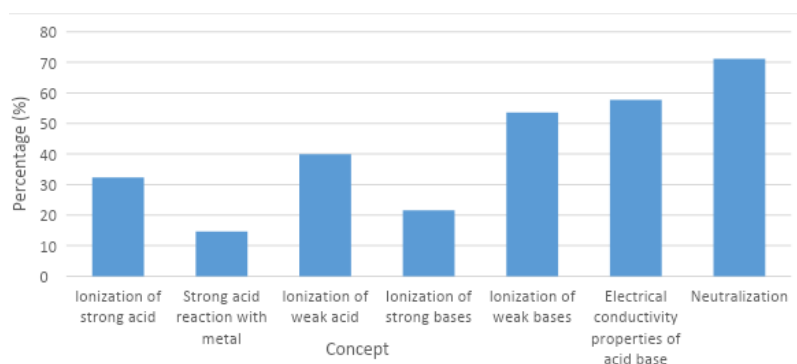


Fig. 6. Comparison of percentage of student misconceptions.

Based on Fig. 6 above, the largest percentage misconception on the concept of neutralization was 71.05%. This meant that almost all students had misconceptions about the neutralization concept. Student thinking that to neutralize strong acid with strong bases needed amount of OH^- ions more than H^+ ions and the amount of moles base must be more, chosen by 23.68% of students; to neutralize strong acid with strong bases needed the amount of OH^- ions equal H^+ ion and moles of acid and base should be the same, chosen by 47.37% student. Their thinking was a misconception. Misconceptions could be caused by themselves and teachers who gave incomplete explanations or inappropriate teaching methods. Thus, many

students had misconceptions. This condition was possible because the characteristic of the chemical concept was abstract [3, 4]. Besides, students must understand macroscopic, sub microscopic, and symbolic levels [5]. Most students had difficulties at the sub microscopic and symbolic levels rather than at the macroscopic level [6].

On the concept label of strong acid ionization, 18.42% of students thought that strong acid perfectly ionized in solution produced many cations, anions, and molecules. Sub microscopic representation of solution contained cations and anions. Such conceptions were categorized as significant errors because the answer was chosen by students more than 10%. But it is in the first and second-tier unrelated [20]. Students knew strong acid from reading and memorizing, but the student could not interpret the concept from the image. Thus, it could not be said misconception.

After applying and analysing, overall misconceptions with the type and number of misconceptions for each target concept were presented in Table 5.

Table 5. Misconceptions about every acid-base concept.

No.	Target Concept	Misconceptions
1	Ionization of Strong Acid	<ul style="list-style-type: none"> Strong acid perfectly ionized in solution produced many cations (H^+), anions, and molecules. A submicroscopic picture of the solution contained cations (H^+), anions, and molecules. Solid acid partially ionized in the solution produced many cations (H^+), anions, and molecules. A submicroscopic picture of the solution contained cations (H^+), anions, and molecules. Strong acid was not ionized in the solution so it was still in its molecular state. Submicroscopic picture of iodide acid solution contained molecules
2	Strong Acid Reaction with Metal	<ul style="list-style-type: none"> Strong acids reacted with metals resulting in H_2 gas because strong acids ionized partially.
3	Ionization of Weak Acid	<ul style="list-style-type: none"> Acid solutions that had an ionization constant of less than one were strong acids that ionized perfectly to produce many cations (H^+) and anions. Submicroscopic images of the solution contained cations (H^+) and anions. Acidic solutions that had an ionization constant of less than one were weak acids that ionized partially to produce a few cations (H^+) and anions. Submicroscopic images of the solution contained cations (H^+) and anions. The compounds which had OH in their compounds included strong bases which ionized perfectly to produce many cations and anions, such as HCOOH
4	Strong Base Ionization	<ul style="list-style-type: none"> Bases that ionized partially to produce cations, anions (OH^-), and molecules. Submicroscopic images contained cations, anions (OH^-), and their molecules Strong bases did not dissociate. Thus, in solution, it is still in its molecular state. Submicroscopic images contained molecules
5	Electrical conductivity properties of acid-base	<ul style="list-style-type: none"> NaOH solutions were good conductors of electricity because NaOH is a strong electrolyte that is partially ionized in solution. At the same molarity, CH_3COOH is partially ionized in water to produce some ions, while KOH is fully ionized to produce many ions, so CH_3COOH is a better conductor of electricity than KOH's lower degree. The reaction formula is as follows: $CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$

No.	Target Concept	Misconceptions
6	Weak Base Ionization	<ul style="list-style-type: none"> Bases that had an ionization constant of less than one were strong bases that perfectly ionized to produce many cations and anions (OH^-). Submicroscopic images contained cations and anions (OH^-). Bases that had an ionization constant of less than one were weak bases that partially ionized to produce a few cations and anions (OH^-). Submicroscopic images contained cations and anions (OH^-). Bases such as $\text{Fe}(\text{OH})_2$ had an ionization constant of less than one weak base which partially ionized to produce a few cations and anions (OH^-). The submicroscopic image contained 2 cations, 2 anions (OH^-), and 2 molecules.
7	Neutralization	<ul style="list-style-type: none"> To neutralize strong acids with strong bases needed amount of OH^- ions are more than H^+ ions and the amount of moles base must be more. To neutralize strong acid with strong bases needed amount of OH^- and H^+ ions same and the mole of acid and base must be the same.

