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Development of Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts to Identify Students' Alternative Conceptions

1st Muntholib
Department of Chemistry,
Faculty of Mathematics
and Natural Science,
Universitas Negeri Malang,
Indonesia
muntholib.fmipa@um.ac.id

2nd Jian Mayangsari
Department of
Chemistry,
Faculty of Mathematics
and Natural Science,
Universitas Negeri
Malang, Indonesia

3rd Yunilia N. Pratiwi
Department of
Chemistry,
Faculty of Mathematics
and Natural Science,
Universitas Negeri
Malang, Indonesia

4th Muchson
Department of
Chemistry,
Faculty of Mathematics
and Natural Science,
Universitas Negeri
Malang, Indonesia

5th Ridwan Joharmawan
Department of
Chemistry,
Faculty of Mathematics
and Natural Science,
Universitas Negeri
Malang, Indonesia

6th Yahmin
Department of
Chemistry,
Faculty of Mathematics
and Natural Science,
Universitas Negeri
Malang, Indonesia

7th Sri Rahayu
Department of
Chemistry,
Faculty of Mathematics
and Natural Science,
Universitas Negeri
Malang, Indonesia

Abstract- Alternative conception is students' conception of scientific concepts that are inconsistent with the conception of scientists. Various studies show that alternative conceptions of chemical concepts occur in students, including acid-base concepts. Various identification of alternative conception methods have also been developed, including a simple multiple-choice diagnostic test. Although not too accurate, simple multiple-choice diagnostic test is easy to develop, use, and analyze, but useful enough to identify students' alternative conceptions. The aims of the study are to develop a valid and reliable simple multiple-choice diagnostic test instrument of acid-base concepts and to identify alternative conceptions of 11th grade students and first year university students of Chemistry Program. This descriptive research design was conducted in two stages 1) development of valid and reliable of simple multiple-choice diagnostic test of acid-base concepts and (2) identification of students' alternative conceptions. Analysis of instrument validity and reliability was performed based on response of 184 students of 11th grade students and 133 first year university students of Chemistry Program who had studied acid-base concepts before. While the identification of students' alternative conceptions was conducted to 59 students of 11th grade and 40 first year university students of Chemistry Program. Analysis to response of 11th grade students indicate that 8 of the 25 test items of the acid-base concepts developed in this research were invalid. Five invalid items that have a negative or very low Pearson correlation coefficient were removed, the rest having better Pearson correlation coefficient refined and used to identify students' alternative conception. The final version of the instrument has a Cronbach's alpha reliability of 0.537 (medium grade) for 11th grade students and 0.470 (upper low grade) for first year university students. The results of the data analysis show that the alternative conceptions of acid-base concepts occurring in the 11th grade students are more extent and intense than that occurs in the first year university students of Chemistry Program. These can be caused by the difference of age, concept ecology, learning motivation, learning fidelity, and discipline background between 11th grade students and first year university students of Chemistry Program.

Keywords- diagnostic test, alternative conception, acid-base concepts, simple multiple-choice

I. INTRODUCTION

Misconception (Cross et al., 1986; Demircioglu et al., 2005; Orgill & Shutherland, 2008; Pinarbasi, 2007; Wattanakasiwich et al., 2013) or alternative conception (Mutlu & Sesen, 2016; Artdej et al., 2010; Damanhuri et al., 2016) is a form of learning difficulty that should be considered in an effort to improve the learning quality. Misconception or alternative conception is the learners' understanding of the science concept that is inconsistent with acceptable understanding. The quantity and intensity of alternative conceptions that occur in learners reflect the learning quality. The higher quantity and intensity of the alternative conceptions occurring in students the lower learning quality they experienced. Consequently, alternative conceptions can be used to measure the effectiveness of learning strategies, curriculum, or pedagogy received by learners (Sharma et al., 2010; Tongchai, 2009).

Alternative conceptions occur almost in all subjects, including Chemistry. The chemistry topics in which students held alternative conceptions are Matter (Cross et al., 1986), Chemical Bonding (Coll & Treagust, 2003), Equilibrium Chemistry (Hackling & Garnet, 1985; Mutlu & Sesen, 2016), Thermochemistry (Mutlu & Sesen, 2016), Acid-Base Chemistry (Cross, 1986; Demircioglu et al., 2005; Orgill & Shutherland, 2008; Pinarbasi, 2007; Demircioglu, 2009), and Electrochemistry (Garnet & Treagust, 1992; Sanger & Greenbowe, 1997a; Sanger & Greenbowe, 1997b; Mutlu & Sesen, 2016).

Acid-Base Chemistry is one of the chemistry topics in which many alternative conceptions are found (Artedj et al., 2010; Cross, 1986; Demircioglu et al., 2005; Mutlu & Sesen, 2016; Orgill & Shutherland, 2008; Pinarbasi, 2007). These alternative conceptions occurred in all subtopics of Acid Base Chemistry (Table 1).

Table 1. Alternative Conceptions of Acid-Base Chemistry

Subtopics	Alternative Conceptions	Uncovered by
Acid-Base Theory	1) Acid is a compound having hydrogen group(s) in its molecular formula. Example: HCl and CH_4.	Damanhuri *et al.* (2015)
	2) Base is a compound having OH group(s) in its molecular formulas. Example: C_2H_5OH.	Juang (2004)
	3) All organic compounds are neutral.	
	4) Brönsted-Lowry acid is capable of receiving protons.	Artdej *et al.* (2010).
	5) Brönsted-Lowry acid is capable of receiving electron pairs.	
	6) The conjugate acid-base pairs are pairs of positively charged ion and negatively charged ion.	
	7) The conjugate acid-base pairs are pairs of reacting species. Example: HPO_4^{2-} and NH_3.	
	8) For polyprotic acid, the conjugate base is the residual acid that has been depleted all protons. Example: Conjugate base of H_2SO_4 is SO_4^{2-}.	
Water Autoionization	1) pH of pure water is 7.	Pinarbasi (2007)
	2) pH neutral solution is always 7.	
Acid-Base Strength	1) The acidity of a compound increases with the increase in the amount of hydrogen in the compound.	Demircioglu *et al.* (2005)
	2) pH is a measure of acid strength.	
	3) The pH of the solution is inversely proportional to the strength of the acid. The lower the pH of the solution, the higher the acidic strength of the solution.	Mutlu & Şeşen (2016)
	4) The order of strength of hydrogen halides acidity is HF>HCl>HBr>HI. The greater electronegativity of the halogen atom (X), the stronger the halogen atom attracts the electron, the more easily the H^+ ion escapes from the hydrogen halide (HX) molecule.	
	5) Concentration shows acid-base strength.	Ross (1989)
	6) The pH reflects acid strength.	Sheppard (2006)
	7) If K_b XOH is smaller than K_b YOH, the concentration of XOH is less than concentration of YOH (Kb value reflects the concentration of the basic solution).	Artdej et al. (2010)
	8) The diprotic acid is stronger than monoprotic acid.	
	9) The acidity of pure ethanoic acid is stronger than the acidity of the ethanoic acid solution.	Hoe & Ramanathan (2015)
	10) Pure ethanoic acid liquid produces more H^+ ions than ethanoic acid solutions.	
	11) The solution may not have a pH of less than 0 or more than 14.	Zoller (1990); Kariper (2011)
Acid-Base Equilibrium	1) If an equilibrium solution of weak acid HX is added with HCl, then the equilibrium shifts toward the product.	Saglam *et al.* (2011)
	2) If an equilibrium solution of weak base YOH is added with NaOH, then the equilibrium shifts toward the reactant.	
	3) If an equilibrium solution of acid HX is added with base YOH, the equilibrium will not shift.	
Salt Hydrolysis	1) Hydrolysis is reaction of water *self-ionization*.	Dermicioglu, 2009
	2) Hydrolysis is water decomposition to be hydrogen and oksygen.	

