

Analyzing of Students' Misconceptions on Acid-Base Chemistry at Senior High Schools in Medan

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Abstract

Students' misconceptions on acid-base chemistry at senior high schools in Medan were investigated in this study. The study involved 179 of XI grade students from six different schools in Medan selected based on their accreditation. Students' misconceptions on acid base chemistry topic were identified and collected by giving a valid test developed by researcher to the students in form of Acid-Base Chemistry Misconception Test containing 12 open-ended multiple choices. The data collected were processed and categorized based on students' achievement and students' understanding. It was revealed that students had fifteen misconceptions and eleven submisconceptions. From five main concepts investigated in acid-base chemistry, percentage of students' responses categorized as specific misconceptions are acid and base concepts (22.07%), pH and pOH concepts (43.58%), ionization degree and equilibrium constant concepts (8.94%), acid-base indicators concept (6.15%), and acid-base titration concept (9.50%). The study also revealed four main students' problems in understanding acid-base chemistry namely fragmentation of students' understanding, problems with symbols and mathematical formula, difficulties in understanding the context in acid-base chemistry, and problems in generalization.

Keywords: students' misconception, acid-base chemistry, students' achievement, students' understanding

1. Introduction

Human beings naturally learn from natural and social environment through the observation using their five senses. This learning process, whether aware or not, occurs continuously from the beginning until the end of human life. In this case, human being especially students, grow and develop various ideas and conceptions about everything they receive from their environment. Consequently, students do not enter the classrooms as blank vessel, but they enter classrooms with preexisting knowledge or ideas of science concepts that will be delivered by teacher (Gonen & Kocakaya, 2010). These ideas, from the students' point of view, can be understood in such a way that strongly held by the students. These ideas and conceptions are possibly correct, but most of them are significantly different from accepted scientific viewpoints and tend to be rationalized by students arbitrarily by only considering what they receive from their five senses.

In science classroom, students bring their prior knowledge from the outside and sometimes relate their prior knowledge to what teacher explains improperly. Therefore, the concepts they construct cannot correctly explain the scientific phenomena and, finally, deviate from scientific concepts. These differences between the students' views and the scientifically accepted views are called misconceptions (Ozmen, 2004; Barke et al., 2009), alternative conceptions (Pedrosa & Dias, 2000; Talanquer, 2006), commonsense reasoning (Talanquer, 2006), preconceptions (Barke et al., 2009), alternative framework (Kuiper, 1994; Maskill & de Jesus, 1997), or naive conception (Reiner et al., 2000) (misconception term is used in this paper for simplicity.) Some of these misconceptions can be removed easily, but most of them are strongly held by students and usually not affected by regular classroom teaching because these are something students believe. If the misconceptions are not corrected, new concepts would be difficult to be learnt (Gonen & Kocakaya, 2010).

Chemistry is sometimes viewed as a difficult subject by students. The chemistry concepts itself are really complex and abstract (Stieff & Wilensky, 2003). Chemistry also makes students go between macroscopic representations, submicroscopic (or molecular) representations, and symbolic (or iconic) representations simultaneously (Johnstone, 2000; Chandrasegaran et al., 2007). In order to get deep and comprehensive understanding in learning chemistry, students need to comprehend those three representations of chemistry. Any chemistry teaching that cannot relate these three chemistry representation properly will have great possibility to create misconceptions in students and make them cannot fully understand the concept.

In general term, misconceptions could be defined as any conceptions that are in disagreement or different with currently accepted scientific view. Various sources of misconceptions have been found and explained such as students (Suparno, 2005), teachers (Suparno, 2005; Drechsler & Schmidt, 2005), textbooks (Pedrosa & Dias, 2000; Chiu, 2005; Sanger & Greenbowe, 1999), teaching method (Tasker & Dalton, 2006), and internet (Sesen & Ince, 2010). Talanquer (2006) had also explained how the way students think about chemical substances and phenomena underlying the misconceptions based on commonsense explanatory framework.

