Calcium contained tap water phenomena: students misconception patterns of acids-bases concept

S Liliasarì1*, A Albaitì2 and A Wahyudi1,3

1Department of Chemistry Education, Indonesia University of Education, Bandung, Indonesia
2Chemistry Study Program, Cenderawasih University, Jayapura, Indonesia
3Study program of Hospital Management, Piki Ganesha College, Bandung, Indonesia

*Corresponding author’s e-mail: liliasarì@upi.edu

Abstract. Acids and bases concept is very important and fundamental concept in learning chemistry. It is one of the chemistry subjects considered as an abstract and difficult concept to understand. The aim of this research was to explore student’s misconception pattern about acids and bases phenomena in daily life, such as calcium contained tap water. This was a qualitative research with descriptive methods. Participants were 546 undergraduate students of chemistry education and chemistry program, and graduate students of chemistry education in West Java, Indonesia. The test to explore students’ misconception about this phenomena was essay test. The results showed that there were five patterns of students’ misconception in explaining the phenomena of calcium carbonate precipitation on heating tap water. Students used irrelevant concepts in explaining this phenomena, i.e. temporary hardness, coagulation, density, and phase concepts. No students had right answer in explaining this phenomena. This research contributes to design meaningful learning and to achieve better understanding.

1. Introduction
Acid-base historic theories are started by Boyle, Lavoisier, Davy, Liebig, Arrhenius, and Brønsted. Other definitions of it came later from Lewis, of Pearson and of Usonovich [1]. Brønsted concept was a concept that is often used than other acid-base concepts. The Brønsted theory defines proton transfer as a molecule or an ion transfers a proton to another molecule or ion, where two conjugated acid-base pairs involved. Thus, Brønsted acids and bases are no more substances, but individual types of particles. The original publication of Brønsted from 1927 makes clear that acids and bases should be molecules or ions, but not substances [2].

Acids and bases concept is very important and fundamental concept in learning chemistry as early as primary school, right through the university level [3-5]. If students understand acid−base chemistry in all its guises, it becomes possible to predict and to explain the outcomes of a wide range of apparently unrelated reactions [3]. The concept of acid-base in chemistry has great relation to other concepts such as material properties, chemical equilibrium, chemical reactions, stoichiometry and solutions [6]. One of application acids and bases concept in daily life is calcium carbonate formation from heating tap water in a kettle. Ca2+ ion in tap water come from chlorite compound Ca(OCl)2 not from the hardness of ground water. CO2 gas and Ca(OCl)2 are dissolved in tap water and forming carbonate acid. Furthermore, carbonate acid is ionized through two stages. It yields two $K_a$ values, i.e $K_{a1}$ and $K_{a2}$. The
heating of tap water causes a shift of the equilibrium to right and increase both the $K_s$ values. An increase of $CO_3^{2-}$ concentration in tap water induced $[Ca^{2+}][CO_3^{2-}] > K_{sp}$, then formed $CaCO_3$ precipitate.

On the other hand, the poor performance of students in learning was not only caused by the lack of understanding but also misconception. If students do not understand the concept, teacher can do remediation to solve the problem. However, students’ misconception will be persistence. In particular, misconception of undergraduate students can be caused of they do not understand a certain concept. It can also be said as an inconsistency in comprehension between students and experts [7]. Previous works demonstrated that students reasoning on acid base reaction showed that 3 from 31 students wrong to describe Bronsted Causal (BC) [3]. Additionally, students’ misconception about neutralization reaction indicated that most of the students, especially in the control group, failed to realize the central role of water in neutralization reactions [8]. Also, students could not describe formula equations as reactions of substances, or by ionic equations as proton transfer reactions according to Brønsted’s model [9]. Other studies about students’ alternative conception using two-tier diagnostic instruments have been conducted to assess Thai high school students understanding on acid–base chemistry [10]. Students in both classes had similar alternative conceptions for several concepts. The results indicated that students possessed alternative conceptions in three major categories: acid–base terminology, acid–base models, and acid–base dissociation. In terms of the terminology, students had alternative conceptions about electrolyte and non-electrolyte solutions, acid–base conjugated pairs, monoprotic and polyprotic acids.

As stated earlier, misconceptions that occurring on students require special handling. To deal with misconceptions, we must know students misconception firstly. Overall, the aim of this research was to explore students’ misconception pattern about acids and bases phenomena in daily life i.e. calcium contained tap water phenomena. This phenomena is quite interesting and can be a meaningful learning context for students in studying acids-bases.