Subtopics	Alternative Conceptions	Uncovered by
	3) The results of acid-base neutralization reaction are always neutral.	Mutlu & Şeşen (2016)
	4) The acid-base neutralization reaction of CH_3COOH with NaOH yields a neutral solution because both of reactants react one another completely.	Zoller (1990); Chiu (2004)
The Composition of Buffer Solution	1) If acid / base is added to the buffer solution, the pH of the buffer solution does not change as the buffer can maintain pH. 2) If acid / base is added to the buffer solution, the pH of the buffer remains 7, since the buffer neutralizes the adding acid or base.	Mutlu & Şeşen (2016)
	3) If a solution with pH = 3 is added with 2-3 mL of concentrated HCl, pH of the solution will increase, because the concentrated HCl increases the H^+ ions concentration.	Kariper (2011)
Titrasi Asam Basa	1) The pH of equivalent point is always 7. 2) At the equivalence point, the solution is always neutral. 3) The equivalent point of titration of strong base with weak acid is at pH = 7.	Mutlu & Şeşen (2016)
	4) The addition of an acid to the bases solution causes the pH of the solution drops dramatically.	Sheppard (2006)

The existence of alternative conceptions is very important to know. Learners who held alternative conceptions can be distracted by their alternative conceptions. Alternative conceptions that occur on the prerequisite necessary to learn a knowledge can disrupt learners in learning incoming knowledge (Robinson, 1998). Acid-Base Chemistry is one of the Chemistry topics related to other topics such as Chemical equilibrium, Solution, Stoichiometry, chemical reaction (Sheppard, 2006), acid-base properties of organic compounds and biomolecules. If students held alternative conceptions in chemical reactions, stoichiometry, chemical solutions, and chemical equilibria, which are prerequisite knowledge of acid base topic, they may experience difficulties to learn acid-base concepts and lead them to hold new alternative conceptions in it. In turn, alternative conceptions in acid-base concepts will disturb students in learning of acid-base properties of organic compounds and biomolecules and can lead them to hold new alternative conceptions in those topics.

Various conditions can lead to alternative conceptions. The alternative conceptions occurring in prerequisite knowledge, life experience of learners, the clarity of the teacher's understanding, the clarity of the language used by the teacher, the chemical terms that undergo a change of meaning, and the textbooks used by the students can be sources of alternative conceptions (Hodge, 1993; Kathleen, 1994; Schmidt, 1997).

The acid-base alternative conceptions that occur in the learners has been widely identified in both secondary (Artedj, 2010; Chiu, 2004; Dermicioglu, 2009; Demircioğlu et al., 2005; Drechsler & Schmidt, 2005; Lin & Chiu, 2010 Sheppard, 2006; Ross, 1989;) and higher education (Cross et al., 1986; Saglam et al., 2011; Banerjee, 1991; Mutlu & Sesen, 2016; Orgill and Shutherland, 2008; Pinarbasi, 2007; Zoller, 1990). The identification of acid-base alternative conceptions in universities is generally carried out partially, e.g. the concept of acid-base (Cross et al., 1986), acid-base reactions (Cooper et al., 2016), and buffers (Orgill & Shutherland, 2008). There have been no reports on the acid-base alternative conceptions identification covering all the acid-base chemistry subtopics carried out in universities.

Various methodes to identify alternative conceptions have been developed, such as open questions and interviews (Pinarbasi, 2007), concept maps (Ross and Munby, 1991; Yemen & Ayas, 2015), and multiple-choice tests (Mutlu & Sesen, 2016; Demircioglu et al., 2005; Damanhuri, 2016). Concept map methods, open questions, and interviews can illustrate how learners relate concepts to one another, but they are less efficient (Ross and Munby, 1991). Multiple-choice tests are considered to be more effective and efficient in term of time, survey objectives, and analysis methods because they can be used in a short period of time, numerous targets, and easy ways of data analysis (Wattanakasiwich et al., 2013). The most common multiple-choice test which is used is the two tier diagnostic test (Treagust, 1988; Chandrasegaran et al., 2007). Two tier diagnostic test is very good. Each item of two tier diagnostic test consists of two questions (two tier). The first question is about students' concept comprehension and the second is about the reason of the first tier. The identification of alternative conception of the first question (comprehension) confirmed its validity with the second question (reason). In other words, the alternative conceptions experienced by learners are inferred from the two questions so the validity of the alternative conception is very convincing. Nevertheless, the development of a two tier diagnostic test requires a long time and great energy so it is less practical (Wattanakasiwich et al., 2013). The developing of two-tier multiple-choice diagnostic test consists of three stages: identification of possible alternative conceptions through interviews, institutional arrangements, and validation. In addition, two-tier multiple-choice diagnostic tests are also pervasive, consuming more pieces of questions than other forms of testing.