Identifying misconception of students is the first step for preventing misconceptions in chemistry. The identification of the students' understandings and misconceptions has been the goal of many of the studies carried out over the last years (Ozmen, 2004). Some of the conceptual areas in which most studies have been conducted are chemical equilibrium (Erdemir et al., 2000; Sendur et al., 2010; Husseini, 2011), acid-base (Ross & Munby, 1991; Kousathana et al., 2005; Sheppard, 2006), chemical bonding (Peterson et al., 1986; Coll & Taylor, 2002; Ozmen, 2004; Smith & Nakhleh, 2011), nuclear chemistry (Nakibog˘Lu & Tekin, 2006), atomic orbital and hybridization (Nakiboglu, 2003), buffer solution (Orgil & Sutherland, 2008), solutions and their components (Çalık & Ayas, 2005; Pinarbasi & Canpolat, 2003), colligative properties (Pinarbasi et al., 2009), thermochemistry (Azliandry, 2007) and electrochemistry (Sanger & Greenbowe, 1999; Huddle & White, 2000).

As mentioned above, there are some topics that chemistry students find more difficult to understand. One of those topics is acid-base chemistry. The topic of acids and bases is dense with concept and requires an integrated understanding of many areas of introductory chemistry (Sheppard, 2006). Students often just gain knowledge of acid-base concepts through memorization without comprehend them (Lin et al., 2004). In the literature, there have been a number of studies that address various aspects of understanding about acids and bases (Huang, 2003; Sheppard, 2006; Schmidt & Chemie, 2007; Halstead, 2009; Cartrette & Mayo, 2010; Chaiyapha et al., 2011; Rahayu, 2011).

Therefore, based on the condition described above, the researcher chose to conduct this research. The objective of this research was to identify High School students' misconceptions about concepts of acid-base chemistry and to determine which misconceptions in basic chemistry concepts causing difficulties in learning the concepts of acid-base chemistry at Senior High Schools in Medan.

2. Methodology

The research was conducted qualitatively by using questionnaire in form Acid-Base Chemistry Misconception Test (ACMT) as the instrument to obtain and identify students' achievement (achievement score) and misconceptions in acid-base chemistry topic. The study was started from sampling process to obtain sample from Senior High Schools situated in Medan. The study was then followed by preparation and testing of research instrument in form of Acid-Base Chemistry Misconception Test (ACMT).

Research object in this study was consisted of XI grade students from one class of a Chemistry Course from six Senior High Schools in Medan Academic Year 2011/2012 who have learnt acid-base chemistry topic. These schools are selected based on their accreditation (accreditation A, B, and C). Two schools were chosen from each accreditation. The samples from these schools were obtained by choosing one class randomly in each school. From those classes in each school, all students were selected as sample without considering their achievement in chemistry class.

The instrument of this research which was used for obtaining data was diagnostic test of misconception in form of Acid-Base Chemistry Misconception Test (ACMT). A 12 open-ended multiple choice item test corresponding to acid-base chemistry concepts was developed by the researcher with respecting to misconceptions obtained from various literatures. Acid-base chemistry concepts analyzed and examined in ACMT included five main concepts namely acid and base, ionization degree and equilibrium constant (K_a and K_b), pH and pOH, acid-base indicator, and acid-base titration. Descriptions of test items in ACMT are presented in Table 1. Each question required students to select one correct answer from the options and wrote expected reason based on scientific concept for each problem. Both of these data were used to group the students based on students' achievement and students' understanding.

In collecting the necessary data in this study, valid ACMT test was given to the sample. This was done after the students have learnt acid-base chemistry matter. In answering the test, students were free to see the data of atomic number from periodic table and use the calculator.

2.1 Students' Achievement Criteria

Data of students' achievement were collected based on the options chosen by students for every question in

ACMT without considering the reason they made for these options. The division of group was done by calculating the average value and standard deviation of students' marks in each class, and then grouped based on the following criteria.

High Group (HG) : $HG \geq X + SD$
Medium Group (MG) : $X - SD < MG < X + SD$
Low Group (LG) : $LG \leq X - SD$
where: X = the average value of sample in each class
SD = the standard deviation

2.2 Students' Understanding Criteria

Grouping of students based on students' understanding was conducted by analyzing the data of students' reasons in answering ACMT. Students' answers were then classified into four categories based on the following criteria.