Figure 7 shows the results of identifying misconceptions between male and female students.

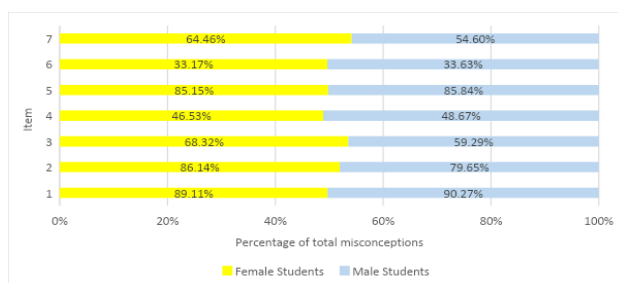


Fig. 7. Comparison of percentage of male and female student misconceptions.

Based on items 1, 4, 5, and 6 in Figure 4, male students are more likely to be misunderstood than female students, and female students are more likely to be misunderstood than male students in items 2, 3, and 7. There is a high percentage of this meant that male students did not tend to make more misconceptions than female students, or that female student had more misconceptions than male students. Thus, there was no significant difference in misunderstandings between male and female students.

3.2. Analysis

The result was a misconception of the student on the acid-base concept. Without a pictorial, the item could not explain the students' conception. Previous studies found students' misconception that strong acid ionized partially. Using the pictorial would identify students' thinking about the concept of ionized partially. Besides, a picture could also convince students to think and helped students explain their thinking. This was consistent with expert explanations of the benefits of pictorials in helping students understand concepts [26]. Besides, the pictorial emphasized sub-microscopic representation in chemical problem-solving [27]. The pictorial could also identify student misconceptions [28]. Using pictorials had given some

advantages, such as obtaining information becomes more concrete and concise, easier to understand, could explain a process more deeply, and could assist students in understanding scientific explanations [29].

The reason for causing misconceptions overall was the students' ability in learning. Students who could not understand a whole concept in chemistry would have difficulties learning chemistry. Incomplete and unclear teachers' explanations could also cause some students' misconceptions. Based on the result of interviews, many students said that teachers rarely explained the concept using pictorial (submicroscopic level), so the concepts received by students were not complete. Such as the teacher explained strong acid ionization, but the teacher did not explain a perfect ionization of the strong acid concept, so students interpreted the concept itself. This could make students' misconceptions. Understanding this concept required a macroscopic, submicroscopic, and symbolic understanding [32].

Previous research had also said that students understood the acid-base explanation, but students could not relate acid-base theory with everyday phenomena [10]. Students misunderstood the concept of acid-base strength. The students thought that the intramolecular bonds were so strong that strong acids would not dissociate in water. A strong acid always had a great concentration [37]. In learning, students should think from low to high levels and from a low cognitive level to a high cognitive level [38]. Besides, the teaching methods could also cause students not to understand the concept. As a result of the analysis, the students knew the concept and neutralization of acid-base starch, but because the teacher did not explain it at the submicroscopic level, they could not interpret their ideas through the pictures, and the students could not understand well.

There was no significant difference in misconceptions between male and female students. This follows studies by several researchers who said gender was not a significant factor in determining student performance [39]. Inyang and Jegede, Shaw and Doan, Hannover, Kessels, and Erinsho reported that gender had no statistical effect on student performance in science and chemistry [40]. According to Beaton, these caused boys to get higher scores than girls on spatial representation, reading and describing the submicroscopic level of a chemical concept, measurement, proportion, and solving complex problems, while girls got a high score on calculations, solving simple problems, and reading charts, so that girls and boys had the same chance of getting high scores [39, 41, 42]. Hyde also showed that gender differences do not significantly affect cognitive performance. Thus, cognitive ability was significantly and positively correlated with learning performance, but it could not explain that gender differences could affect learning performance. Other factors that influenced learning success were heredity, attitudes, interests, talents, individual motivations, habits in the child's development, impressions of particular subjects, and social environments such as teachers, parents, and friends [43].

4. Conclusion

The development of the two-tier ABMDT consists of 15 elements. Each ABMDT item had a CVR value of 1 and a Cronbach alpha of 0.771. The conceptual targets of acid-base where misconceptions were confirmed were the ionization of strong acids, strong acid reactions with metals, ionization of weak acids, ionization of strong bases, electrical conductivity properties of acid-base, and ionization and

neutralization of weak bases. The largest percentage misconception on the concept of neutralization was 71.05%. This meant that almost all the students had misconceptions about the neutralization concept.

Acknowledgements

Rector of Universitas Pendidikan Indonesia, Dean of FPMIPA, and Head of the Department of Chemistry Education, which provided facilities and support to conduct this research.

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