Two-tier multiple-choice diagnostic tests are very accurate and effective to identify alternative conceptions held by the learners. However, formative assessments intended to determine the presence or absence of students' particular alternative conceptions, the development of two-tier multiple-choice diagnostic test is too time and energy consuming, and costly. Adams & Wieman (2011) and Wattanakasiwich et al. (2013) has developed a one-tier multiple-choice diagnostic test or simple multiple-choice diagnostic test as a modification of a two-tier multiple-choice diagnostic test. The development of simple multiple-choice diagnostic test the first phase of development of two-tier multiple-choice diagnostic tests, i.e. interviews or open-ended questions, were replaced by collecting alternative conceptions that have been identified by previous researchers. The sets of alternative conceptions then used as a choice in the development of simple multiple-choice diagnostic tests.

Objectives of the Study

This research is intended to develop a simple multiple-choice diagnostic test of acid-base concepts that easy to use for a lot of participants; to analyze the validity and reliability of developed instrument, and to identify the acid-base alternative conception occurring in 11th grade students and first year university students.

Acid-Base Chemistry Learning Material for 11th Grade and First-Year University Students

The difference age between 11th grade students and first year university students is 2 years. The average age of 11th grade students are 17 years, while first year university students are 19 years. Although bears status of university students, first year university students experienced a little college life. They are still learning to adapt to real campus life.

Table 2. Materials of Acid-Base Chemistry in Chemistry Syllabus for Senior High School and in Basic Chemistry Syllabus for Bachelor Program

Materials of Acid-Base Chemistry		
Chemistry Syllabus for Senior High School		**Basic Chemistry Syllabus for Bachelor Program**
Competence	**Materials**	
3.10 Understanding acid-base concepts, acid-base strength, and equilibrium of acid-base ionization in solution. 4.10 Determining the traject of pH change of several indicators extracted from natural materials.	• Acid-base concepts development • Acid-base indicator • The pH of strong acid, strong base, weak acid, and weak base.	• Arrhenius and Bronsted Lowry theory of acid-base • Acid-base equilibrium • Water autoionization and pH scale • the strength of acid • equilibrium constant of weak acids and weak bases (Ka and Kb)
3.11 Analyzing the ionic equilibrium in the salt solution and calculate the pH. 4.11 Doing experiment to show the acid-base properties of various salt solutions.	• Equilibrium ions of salt • pH of salt solution • Acid-base properties of salt solution	• Salt Hydrolysis and Its pH
3.12 Describing the working principle, pH calculation, and the role of buffer solution in the body of living things. 4.12 Creating buffer solution with a certain pH.	• how the buffer solution works • pH of buffer solution • the role of buffer solutions in living things • Preparation of buffer solution	• Buffer solution
3.13 Determining the concentration of an acid or base solution	• Titration: determination of concentrations of acidic or basic solutions	• Acid-base Titration • Indicator

Materials of Acid-Base Chemistry		
Chemistry Syllabus for Senior High School		Basic Chemistry Syllabus for Bachelor Program
Competence	Materials	
based-on acid-base titration data. 4.13 Designing, performing, concluding, and presenting results of experiments on acid-base titration.	• Design, perform, and report results of acid-base titration	

Source: Catalog of Chemistry Department Universitas Negeri Malang & Syllabus of Chemistry Subject for Senior High School Indonesian Curriculum of 2013

Basic Chemistry learning materials in university are also not too different from Chemistry Subject learning materials for 11th grade students (Table 2). The difference lies on the depth of discussion and prior knowledge held by the learners. First year university students have been studied Acid Base Chemistry twice, when they were in the 8th and 11th grade, while the 11th grade students only learned the Basic Acid Chemistry one time, when they were in the 8th grade. This situation is also a concern of researchers in the development of simple multiple-choice diagnostic test.

II. METHODS

Development of Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts

The Simple Multiple-Choice Diagnostic Tests of Acid-Base Concepts developed in this study covers all the Acid-Base Chemistry Subtopics taught in the 11th grade students and first year university students. The development of the research instrument was carried out by using a procedure as shown in Figure 1. Literature review is intended to collect acid-base alternative conceptions (Table 1) that have been uncovered by previous researchers, both through quantitative and qualitative research. This collection of acid-base alternative conceptions then used to construct destructor in the development of the Simple Multiple- Choice Diagnostic Test of Acid-Base Concepts. Generally conceptual survey instruments consist of 25-35 common multiple-choices model within an hour testing period (Hestenes et al., 1992, Maloney et al., 2001; Wattanakasiwich et al., 2013). This developed instrument consists of 25 questions with time allocation of 75 minutes.