- *Scientifically Correct (SC)*: This group consists of scientifically complete responses and correct explanations
- *Partially Correct (PC)*: Any scientifically correct responses but incomplete explanations are fit in this category.
- *Specific Misconceptions (SM)*: Any completely scientifically unacceptable responses or explanations are included into this category
- *No Understanding (NU)*: Students who do not make any response; make irrelevant or unclear explanations; just rewrite the question or no explanation are put in this category.

3. Result and Discussion

3.1 The Grouping of Students Based on Students' Achievement

Data of students' achievement were collected based on the options chosen by students for every question in ACMT without considering the reason they made for these options. In grouping of students based on their achievement, students' marks were converted in form of achievement. Averages of students' achievement in answering ACMT and number of students in each group for all schools were presented in Table 2.

3.2 The Grouping of Students Based on Students' Understanding

Grouping of students based on their understanding were conducted by dividing the students into four different groups. These groups consisted of scientifically correct (SC), partially correct (PC), specific misconception (SM), and no understanding (NU). Based on the data analyzed from students' responses in ACMT, as a whole, there were fifteen misconceptions and eleven submisconceptions identified. Percentage of students' understanding analyzed based on selected option and reason made by students and percentage of students' misconceptions identified on acid-base chemistry topic from all schools could be seen in Table 5 and Table 6, respectively. An example in analysis of question 8 is presented as the following.

3.2.1 Analysis of Question 8

Question 8 was proposed in order to know students' understanding about acid-base reaction from the three acid-base theories (Arrhenius, Bronsted-Lowry, and Lewis theories) and chemical bonding concepts that have been learned by students. Arrhenius theory emphasized on H^+ and OH^- produced when substance was dissolved in aqueous solution, while Bronsted-Lowry theory emphasized on species acting as proton donor and acceptor, and further, Lewis theory involved the species that can act as electron pair donor and acceptor. Answer for question 8 and percentage of students' responses for question 8 in ACMT are presented in Table 3 and Table 4, respectively.

From the sample investigated, it was obtained that 8.38% of students' responses was categorized as partially correct, 24.02% of students' responses was categorized as specific misconception, and 67.6% of students' responses was categorized as no understanding in question 8. Table 4 shows in general about the percentage of students' understanding analyzed based on selected option and reason made by students for question 8.

Students' responses categorized as partially correct chose option E, however, students were wrong in giving a correct reason. Students knew that reaction in option E was an oxidation-reduction reaction, but they differentiated incorrectly between reducing and oxidizing agents. The following statement had shown these partially correct answers.

"E. $3Ni^{2+}_{(aq)} + 2Cr(OH)_{3(s)} + 10OH^{-}_{(aq)} \leftrightarrows 3Ni_{(s)} + 2CrO_4^{2-}_{(aq)} + 8H_2O_{(l)}$

Alasan: karena $Cr(OH)_3$ bukan basa tetapi oksidator" (Accreditation B school)

Students' misconceptions in question 8 led to one kind of misconception namely "*one acid-base theory can explain all acid-base reaction*." This misconception was divided into two submisconceptions namely "*Arrhenius theory can explain all acid-base reactions*" and "*Bronsted-Lowry theory can explain all acid-base reactions*."

Arrhenius theory can explain all acid-base reactions. Students whose this misconception in general explained that, in an acid-base reaction, the reactants should contain H recognized as an acid and OH recognized as a base. Students also tended to explain that compound containing H is an acid and one containing OH is a base. Several students' statements containing this misconception are stated as the following.

"A. $Al(OH)_{3(s)} + OH^{-}_{(aq)} \rightleftarrows Al(OH)_4^{-}_{(aq)}$

Alasan: karena setiap reaksi asam-basa harus melibatkan H^+ dan OH^-"

(Accreditation B school)

"C. $NH_{3(g)} + BF_{3(g)} \rightleftarrows H_3N\text{-}BF_{3(s)}$

Alasan: karena umumnya reaksi asam + basa akan menghasilkan garam + air (H_2O)"

(Accreditation B school)

Bronsted-Lowry theory can explain all acid-base reactions. Students' responses containing this misconception showed that, in every acid-base reaction, there should be proton transfer (H^+). Student's response clarifying this misconception is presented as the following.