2. Methods
This study was a qualitative research with descriptive methods to explore students’ misconception pattern about Calcium contained tap water phenomena. Participants were 485 students from the first, second, third, and fourth level of undergraduate chemistry education and chemistry programs in West Java, Indonesia. It also involved 61 students from the first and second level of postgraduate chemistry education program. There were five stages of study, i.e (1) analyzed acid-base misconceptions based on literature; (2) designed instrument to measure students conceptions; (3) investigated students conceptions, (4) analyzed students conceptions; and (5) categorized students misconception patterns. The essay test was employed to explore students’ misconception about calcium contained tap water phenomena. The developed instrument was adapted from the instrument of Questionnaire Acids Bases by Hans-Dieter Barke [1,2].

3. Results and Discussion
Students were given a question: “Normal tap water containing dissolved calcium carbonate. When tap water is heated, calcium carbonate precipitate forming”. Then, students are asked to give scientific explanation about this phenomena. A number of students’ misconception about calcium contained tap water phenomena was presented in Table 1. It showed that no students gave right answer and 269 students (49%) had misconception in explaining the phenomena of calcium carbonate precipitation in heating tap water. Other 277 students (51%) did not answer the question. Furthermore, the exploration results of students misconception about calcium contains tap water phenomena based on their answer was presented in Table 2. It showed that there were five patterns of student’s misconception in explaining this phenomena using (1) temporary hardness concept, (2) formation of $CaCO_3$ caused by the heating and evaporation of tap water (In this case, students did not describe the temporary hardness concept), (3) coagulation concept, (4) density concept, and (5) phase concept. It indicated that student’s prior and current knowledges were inaccurate. All students did not recognize that explanation of calcium carbonate precipitated phenomena of heating tap water using acids and bases concept. Some students (49%) used irrelevant concepts to explain this phenomena and most of them did not answer the question. This subject matter was a difficult concept of them. In line with these results, acids and bases is one of
the chemistry subjects considered as abstract and difficult to understand [11]. Students have some difficulties and misconceptions about acid and bases theories [4].

Table 1. A number of students’ misconception about calcium contains tap water phenomena

| Study Program            | Level | Misconception Code | No | Right Answer | Total |
|--------------------------|-------|--------------------|----|--------------|-------|
| Chemistry Education      | 1     | a 15 : b 10 : c 3 : d 2 : e 1 | 61 | 0            | 92    |
| (undergraduate)          | 2     | a 7 : b 35 : c 1 : d 1 : e 1 | 33 | 0            | 78    |
|                          | 3     | a 8 : b 32 : c 0 : d 0 : e 0 | 39 | 0            | 79    |
|                          | 4     | a 5 : b 27 : c 7 : d 0 : e 1 | 32 | 0            | 72    |
| Chemistry (Undergraduate)| 1     | a 9 : b 15 : c 3 : d 1 : e 1 | 44 | 0            | 73    |
|                          | 2     | a 4 : b 15 : c 0 : d 0 : e 0 | 21 | 0            | 40    |
|                          | 3     | a 1 : b 13 : c 0 : d 0 : e 2 | 18 | 0            | 34    |
|                          | 4     | a 1 : b 7 : c 0 : d 0 : e 0 | 9  | 0            | 17    |
| Chemistry Education      | 1     | a 10 : b 28 : c 1 : d 2 : e 0 | 20 | 0            | 61    |
| (Graduate)               | 2     | a 1 : b 5 : c 1 : d 1 : e 0 | 2  | 0            | 10    |
| The total number of students |      |                    | 546 |              |       |

Table 2. Students Misconception about Phenomena of Calcium Carbonate Precipitation on Heating Tap Water