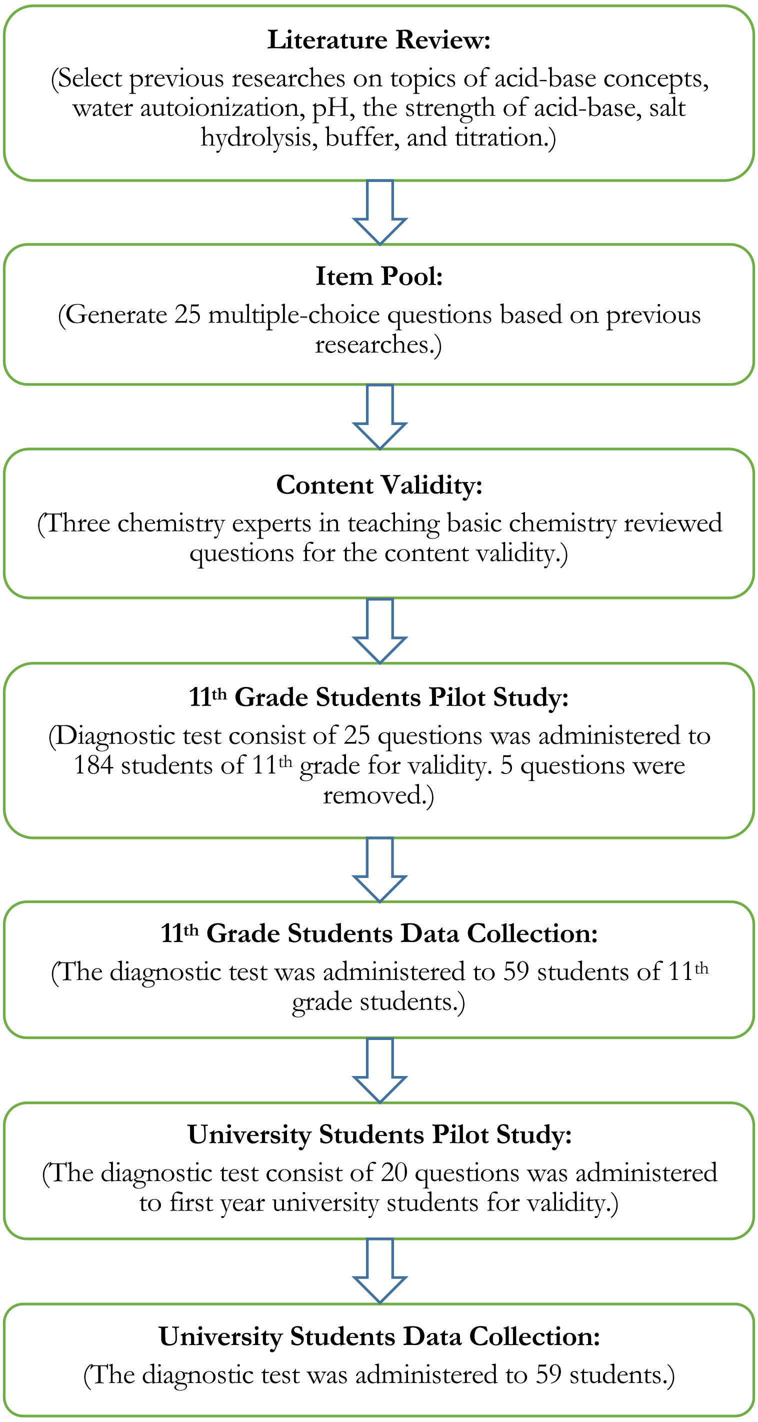

Figure 1: Summary of the Simple Multiple-Choice Diagnostic Test Instrument construction procedure

This developed instrument then tested for its validity and reliability. Validity is a measure of the accuracy between the instrument used to measure and the what it intends to measure. In this study, the measured objects is students' alternative conceptions of acids and bases while the measuring instrument is The Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts. The validity test of the instrument is conducted on content validity and item validity. Content validity is a measure of the accuracy of item points according to the views of those skilled in the art (Wattanakasiwich et al., 2013). The validity of the instrument content of this study was calculated using the equation:

$$VS_n = \frac{total\ score\ of\ an\ instrument}{maximum\ score\ can\ be\ earn}\ X\ 100\%$$

VS_n is the percentage of validator scores n, with n = 1, 2, or 3. The validity criteria used may vary from one researcher to another. The validity criterion used in this study is very high when $VS_n > 80$; high when $80 \geq VS_n > 60$; while when $60 \geq VS_n > 40$; low when $40 \geq VS$n> 20; and very low when $20 \geq VS_n$.

The valid items in expert judgement then administered to 184 of 11th grade students from three State Senior High Schools in Malang and 133 Undergraduate Chemistry Students of Universitas Negeri Malang. The results of this trial are used to determine the validity of items and reliability of instrument of Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts. The validity of the item is determined by using the value of the Pearson correlation coefficient. Pearson correlation coefficient is a measure of the correlation between the grain score with the overall score of the question. The high correlation coefficient indicates that most learners who answer correctly a problem generally have a high total score. The problem is said to be good if the value of r arithmetic is greater than r table (at signification level α = 0,05). This criterion is actually less suitable to be used to determine the validity of the items used to measure alternative conceptions of students, but suitable to determine the validity of items that measure student achievement. Alternative conceptions are formed through all learning experiences, while learning achievements are formed through planned learning with clear study materials. However, although not very appropriate these criteria can still be used to determine the validity of the items on the diagnostic tests used to determine alternative conceptions. Calculation of Pearson correlation test is done by using SPSS Statistic 23.0 for Windows program.

In addition to the validity, instrument developed also passed the reliability test. A research instrument is said to have good reliability if used to retrieve data from the same respondent over and the results are not much different (Kimberlin & Winterstein, 2008). Reability is a measure of the consistency of research instruments (Wiersma, 1991: 274; Kimberlin & Winterstein, 2008). Ideally, the reliability of the instrument is determined by the test-retest method. However, this method also has weaknesses. In the second test there is the possibility that the learner still remembers the problem that he had done in the first test. It could also be the second test that students have prepared well, especially to solve the problems that the first test can not be done. This causes a decline in the value of the reliability of the test instrument.

SPSS Statistic 23.0 for Windows calculates instrument reliability using *Cronbach's Alpha* calculations. The category of reliability value used in this study is low if x <0.5; moderate if 0.5 ≤ x ≤ 0.8; and high if 0.8 <x (Salvucci et al., 1997: 115).

Investigation of Students' Alternative Conception on Acid-Base Chemistry

The valid and reliable of Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts then used to identify students' alternative conceptions. For this purpose, 59 of 11th grade students and 40 of first year undergraduate chemistry students are involved in the data collection. The data obtained is then analyzed to determine the existence of alternative conceptions experienced by learners. Data processing is done by intrepretative descriptive technique. This technique is done by processing the data in the form of percentage, present it in tabular form, and describe it narratively. Data analysis is done by procedure 1) make corrections to learners answer according to answer key; 2) give score 1 for correct answer and 0 for wrong answer; 3) perform tabulation of data, the results of scores that have been scored are inserted into the table to facilitate the calculation process; 4) calculate the percentage of learners' answers to each option for each question by using equation

$$P = \frac{amount\ of\ students\ answering\ oftion\ x}{total\ students\ conducting\ test}\ x\ 100\%$$

5) analyze alternative conceptions experienced by learners [alternative conceptions experienced by more than 10% of students need to be discussed (Gilbert, 1977; Tsai, 2007)]; 6) to describe the alternative conceptions experienced by learners, whether experienced by 11th grade students and first year chemistry students; and 7) comparing the alternative conception profiles of the 11th raders with an alternative concept profile of First Year Chemistry students.

III. RESULTS AND DISCUSSIONS

Instrument Reliability and Validity

The initial draft of simple multiple-choice diagnostic test of acid-base concepts developed in this research consists of 25 items. Expert judgment carried out by three basic chemistry educators having experienced more than 10 years show that content validity of the instrument is very high (Table 3) and only need of light revision. The language of the instrument needs to be adjusted according to the language of the 11th grade students.

The valid Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts consisting of 25 items is then administered to 184 of 11th grade students in Malang City. Of the 25 tested items, 18 were valid and 8 were invalid. Of the 8 invalid items, 5 questions that have negative or very low Pearson correlation coefficients are removed (ie, questions 4, 5, 6, 8, and 12) and 3 items having correlation coefficients not too bad were revised and used for data collection. The result of Pearson correlation coefficient analysis can be seen in Appendix A.