"C. $NH_{3(g)} + BF_{3(g)} \rightleftarrows H_3N\text{-}BF_{3(s)}$

Alasan: karena tidak ada yang menjadi donor proton dan akseptor proton (pemberi dan penerima)" (Accreditation A school)

Both of these submisconceptions indicated that students were not too familiar with these three acid-base theories and their application in certain context especially for Lewis theory. Some students just comprehended one acid-base theory and applied this one to all acid-base reactions as shown in those statements. These submisconception leaded to one main misconception indicating that students tended to use one acid-base theory to explain all acid-base reaction.

3.3 Discussion

Based on the analysis that has been conducted, most of students' responses in ACMT were categorized into specific misconception and no understanding rather than scientifically correct and partially correct. These results indicated that students of Senior High Schools in Medan have low understanding in acid-base chemistry topic. Students, in general, couldn't make any correct reasons for what they know.

Misconceptions analysis that have been conducted show several difficulties in learning acid-base chemistry. At least, there are four main issues that could be addressed in this analysis namely fragmentation of students' understanding, problems with symbols and mathematical formula, difficulties in understanding the context in acid-base chemistry, and problems in generalization. Further explanations for these difficulties are presented as follow.

3.3.1 Fragmentation of students' understanding

This issue was identified from some questions that needed students' understanding in other area of acid-base chemistry such as chemical equilibrium, stoichiometry, chemical bonding, and thermochemistry. In learning acid-base chemistry, students tended to ignore the other topics and not made any connection to what they learn in acid-base chemistry. Ozmen (2004) also explained that the persence of students' misconceptions indicates the fragmented understanding in students' minds. These phenomena could be seen in students' responses in solving questions 1, 3, 4, 10, and 11. From these questions, it could be seen that students didn't try to solve the problem by using other concepts from different topics; they just did it in scope of acid-base chemistry.

3.3.2 Problems with symbols and mathematical formula

This problem clearly made the students difficult in proving any statements in ACMT. Students, generally, made miscalculation, misinterpretation the symbols, and then they were wrong in concluding the result. Students even didn't understand [H_3O^+] symbol that they have learned in previous topics such as in reaction rate and chemical equilibrium. Sirhan (2007) also have recognized this as one of five main problems In learning chemistry. He explained that the use of representational symbolisms in chemistry could create misunderstandings and confusions and suggested that students should be given more opportunity to verbalise and discuss ideas when chemistry concepts were being taught (Sirhan, 2007). This difficulty could be seen in students' responses for solving question 2, 5, and 9.

3.3.3 Difficulties in understanding the context in acid-base chemistry

Students, in solving the ACMT, were difficult and tended to ignore the real context of problem. Students just focus on the number and mathematical formula given in the problem without considering what actually asked. Problem with context also could be found in implementation of acid-base theory. Students used one acid-base theory and utilized it to explain all acid-base reaction. Talanquer (2006) also found these phenomena through the analysis of misconceptions from various researches. In that paper, Talanquer (2006) explained that students tend to apply general principles and laws without considering the particular characteristics of the system or conditions of process. Problem in understanding the context could be seen from students' responses in solving questions 3 and 8.

3.3.4 Problems in generalization

Students tended to be trapped by some generalization created when they learned acid-base chemistry. Students just memorized these generalizations without understanding the underlying theory of these. These generalizations created misconception in students' mind and, finally, students just answer ACMT by writing a meaningless statement. Talanquer (2006) called this as fixation and explained that students tend to apply the same principles, strategies, and interpretations automatically in solving various problems, without considering other strategies or meaning and ignoring the nature of problems. These problems could be seen from students' responses in solving questions 6, 7, 9, and 12.

These difficulties showed that students had not fully understood about acid-base chemistry. Most of students couldn't integrate their understanding in other areas of chemistry in learning acid-base topic. Students just focused in memorizing the formulas and theories given in learning process without comprehending them. These problems were also strengthened by low mathematical skills of students that increased the degree of difficulties in learning acid-base chemistry.