| Misconception Pattern | Students Misconception                                                                 | Scientific Conception                                                                 |
|-----------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| a                     | The temporary hardness is generally removed by heating the water, thus CaCO₃ will separate | Ca²⁺ ions come from chlorite compound Ca(OCl)₂ not from the hardness of ground water. |
| b                     | The calcium carbonate (CaCO₃) will precipitate after tap water heated and the water evaporates. | For b, c, d, and e scientific conception is CaCO₃ precipitated phenomena of heating tap water is not caused by evaporation of water, coagulation, density or phase differences. Explanation of the phenomena of heating tap water containing lime soluble calcium, that produce carbonate precipitation, based on : CO₂ gas and chlorite compound Ca(OCl)₂ are dissolved. The reaction result is the ionization of chlorite compound : Ca(OCl)₂ (aq) → Ca²⁺(aq) + 2OCI⁻(aq), as well as the dissolution of CO₂ : CO₂(g) + H₂O(l) ⇄ H₂CO₃(aq), which is ionized through 2 stages. Stage 1 ionization : H₂CO₃(aq) + H₂O(l) ⇄ H₃O⁺(aq) + HCO₃⁻(aq) K͑ca₁ = 4.45 x 10⁻⁷ Stage 2 ionization : HCO₃⁻(aq) + H₂O(l) ⇄ H₃O⁺(aq) + CO₃²⁻(aq) K͑ca₂ = 4.69 x 10⁻¹¹ This heating process causes a shift of the equilibrium to the right and increase both the Kₐ values. An increase of CO₃²⁻ concentration, resulting in [Ca²⁺][CO₃²⁻] > Kₚ, then formed CaCO₃ precipitate. |
Misconception is an inconsistency in students’ conception with scientific concept [12]. Undergraduate students’ misconception can be brought from prior learning experience or occurs at college level. Misconception also occur when undergraduate students related between prior knowledge and current knowledge inaccurately. In chemistry, it is fairly common that students have different ideas about chemistry concept than scientist or their teacher. It has been proposed that students are not constructing appropriate understandings of fundamental chemical concepts from the beginning of their studies and these alternative conceptions are resistant to change [13]. Alternative conceptions are deeply embedded on student and persistence for a long time.

Students can develop their own ideas about scientific phenomena based on many factors such as real-world experiences, media, books, and interaction with people [14]. In line with this, student’s experiences in studying acids-bases at primary school right through the university level give contribution in constructing conception about this subject matter in their mind. Therefore, this research contributes in designing of meaningful learning and improving their better understanding.

4. Conclusion
There were five patterns of students’ misconception in explaining calcium carbonate precipitated phenomena of heating tap water. Students used irrelevant concepts in explaining this phenomena, i.e temporary hardness, coagulation, density, and phase concept. Therefore, students have many difficulties and misconceptions about application acid and bases concept in daily life. Nevertheless, every pattern of students’ misconception decreases along with the increase of study level.

5. References
[1] Barke H D, Hazari A and Yitbarek S 2009 "Acid–base reactions" Misconceptions in chemistry 173-206
[2] Barke H and Harsch N 2014 Broensted Acids and Bases: They are not Substances but Molecules or Ions! African Journal of Chemical Education 4 4 82-94
[3] Cooper M M, Kouyoumdjian H and Underwood S M 2016 Investigating Students’ Reasoning about Acid–Base Reactions Journal of Chemical Education 93 10 1703-1712
[4] Tarhan L and Sesen B A 2012 Jigsaw cooperative learning: acid–base theories Chemistry Education Research and Practice 13 3 307-313
[5] Çetingül, İ and Geban Ö 2011 Using conceptual change texts with analogies for misconceptions in acids and bases Hacettepe Üniversitesi Eğitim Fakültesi Dergisi 41 41
[6] Sheppard K 2006 High school students’ understanding of titrations and related acid-base phenomena Chemistry Education Research and Practice 7 1 32-45
[7] Luoga N E, Ndunguru P A and Mkoma S L 2013 High school students’ misconceptions about colligative properties in chemistry TaJONAS: Tanzania Journal of Natural and Applied Sciences 4 1 575-581
[8] Demircioglu G Ayas A and Demircioglu H 2005 Conceptual change achieved through a new teaching program on acids and bases Chemistry Education Research and Practice 6 1 36-51
[9] Drechsler M and 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
[10] Artdej R, Ratanaroutai T, Coll R K and Thongpanchang T 2010 Thai Grade 11 students’ alternative conceptions for acid–base chemistry Research in Science & Technological Education 28 2 167-183
[11] Sesen B A and Tarhan L 2011 Active-learning versus teacher-centered instruction for learning acids and bases Research in Science & Technological Education 29 2 205-226
[12] Pinarbasi T 2007 Turkish Undergraduate Student’s misconceptions on Acids and Bases Journal of Baltic Science Education 6 1
[13] Nakhleh M B and Krajcik J S 1994 Influence of levels of information as presented by different technologies on students’ understanding of acid, base, and pH concepts Journal of Research in Science Teaching 31 10 1077-1096
[14] Driver R and Erickson G 1983 *Theories-in-action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science* 37-60 (Francis: Taylor and Francis)

**Acknowledgments**
The authors acknowledge Hans-Dieter Barke for the instrument “Questionnaire Acids Bases” that used in this research.