Table 3. Content Validity of Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts Instrument Based on Experts Judgement

Validator	VSn (%)	Content Validity
1	97,33	Very high
2	98,67	Very high
3	94,67	Very high
Average	96,89	Very high

The valid items according to the Pearson correlation coefficient value, i.e. 20 items, then calculated its reliability coefficient value using *Cronbach's Alpha* calculations. The calculation results show that the value of *r* (coefficient of reliability) of the instrument is 0.537 (moderate). This result can't be interpreted that the instrument is less reliable. High calculated reliability coefficients (*Cronbach's alpha*) do not guarantee the reliability of an instrument (Adams & Wieman, 2011).

Alternative conceptions used as destructors for the Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts essentially have been valid as they are taken from valid alternative conceptions uncovered by previous researchers. The validity of the content and the validity of the item are bound to the learning achievement. Alternative conception is more determined by the perspective or understanding of the learners of certain knowledge, whether there is learning achievement or not. Consequently, the internal consistency reliability of the instrument composed of items of validity not tied to learning achievement is also not high.

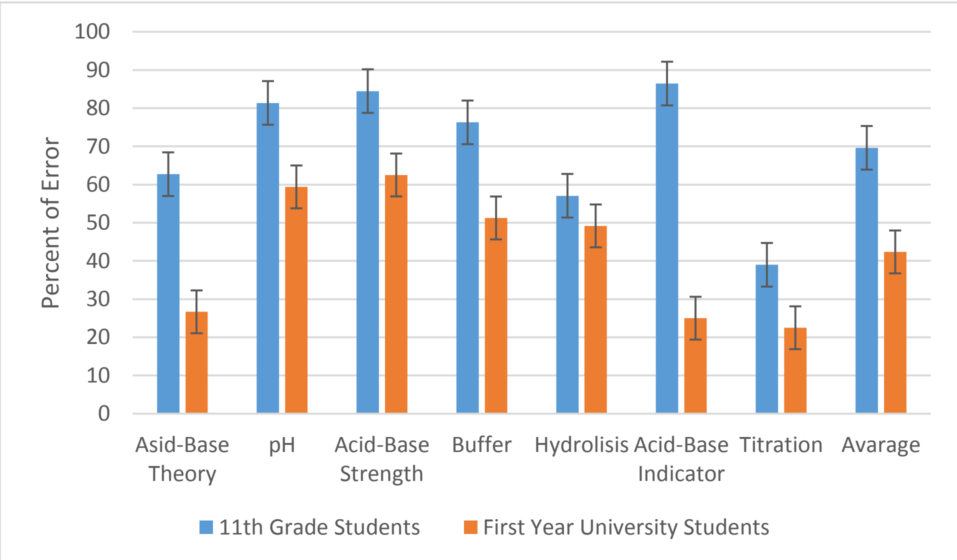

Figure 2. Level of Error of 11th Grade Senior High School and First Year University Students in Solving of Research Instrument

The Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts consisting of 20 valid items, having moderate reliability, and has experienced content and language adjustments then administrated to 133 of first year university chemistry students. The analysis of the experimental results shows that all items (20 items) are valid with the reliability coefficient of 0.470 (low to moderate). Although the internal consistency reliability of these instruments is not high, these instruments can still be used with past explanations. Research instruments with low internal consistency reliability values were also used by previous researchers, eg Damanhuri et al. (2016) used two instruments of the Acids-Bases Chemistry Achievement Test with coefficients of 0.54 and 0.42; Tsui & Treagust (2010) used the Two-Tier Diagnostic Instrument of Students' Scientific Reasoning in Genetics with a coefficient of 0.64; and Abdullah & Shariff (2008) used The

Gas Laws Performance Test with a coefficient of 0.61.

Acid-Base Alternative Conception of 11th Grade and First Year University Students

Table 4. Percentage of Answer of 11th Grade Students and First Year University Students to Any Alternative Answers

No	Sub-topic	Items No.	Students' Answer							
			11th Grade Students				First Year University Students			
			A	B	C	D	A	B	C	D
1.	Acid-base Theory	1	**32,4**	0	**19,6**	48,0	**35**	0	**20**	45
2.		2	3,9	**20,6**	71,6	3,9	3	**18**	80	0
3.		3	0	57,8	**38,2**	3,9	0	95	0	5
4.	Water Autoionization and pH	4	**40,2**	**24,5**	28,4	6,9	**43**	**45**	10	3
5.	The pH	5	**19,6**	17,6	**18,6**	**44,1**	0	40	**48**	**13**
6.		6	6,9	47,0	**28,4**	**18,6**	5	60	**28**	8
7.		7	8,8	**42,2**	45,1	3,9	**13**	**28**	53	8
8.	The Strength of Acids and Bases	8	**11,8**	**19,6**	**41,2**	27,5	0	0	**68**	33
9.		9	**21,6**	2,9	**38,2**	37,3	**30**	0	**13**	58
10.		10	**47,1**	3,9	**23,5**	24,5	**38**	8	**13**	40
11.		11	**47,1**	3,9	**23,5**	**24,5**	**53**	33	8	8
12.		12	**57,8**	**28,4**	12,7	1,0	**73**	8	20	0
13.		14	**38,2**	**12,7**	47,1	2,0	**58**	0	43	0
14.	Buffer	13	52,0	**11,8**	**25,5**	**10,8**	70	8	**18**	5
15.		15	**16,7**	**13,7**	36,3	33,3	**20**	**30**	23	**28**
16.	Hydrolysis dan Neutralization	16	79,4	7,8	4,0	8,8	78	**13**	5	5
17.		17	**52,0**	6,9	12,7	**28,4**	**13**	3	28	**58**
18.		18	**17,6**	7,8	**19,6**	54,9	**20**	**23**	**10**	48
19.	Titration	19	**16,7**	2,0	52,0	**29,4**	5	**18**	75	3
20.	Indicator	20	**15,7**	9,8	49,0	**25,5**	3	3	78	**18**

Note: The shaded box is the correct answer, bold is an alternative conception, and the bottom line is the most selected answer choices by respondents.

Survey of conceptual knowledge and identification of acid-base alternative conceptions was done to 59 of 11th grade students from three state senior high school of Malang and 40 first year university students of Chemistry Department FMIPA UM. Figure 2 shows the level of error of 11th grade students and first year university students in completing test. While the details of the research subjects' answer to each options can be seen in Table 4.