4. Conclusion and Suggestion

Result of students' misconceptions analysis indicated that students of Senior High Schools in Medan have low understanding in acid-base chemistry topic. It was found that there were fifteen kinds of misconceptions identified in five main concepts of acid-base chemistry. Analysis of students' responses also showed that there were four areas as the main problems in formation of students' misconceptions namely fragmentation of students' understanding, problems with symbols and mathematical formula, difficulties in understanding the context in acid-base chemistry, and problems in generalization.

The results of analysis in students' misconception could be used as references for chemistry teachers for identifying students' misconception in classroom. Further investigations about students' misconceptions on acid-base chemistry topic are suggested using various methods to get better data analysis. Considering the importance in collecting the data of students' misconceptions, it is also suggested for other researchers to investigate students' misconception for other topics in chemistry.

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References

Azliandry, H. (2007), Analisis Miskonsepsi Siswa Kelas XI MAN 1 Medan dan Upaya Penanggulangannya pada Pokok Bahasan Termokimia, *Thesis*, Mathematics and Natural Sciences Faculty, State University of Medan,

Medan.

Barke, H.D., Hazari, A., & Yitbarek, S. (2009), *Misconceptions in Chemistry, Addressing Perceptions in Chemical Education*, Berlin: Springer.

Çalık, M., & Ayas, A. (2005), A Cross-Age Study on the Understanding of Chemical Solutions and Their Components, *International Education Journal*, **6(1)**, 30-41.

Cartrette, D.P., & Mayo, P.M., (2010), Students' Understanding of Acids/Bases in Organic Chemistry Contexts, *Chemistry Education Research Practice*, **12**, 29–39.

Chaiyapha, P., Chayajarus, K., & Chairam, S. (2011), Investigation of High School Students' Understanding of Acid-Base Chemistry Based on Jigsaw Method, *Pure and Applied Chemistry International Conference 2011*, 139-142.

Chandrasegaran, A.L., Treagust, D.F., & Mocerino, M. (2007), The Development of A Two-Tier Multiple-Choice Diagnostic Instrument for Evaluating Secondary School Students' Ability to Describe and Explain Chemical Reactions Using Multiple Levels of Representation, *Chemistry Education Research and Practice*, **8(3)**, 293-307.

Chiu, M.H. (2005), A National Survey of Students' Conceptions in Chemistry in Taiwan, *Chemical Education International*, **6(1)**, 1-8

Coll, R.K., & Taylor, N. (2002), Mental Models in Chemistry: Senior Chemistry Students Mental Models of Chemical Bonding**,** *Chemistry Education: Research and Practice in Europe*, **3(2),** 175-184.

Drechsler, M., & Schmidt, H. J. (2005), Textbooks' and Teachers' Understanding of Acid-Base Models Used in Chemistry Teaching, *Chemistry Education Research and Practice*, **6 (1)**, 19-35

Erdemir, A., Geban, O., & Uzuntiryaki, E. (2000), Freshman Students' Misconceptions in Chemical Equilibrium, *Journal of Chemical Education*, **18**, 79-84.

Gonen, S., & Kocakaya, S. (2010), A Physics Lesson Designed According to 7E Model with the Help of Instructional Technology (Lesson Plan), *Turkish Online Journal of Distance Education*, **11(1)**, 98-113.

Halstead, S.E., (2009), A Critical Analysis of Research Done to Identify Conceptual Difficulties in Acid-Base Chemistry, *MSc Dissertation*, School of Biochemistry, Genetics and Microbiology, University of Kwazulu-Natal, Pietermaritzburg.

Huang, W. (2003), The Misconceptions on Acid and Base Held by the Elementary Students in Northern Taiwan, *World Conference on Science & Technology Education ICASE 2003*, 1-10.

Huddle, P.A., & White, M.D. (2000), Using a Teaching Model to Correct Known Misconceptions in Electrochemistry, *Journal of Chemical Education*, **77(1)**, 104-110.

Husseini, A. (2011), Analyzing of Students' Misconceptions on Chemical Equilibrium at Senior High School in Medan., *Thesis*, Mathematics and Natural Sciences Faculty, State University of Medan, Medan.

Johnstone, A.H. (2000), Teaching of Chemistry-Logical or Psychological?, *Chemistry Education: Research and Practice in Europe*, **1(1)**, 9-15.