Figure 2 shows that overall 11th grade students doing more error (69.61%) in solving test items than first year university students do (42.35%). The lowest difference of error level occurred in hydrolysis subtopic (student error is 57,06%; college student error is 49,17%), while the highest difference occurred in subtopic of acid-base indicator (student error is 86,44%; college student error is 25,00%). When viewed from the curriculum document, this is very surprising because the acid-base indicator is the learning material of chemistry subject for 11th grade students. Basic Competence No. 4.10 of Chemistry Subject of Indonesian Curriculum of 2013 for 11th grade student states:

> "(Students are able to) determine the pH change route of some indicators extracted from natural materials."

With this learning outcome, logically students understand that the change of color of indicator does not occur at pH 7 only. However, events that occur in the classroom are often different from those written in the document.

Table 4 shows that acid-base alternative conceptions (bold answers, experienced by more than 10% of research subjects) occur in all subtopics of Acid-Base Chemistry, i.e. (1) Acid-Base Theory, (2) Water Autoionization and pH, (3) pH, (4) The Strength of Acids and Bases, (5) Buffer, (6) Hydrolysis, and (7) Acid-Base Titration. The following description describes acid-base alternative conceptions experienced by the research subjects.

1) Acid-Base Theories

Identification of alternative conceptions of research subjects on the concepts of acid-base theory is done by using items 1-3. Item # 1 is shown in Figure 3. The answers of the research subjects to the three items all indicate strong alternative conceptions. Alternative conceptions that occur in the research subjects include 1) "the compound whose molecular formula contains the OH group is a base" (Juang, 2004), selected by 32.4% 11th grade students and 35.0% first year university students; and 2) "all organic compounds are neutral" (Damanhuri et al., 2015), selected by 19.6% of 11th grade students and 20.0% first year university students.

1. Methanol (CH3OH) is known as the rubbing alcohol component. When the methanol ionization constant is greater than the water ionization constant, which of the following statements is proper about methanol? (methanol may form a solution with water in any proportion)
   A. CH_3OH is a base because its molecular formula containing OH group
   B. CH_3OH is an acid because its molecular formula containing some H atoms
   C. CH_3OH is neutral because all organic compounds are neutral
   D. **CH_3OH is ac acid because releasing H^+ ions when dissolved into water**

Figure 3. Item Number 1; the bold is the right answer.

These findings indicate that college lectures do not reduce the number of research subjects experiencing alternative conceptions, even their quantity increases. This may be due to 1) lectures at universities focusing on the algorithmic-mathematical aspect, 2) lecturing less attention to aspects of alternative conceptions, and 3) students do not feel there is a problem with their understanding so that they do not feel something needs to be fixed. Can also be caused by the basic chemistry lecture assumption, that is basic chemistry review of high school chemistry review materials so it does not need to be done in depth. As it is known that basic chemical recovery only occurs in 2 semesters, while high school chemistry lessons lasted for 6 semesters. However, whatever the reason this assumption cannot be justified and must be eliminated because the risk is too great, that is to allow the occurrence of alternative conceptions on the students so that interfere with their further chemistry learning process.

2) Autoionisation of Water and pH

Point 4 (Figure 4) identifies the alternative conception of the water autoionization pH of the research subject. The answer of the research subject in this issue indicates a very strong alternative conception, far above the scientific conception. Alternative conceptions experienced by research subjects are 1) pH of pure water is always 7 and is neutral (Pinarbasi, 2007), selected by 40.2% 11th grade students and 43.0% first year university students; and 2) the increase in degree of autoionization lowers the pH of pure water and converts its nature to acid, selected by 24.5% 11th grade students and 45.0% first year university students.

4. At temperature of 40 ºC pure water has $K_w = 4.0 \times 10^{-14}$. What is the pH and properties of pure water at that temperature?
   A. pH of pure water is 7 and always neutral
   B. pH < 7, acidic
   C. pH < 7, neutral
   D. pH > 7, basic

Figure 4. Item Number 4; the bold is the right answer.

These findings indicate that inadequate reasoning can corroborate the occurrence of alternative conceptions. It is true that increasing the degree of water autoionization increases the concentration of H + ions and decreases the pH. However, a decrease in pH that does not alter the composition of H + and OH-ion ions will not change the acidity, alkalinity, and neutrality of the substance. This latter reasoning may not have been possessed by first-year students so that 45% of them experienced an alternative conception of "an increase in the degree of water autoionization causing the water pH to fall and its nature to turn into acid." The 11th grade experiencing this alternative conception are not too large (24.5%). It could be that this is because they do not think up to the level of quantitative-qualitative relation between Kw change, pH, and pure water acidity.

Information about pH of pure water = 7 and being neutral has become common knowledge that everyone knows. This knowledge may cause the subject of the study to have misconstrued the concept of "pure water whose temperature is 40 oC with Kw = 4.0 x 10-14 also has pH = 7 and is neutral". Because it has become common knowledge, the subject of research feels no need to guess again in answering this question.

3) pH

The pH solution alternative conceptions are identified by using 3 items, number 5, 6, and 7. Item #5 is shown in Figure 5. The answer of the research subject in this case also indicates a very strong alternative conception, although the answer is correct according to the conception science is also great. The alternative conception recorded is "the solution is unlikely to have a pH of less than 0 or more than 14" (Zoller, 1990; Career 2011). The research subjects' answers to the strong HX 2 M acid pH are 1) unpredictable, the price is returned to pure water pH, selected by 19.6% of 11th grade students and 0% of first year university students; 2) pH = 0, since the pH value is not possible less than 0, selected by 18.6% of 11th grade students and 48.0% first year university students; and 3) cannot be determined because the concentration of HX acid is too concentrated, selected by 44.1% 11th grade students and 13.0% first year university students. Answers 19.6% of 11th grade students "pH of solution cannot be determined, the price is returned to pH of pure water" is a rational unreachable answer. The answer of 48.0% first-year students and 18.6% of 11th grade students "pH of solution = 0 because pH value is not possible less than 0" is still rational, that is supported by a pH scale that only extends from 0-14.

5. pH = - log[H_3O^+]. A pH meter has scale of 0-14. What is the pH of strong acid HX solution with concentration 2M? (log 2 = 0,3)
   A. pH = 7, because HX acid is not a dilute acid so the pH of the solution is returned to pH of pure water
   B. pH = -0,3, because -log[H3O+] = -0,3
   C. pH = 0, because the pH value can not be less than 0.
   D. pH can not be determined because HX acid is over concentrated.