Kousathana, M., Demerouti, M., & Tsaparlis, G. (2005), Instructional Misconceptions in Acid-Base Equilibria: An Analysis from a History and Philosophy of Science Perspective, *Science and Education*, **14**, 173-193.

Kuiper, J. (1994), Student Ideas of Science Concepts: Alternative Frameworks?, *International Journal of Science Education*, [e-journal] **16(3)**, abstract only. Available through: Tailor and Francis Online website< http://www.tandfonline.com/> [Accessed 25 July 2012].

Lin, J.W., Chiu, M.H., & Liang, J.C. (2004), Exploring Mental Models and Causes of Students' Misconceptions in Acids and Bases, *NARST 2004*, 1-12.

Maskill, R., & de Jesus, H.P. (1997), Pupils' Questions, Alternative Frameworks and The Design of Science Teaching, *International Journal of Science Education*, [e-journal] **19(7),** abstract only. Available through: Tailor and Francis Online website< http://www.tandfonline.com/> [Accessed 25 July 2012].

Nakibog˘Lu, B., & Tekin, B. B. (2006), Identifying Students' Misconceptions about Nuclear Chemistry, *Journal of Chemical Education*, **83(11)**, 1712-1718.

Nakiboglu, C. (2003), Instructional Misconceptions of Turkish Prospective Chemistry Teachers about Atomic Orbitals and Hybridization, *Chemistry Education: Research and Practice*, **4(2)**, 171-188.

Orgil, M., & Sutherland, A. (2008), Undergraduate Chemistry Students' Perceptions of and Misconceptions about Buffers and Buffer Problems, *Chemistry Education Research Practice*, **9**, 131-143.

Ozmen, H. (2004), Some Student Misconceptions in Chemistry: A Literature Review of Chemical Bonding, *Journal of Science Education and Technology*, **13(2)**, 147-159.

Pedrosa, M.A., & Dias, M.H. (2000), Chemistry Textbooks Approaches to Chemical Equilibrium and Student Alternative Conceptions, *Chemistry Education: Research and Practice in Europe*, **1(2)**, 227-236.

Peterson, R., Treagust, D., & Garnett, P. (1986), Identification of Secondary Students' Misconceptions of Covalent Bonding and Structure Concepts Using A Diagnostic Instrument, *Research in Science Education*, **16**, 40-48.

Pinarbasi, T., & Canpolat, N. (2003), Students' Understanding of Solution Chemistry Concepts**,** *Journal of Chemical Education*, **80(11)**, 1328-1332.

Pinarbasi, T., Sozbilir, M., & Canpolat, N. (2009), Prospective Chemistry Teachers' Misconceptions about Colligative Properties: Boiling Point Elevation and Freezing Point Depression, *Chemistry Education Research and Practice*, **10**, 273–280.

Rahayu, I. (2011), Analysis of Student's and Teacher's Misconceptions on Acid-Base Reactions of SMAN RSBI in Malang and The Effect for Their Improvement Using Conflict Cognitive Strategy., *Thesis*, Chemistry Education Study Program, Faculty of Graduate Study, State University of Malang, Malang. Abstract only. Available through: State University of Malang Library website< http://karya-ilmiah.um.ac.id/> [Accessed 03 January 2012].

Reiner, M., Slotta, J.D., Chi, M.T.H., & Resnick, L.B. (2000), Naive Physics Reasoning: A Commitment to Substance-Based Conceptions, *Cognition and Instruction*, **18(1)**, 1–34.

Ross, B., & Munby, H. (1991), Concept Mapping and Misconceptions: A Study of High School Students' Understandings of Acids and Bases, *International Journal of Science Education*, **13(1)**, 11-13.

Sanger, M.J., & Greenbowe, T.J. (1999), An Analysis of College Chemistry Textbooks as Sources of Misconceptions and Errors in Electrochemistry**,** *Journal of Chemical Education*, **76(6)**, 853-860.

Schmidt, H.J., & Chemie, F. (1995), Applying the Concept of Conjugation to the Bronsted Theory of Acid-Base Reactions by Senior High School Students from Germany, *International Journal of Science Education*, **17(6)**, 733-741.