Figure 5. Item Number 5; the bold is the right answer.

4) Acid-Base Power

The identification of alternative conceptions of acid-base strength occurring in the study subjects was conducted with 6 items (numbers 8, 9, 10, 11, 12, and 14). Item number 8 is shown in Figure 6. The answer of the research subject in this issue also indicates a very strong alternative conception. Alternative conceptions recorded in this issue include 1) concentrations describing acid-base strengths (Ross, 1989), and 2) diprotic acid stronger than monoprotic acid (Artdej et al., 2010) or more hydrogen groups present in a compounds, the stronger the acidity of these compounds (Demircioglu, 2009). The research subjects' answers to this acid-base strength are 1) 0.1 M HCl as strong as CH_3COOH 0.1 M because of the same concentration, selected by 11.8% 11th and fifth grade students; 2) 0.01 M HCl is weaker than CH3COOH 0.1 M because the H group present in the HCl molecule is less than the CH3COOH molecule, selected by 19.6% of 11th grade students and 0% of first year university students; and 3) 0.1 M HCl is stronger than HCl 0.01M because the concentration of 0.1 M HCl is greater than 0.01 M HCl, selected by 41.0% of 11th grade students and 68.0% of first-year students.

There are two important lessons recorded from the research subject's answer. First, lectures can eliminate light alternative conceptions such as "poliprotic acid is stronger than monoprotic acid". Secondly, for the first-year student, the alternative conception of "concentration describes acid-base strength" only applies if the compound is the same, but for the eleven-year-old students this alternative conception is general, both compounded and different.

These findings reinforce the explanation that complicated concepts can only be understood using good reasoning abilities, the results of upper student learning that learn to use the model of argumentation learning is higher than that of learning using direct instruction model.

8. Which of the following statements is right?
   A. The acid strength of 0.1 M HCl and 0.1 M CH_3COOH are the same, because both of them have the same concentration.
   B. The acidity of 0.01 M HCl is weaker than 0.1 M CH3COOH because HCl molecule consists of H atoms fewer than CH3COOH molecule
   C. The acidity of HCl 0.1 M is stronger than HCl 0.01M because the concentration of HCl 0.1 M is greater than HCl 0.01 M
   D. The acidity of HCl 0.01 M was stronger than CH_3COOH 0.1 M because CH_3COOH is a weak acid

Figure 6. Item Number 8; the bold is the right answer.

5) Buffer

One of alternative conceptions recorded in this issue is "adding acid / base to a buffer solution does not change the pH of the solution because the acid / base will be neutralized by the buffer" (Mutlu & Şeşen, 2016). This answer is selected by 25.5% of 11^{th} grade students and 18% of first year university students. This shows that lectures have not changed the alternative conception of buffer solution. Limitations of lecture time can be considered as the cause of lectures that are too hasty. However, if the use of time outside the lecture can be optimized then the problem of the occurrence of this alternative conception can be reduced.

6) Salt Hydrolysis

Items #16, #17, and #18 identify the alternative conceptions of salt hydrolysis. Figure 7 shows item #17. The subject's answer to this question also indicates a very strong alternative conception. Alternative conceptions recorded in this issue include "hydrolysis is the reaction of self-ionization of water" (Demircioglu, 2009). The answers of the research subjects on salt hydrolysis are 1) hydrolysis is water autoionization, selected by 52.0% 11^{th} grade students and 13.0% first year university students; and 2) hydrolysis is the ionization of weak acid in water, selected by 28.4% of 11^{th} grade students and 58.0% first year university students. This finding is very surprising because water ionization and weak acid ionization are the main concepts in Acid-Base Chemistry topic. In addition, students who answered that hydrolysis is ionization of weak acids reached 58.0%. This means that students have not been able to distinguish between salt hydrolysis and weak acid ionization.

17. Which of the following equations shows the reaction of hydrolysis?
   A. $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$
   B. $2H_2O(l) \rightleftharpoons 2H_2(g) + O_2(g)$
   C. $CN^-(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq)$
   D. $HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$

Figure 7. Item Number 17; the bold is the right answer.

Figure 7 shows that alternative answers C (scientific conception) and D (alternative conceptions) equally involve water and cyanide, one in the form of ions or other cyanide salts in the form of cyanide acid. Alternative conception that happened in 11^{th} grade (28,4%) was not as big as happened in first year student (58,0%). Again, these findings reinforce the conclusion that less than perfect reasoning can decrease learners' understanding or learning outcomes. This is in line with the conclusion of Walker et al. (2016) which states that the learning outcomes of lower class students who learn to use argumentation strategies are lower than the learning outcomes of those who learn to use conventional learning strategies. The 11^{th} grade determines "whether a hydrolysis or hydrolysis reaction is sufficient by looking at the involvement of a species that acts with water, if the one reacting with water is salt or ion then the reaction is hydrolysis. On the other hand, the first year university students determine "whether a reaction is hydrolyzed or not" of water involvement. This is what causes them to experience a severe alternative conception, i.e. 58.0% experienced alternative conception and only 28.0% who have a scientific conception.

Equally important is the number of 11^{th} grade experiencing an alternative conception of "hydrolysis is water autoionization". No less than 52.0% of 11^{th} grade experience this alternative conception. This implies an incomplete understanding, which takes the understanding of a piece of information, in this case is to understand the word "hydrolysis or decomposition by water" as "decomposition or decomposition of water".

7) Acid-Base Titration

Alternative conceptions of acid-base titration are identified using items #19 and #20. Figure 8 shows the number 19. Alternative conceptions recorded in this problem are “pH of the equivalent point always 7" or "the nature of the equivalence point is neutral” (Mutlu & Şeşen, 2016). The answers of the research subjects on this issue are 1) the color change of the indicator occurs at pH = 7, selected by 16.7% of the 11th grade students and 5.0% of the first year university students; 2) indicator color change occurs at pH less than 7, selected by 2.0% of 11th grade students and 18.0% first year university students; and 3) the pH of the change of indicator cannot be estimated, chosen by 29.4% of 11th grade students and 3.0% of first year university students. This suggests a shift in alternative conceptions. The 11th grade students experience an alternative conception of “discoloration of weak acid titration indicator with strong base occurring at pH = 7”, whereas first year university students experience an alternative conception "color change of weak acid titration indicator with strong base occurs at pH less than 7". Although in this case the first year university students experienced a mild alternative conception, these findings also reinforce the conclusion that a less than perfect understanding can decrease the learning outcomes of learners.