Sendur, G., Toprak, M., & Pekmez, E.S. (2010), Analyzing of Students' Misconceptions about Chemical Equilibrium, *International Conference on New Trends in Education and Their Implications November 2010*, 1-7

Sesen, B.A., & Ince, E. (2010), Internet as A Source of Misconception: "Radiation and Radioactivity," *Turkish Online Journal of Educational Technology*, **9(4)**, 94-100.

Sheppard, K. (2006), High School Students' Understanding of Titrations and Related Acid-Base Phenomena**,** *Chemistry Education Research and Practice*, **7(1)**, 32-45.

Sirhan, G. (2007), Learning Difficulties in Chemistry: An Overview, *Journal of Turkish Science Education*, **4(2)**, 2-20.

Smith, K.C., & Nakhleh, M.B. (2011), University Students' Conceptions of Bonding in Melting and Dissolving Phenomena, *Chemistry Education Research Practice*, **12**, 398-408.

Stieff, M., & Wilensky, U. (2003), Connected Chemistry-Incorporating Interactive Simulations into the Chemistry Classroom, *Journal of Science Education and Technology*, **12(3)**, 285-302.

Suparno, P. (2005), *Miskonsepsi dan Perubahan Konsep dalam Pendidikan Fisika*, Jakarta: Grasindo.

Talanquer, V. (2006), Commonsense Chemistry: A Model for Understanding Students' Alternative Conceptions, *Journal of Chemical Education*, **83(5)**, 811-816.

Tasker, R., & Dalton, R. (2006), Research into Practice: Visualization of the Molecular World Using Animations, *Chemistry Education Research and Practice*, **7(2)**, 141-159.

Table 1. Description of test items In ACMT developed by researcher from various sources

No	Concepts in Acid-Base Chemistry	Test Items	Description
1	Acid and Base	1	examples acid-base compounds
		2	characteristics of acidic-basic solutions
		8	acid-base theories
		10	acid-base reactions
2	pH and pOH	3	pH calculation in extremely small concentration of acid
		6	the dependence of K_a, pH, and equilibrium in solution to the temperature
		9	comprehension about solution with pH = 0
		12	application of the dependence of K_a, pH, and equilibrium in solution to the temperature
3	Ionization Degree and Equilibrium Constant (K_a and K_b)	4	equilibrium shifting in dilution process of acidic-basic solution
		5	the nature of K_a of weak acid
4	Acid-Base Indicators	7	acid-base indicator in macroscopic and microscopic scopes
5	Acid-Base Titration	11	acid-base titration process and change of pH along the titration
Total		**12 test items**	

Table 2. Number of students for each group based on students' achievement

Students' Achievement	Accreditation A		Accreditation B		Accreditation C	
	School A	School B	School C	School D	School E	School F
Mean±Standard Deviation	17.6±10.1	9.7±6.5	28.8±14.5	16.2±7.3	8.9±8.3	9.2±7.1
HG	3	8	7	8	5	4
MG	29	18	27	17	9	12
LG	4	5	5	12	2	4
Number of Student	36	31	39	37	16	20

Table 3. Question 8 and its answer in ACMT

The followings are acid-base reaction, **EXCEPT**...

A. $Al(OH)_{3(s)} + OH^-_{(aq)} \rightleftarrows Al(OH)_4^+{}_{(aq)}$

B. $2H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$

C. $NH_{3(g)} + BF_{3(g)} \rightleftarrows H_3N\text{-}BF_{3(s)}$

D. $2NH_{3(l)} \rightleftarrows NH_4^+{}_{(ammonia)} + NH_2^-{}_{(ammonia)}$

E. $3\ Ni^{2+}_{(aq)} + 2\ Cr(OH)_{3(s)} + 10\ OH^-_{(aq)} \leftrightarrows 3\ Ni_{(s)} + 2\ CrO_4^{2-}{}_{(aq)} + 8\ H_2O_{(l)}$

Answer:

E. $3Ni^{2+}_{(aq)} + 2Cr(OH)_{3(s)} + 10OH^-_{(aq)} \leftrightarrows 3Ni_{(s)} + 2CrO_4^{2-}{}_{(aq)} + 8H_2O_{(l)}$

Reason:

Reaction in option E is an oxidation-reduction reaction in which Ni^{2+} act as oxidizing agent and $Cr(OH)_3$ as reducing agent. Reaction in options A and C are considered as acid-base reaction based on Lewis theory. There are transfer of electron between $Al(OH)_3$ and OH^- and between NH_3 and BF_3. Option A and C are recognized as autoionization reactions of water and ammonia in which there are transfer of proton (H^+ ion) between water and ammonia molecules that agree with Bronsted-Lowry theory.

Table 4. Percentage of students' responses for question 8 in ACMT

Categories	**Sample (%)**						**Total (%)**
	Accreditation A		**Accreditation B**		**Accreditation C**		
	School A	**School B**	**School C**	**School D**	**School E**	**School F**	
SC	0	0	0	0	0	0	0
PC	0	0	38.46	0	0	0	8.38
SM	50	6.45	33.33	18.92	18.75	0	24.02
NU	50	93.55	28.21	81.08	81.25	100	67.6

Table 5. Percentage of students' understanding analyzed based on selected option and reason made by students

No	Concepts in Acid-Base Chemistry	Test Item	Categories based on Students' Understanding (%)			
			SC	PC	SM	NU
1	Acid and base Concepts	1, 2, 8, 10	0	2.38	22.07	75.56
2	pH and pOH concepts	3, 6, 9, 12	5.73	0.56	43.58	50.14
3	Ionization Degree and Equilibrium Constant (Ka and Kb) Concepts	4, 5	5.03	4.75	8.94	81.29
4	Acid-base Indicators Concept	7	0	27.93	6.15	65.92
5	Acid-Base Titration Concept	11	0	0	9.50	90.50

Table 6. Percentage of students' misconceptions identified in acid-base chemistry topic using ACMT

No	**Misconception / submisconception**	**f**	**%**	**Test Item**
1	Chemical formula containing H indicates an acid (Halstead, 2009)	106	59.22	1
1a	CH_4 is an acid.	60	33.52	
1b	NaH is an acidic compound	10	5.59	
1c	PH_3 is an acidic compound	36	20.11	
2	One acid-base theory can explain all acid-base reaction (Halstead, 2009)	43	24.02	8
2a	Arrhenius theory can explain all acid-base reaction	28	15.64	
2b	Bronsted-Lowry theory can explain all acid-base reaction	15	8.38	
3	Polyprotic acid behaves as strong monoprotic acid	9	5.03	10
3a	Ionization of polyprotic weak acid, HnX, is H_n^{n+} and X^{n-}	6	3.35	
3b	There's no basic species in acidic aqueous solution	2	1.12	

3c	Polyprotic acid is ionized in one step ionization reaction	1	0.56	
4	In calculation of pH using the formula pH = -log[H_3O^+], [H_3O^+] is just from the solute	158	88.27	3
5	Equilibrium system in acidic or basic solution is not affected by the temperature	59	32.96	6
		18	10.06	12
5a	Neutral solution is equivalent with pH = 7 (Halstead, 2009)	7	3.91	6
5b	Statements explaining that "acidic aqueous solution has pH < 7, basic aqueous solution has pH > 7, neutral aqueous solution has pH = 7, and value of Kw equals to 1.0 x 10^{-14}" are correct	49	27.37	
5c	K_w water equals to 1.0 x 10^{-14}	3	1.68	
		18	10.06	12
6	Solution with pH = 0 doesn't contain H_3O^+ and OH^- ion	13	7.26	9
7	Solution with pH = 0 is a strong base 10^{-14} M solution	61	34.08	
8	Solution with pH = 0 have [H_3O^+] = 0 M	3	1.68	
9	pOH of acidic solution increases in dilution process	8	4.47	4
10	K_a increases in dilution process	9	5.03	
11	As the value of K_a is smaller, molarity of H_3O^+ in the solution is bigger	15	8.38	5
12	Acid-base indicator changes the color at the same pH value namely >7 or <7 in which there's no change in pH = 7	8	4.47	7
13	Acid-base indicator is a catalyst in acid-base reaction	3	1.68	
14	Solutions containing the same molarity, volume, and number of H in the formula, have same pH	13	7.26	11
15	All solutions in equivalent point have the same pH	4	2.23	