19. The titration of weak acid with a strong base (as titrant) is performed using the appropriate indicator. If the end point of the titration equals to the equivalence point, what is the pH of the indicator color changing?
    A. pH = 7 because the pH of the end point of titration is always 7
    B. pH < 7 because the end point of the titration equals to the equivalence point
    C. pH > 7 because the salt of the weak acid undergoes hydrolysis
    D. cannot be predicted

Figure 8. Item Number 1; the bold is the right answer.

The complete alternative conceptions of Acid-Base Chemistry Topic confirmed in this study listed in Appendix B.

IV. CONCLUSION AND SUGGESTIONS

The diagnostic test instrument of acid-base concepts developed in this study, i.e. *Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts*, consists of 20 items with reliability of 0.537 for 11th grade Students and 0.470 for first year university students. The items’ destructor of the instrument were constructed based on the students’ alternative conceptions uncovered by previous researchers so no longer validation required.

The results of this study indicate that 1) there are some alternative conceptions occurring in university students more intensive than in the 11th grade students; 2) there are some alternative conceptions that do not occur in university students, but intensively occurred in the 11th grade students; 3) there are sub-topics where alternative conceptions that occurred in university students are different with in 11th grade students; and 4) learning materials requiring a lot of reasoning tend to give rise many alternative conceptions. The alternative conceptions identified in this study confirm the alternative conceptions uncovered by previous researchers, except for some alternative conceptions revealed here that require further confirmation with the appropriate instrument.

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Appendix A. Items Validity of Simple Multiple-Choice Diagnostic Test of Acid-Base Concepts.

Pilot study carried out to 184 of 11th grade students form three state senior high school of Malang City.

Number of Item	**Pearson Correlation Score**	**Sig. (2-tailed)**	**Validity**	**Status**
1.	0,231**	0,002	Valid	
2.	0,102--	0,169	No	Revised
3.	0,223**	0,002	Valid	
4.	-,086--	0,245	No	Drop
5.	-,103--	0,163	No	Drop
6.	-,058--	0,436	No	Drop
7.	0,050--	0,503	No	Drop
8.	0,206**	0,005	Valid	
9.	0,287**	0,000	Valid	
10.	0,342**	0,000	Valid	
11.	0,412**	0,000	Valid	
12.	-,002--	0,975	No	Drop
13.	0,134--	0,069	No	Revised
14.	0,546**	0,000	Valid	
15.	0,190**	0,010	Valid	
16.	0,219**	0,003	Valid	
17.	0,488**	0,000	Valid	
18.	0,474**	0,000	Valid	
19.	0,134--	0,069	No	Revised
20.	0,385**	0,000	Valid	
21.	0,301**	0,000	Valid	
22.	0,326**	0,000	Valid	
23.	0,548**	0,000	Valid	
24.	0,359**	0,000	Valid	
25.	0,254**	0,001	Valid	

Appendix B. Acid-Base Alternative Conceptions Confirmed or Supposed to be Uncovered in this Study

Item Number	Alternative Conception	Percentage	
		11th Grade Studens	College Students
1.	• Bases are compounds containing OH group(s) in their molecular formulas. Ex: C_2H_5OH	32,4	35,0
2.	• All organic compounds are neutral.	19,6	20,0
3.	• NH_4^+ is a Bronsted-Lowry's base.	20,6	18,0
4.	• The conjugate acid-base pair is a pair of reacting species.	38,2	0,0
5.	• The pH of pure water is always equal to 7 and always neutral. • When the constant of water autoionization increases, pH of water decreases, and water property to be acidic.	40,2 24,5	43,0 45,0
6.	• The pH of the acidic solution may not be less than zero. • **The pH of concentrated acid is unpredictable.** • **The pH of the concentrated acid is returned or equal to the pH of pure water.**	18,6 **44,1** **19,6**	0,0 **48,0** **13,0**
7.	• The pH of the basic solution may not be more than 14.0.	28,4	28,0
8.	• **When added with a little strong acid, the pH of the acidic solution is remain unchanged.**	**42,2**	**28,0**
9.	• The strength of acid-base is determined by its concentration.	41,2	68,0
10.	• Poliprotic acid H_3PO_4 is stronger than monoprotic acid HCl. • The pH of an acid determines its strength.	38,2 21,6	30,0 13,0
11.	• The acidic strength of pure ethanoic acid is higher than that of ethanoic acid solution. • At equivalent, pure ethanoic acid and ethanoic acid solution produce the same amount of H^+ ions.	47,1 23,5	38,0 13,0
12.	• The base strength is determined by the concentration of the solution, not the value of Kb of the base. • The base strength is determined by the OH concentration present in the solution regardless of the concentration of the base solution. • **The strength of a base can not be determined by its sub-microscopic representation.**	47,1 23,5 **24,5**	53,0 8,0 8,0
13.	• The acid strength sequence of hydrogen halides is HF> HCl> HBr> HI, the greater halogen electronegativity the stronger halogen to attract electron pair, the more easily the H^+ ion is removed. • The acid strength sequence of hydrogen halides is HF> HCl> HBr> HI, the greater the electronegativity of the halogen the stronger halogen to attract H atom, the harder ion H^+ is removed.	57,8 28,4	73,0 8,0
15.	• adding a base to a buffer solution will not cause a change in the number of components in the solution. • when a small amount of strong base is added to the buffer solution, a small amount of the base will react with the basic component in the solution. • in the addition of a strong base, all the acidic components of buffer will react with the acid component.	11,8 25,5 10,8	20,0 30,0 28,0
16.	• Intermixture of equivalent solution of NaOH and CH_3COOH resulting in a mixture with pH of 7 and neutral solution because both of solution reacts one another completely	7,8	13,0
17.	• hydrolysis reaction is a water autoionization reaction • hydrolysis reaction is a reaction of weak acid with water	52,0 28,4	13,0 58,0

18.	• All intermixture of an acid with a base always results in neutral salt and water.	27,4	43,0
	• The resulting solution of an equivalent acid and base mixture is always neutral.	17,6	10,0
19.	• The color change of indicator of titration always occurs at pH 7.	16,7	5,0
	• In titration of weak acid with strong base, the change of color of indicator occurs at pH less than 7.	25,5	18,0

Note: The bold sentences are supposed to be alternative conceptions. This requires the appropriate test instrument for confirmation.