DIFFICULTIES ENCOUNTERED IN UNDERSTANDING ACID-BASE CHEMISTRY

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Abstract

The present study reports findings from the investigation of students' understandings of acid-base chemistry. Previous research has consistently indicated that many high school students had serious difficulty in understanding this concept. A two-tier multiple choice diagnostic test was administered to 126 students in grade 11 who studied at small rural schools located in four Northeastern provinces of Thailand and had never received instruction in acid-base chemistry. Students' responses were assessed and grouped into five different levels of students' understanding: sound understanding, partial understanding, partial understanding with specific alternative conception, specific alternative conception, and no understanding. The data indicated that most respondents held alternative conceptions on several concepts: acid-base theory, dissociation of weak acids, weak bases, and water. Particularly acid-base theory, the students seemed to experience considerable difficulty in understanding. The findings provide evidence for teachers to help the students grasp acid-base chemistry which is a fundamental concept in learning further advanced concepts.

Keywords: acid-base chemistry, alternative conceptions, difficulty in understanding

Introduction

Chemistry is one of important subject of science consisting of topics that are related to the structure of matter. It enables students to understand phenomena in the world and to know how the world functions in their daily life (Chiu, 2007; Taber & Coll, 2003). However, literature review in science education revealed that many high school students experience difficulties in learning chemistry. Due to the nature of chemistry, students cannot easily understand or imagine many abstract concepts of chemistry (Nakhleh, 1992).

Acid-base chemistry is an abstract concept (Barrette-Ng, 2011) and is introduced in high school chemistry course. This concept requires students to understand content knowledge from many topics of general chemistry, including chemical equilibrium, chemical reactions, stoichiometry, the nature of matter, and solutions (Sheppard, 2006). Acid-base chemistry is considered as a difficult concept for high school students (Demircioğlu, Ayas, and Demircioğlu, 2005). Previous numerous studies have demonstrated that some difficulties in learning are derived from alternative conceptions (Levy Nahum, Hofstein, Mamlok-Naaman, & Bar-Dov, 2004; Treagust & Chandrasegaran, 2007).

According to constructivism, it believes that students come to classroom with their own existing knowledge. They construct new ideas or interpret concepts based on their current and past knowledge (Phillips, 1995). Frequently, they tend to develop their knowledge in chemistry class which are different or do not agree with the accepted scientific views (Chandrasegaran, Treagust, Mocerino, 2007; Teichert & Stacy, 2002). Holding alternative conception interferes with the subsequent conceptual learning (Özmen, 2008). Thus, it is difficult to connect new information to prior knowledge.

As mentioned above, it is necessary for teachers to identify possible alternative conceptions that students may bring to the lesson. An instrument which has been extensively used to examine students' alternative conception is a two-tier multiple choice diagnostic test (Tan, Taber, Goh, Chia, 2005). Previous studies demonstrated that this test provides important evidence for teachers to develop strategies to help students form accurate concepts (Kao 2007; Lin 2004; Treagust, 1988) Furthermore, it is readily administered and easily scored (Tan, Goh, Chia, Treagust, 2002). In chemistry, the two-tier method had been widely used to assess students' understanding in several topics, e.g. inorganic chemistry (Tan et al., 2002), ionisation energy (Taber & Tan, 2007). Consequently, this study highlights the use of a two-tier multiple choice diagnostic test to investigate students' understandings of acid-base chemistry.

Research Questions

The research question examined in this study is: what are students' understandings of acid-base chemistry?

Methodology

Participant

In a survey study, one hundred and twenty-six students were in grade 11 and their aged between 17 and 18 years. All participants came from five classes from four public high schools located in four Northeastern provinces of Thailand. Class A consisted of 22 students (15 males, 7 females), class B consisted of 14 students (6 males, 8 females), Class C consisted of 35 students (9 males, 26 females), class D consisted of 22 students (1 male, 21females), and class E consisted of 33 students (19 males, 14 females). They were studying in the science and mathematics program in the first semester of the 2011 academic year.

Instrument

A two-tier multiple-choice test used in this study was developed by Artdej, Ratanaroutai, Coll, and Thongpanchang (2010). It has been shown to be a reliable and valid instrument for the investigation of Thai students' understandings of acid-base chemistry concepts. The first tier of each item investigated the content knowledge and the second tier designed to determine that students were able to give reasons supporting their answer for the first tier. The first tier consisted of four choices but the second tier consisted of five possible reasons. This instrument consisted of 18 items which were employed to explore the following concepts of acid-base chemistry, including electrolyte and non-electrolyte solutions, acid and base solutions, acid-base theory, conjugate acid-base pairs, dissociation of strong acids or bases, dissociation of weak acids, dissociation of weak bases, dissociation of water, and the concentration changes of H_3O^+ and OH^- in water.

Data collection

A two-tier multiple choice diagnostic test was administered to 126 students at the first week of the first semester of the 2011 academic year. At that time, the students had never received instruction in acid-base chemistry. In this test, students had 45 minutes to answer 18 questions.

Data analysis

The scheme provided by Çalik and Ayas (2005) was used to analyze students' responses. Both content answers and reasons were categorized into five following levels of understanding.

Sound Understanding (SU): Responses that provided both correct answer and reasoning.

Partial Understanding (PU): Responses that included either correct answer or correct reasoning while leaving another tier unanswered.

Partial Understanding with Specific Alternative Conception (PS): Responses that included either correct answer with wrong reasoning or wrong answer with correct reasoning.

Specific Alternative Conceptions (SA): Responses that included wrong answers in both tiers.

No Understanding (NU): Responses with blank or multiple responses in one test item.

Results and Discussion

The purpose of this study was to investigate grade 11 students' understanding of the concept of acid-base chemistry. The results indicated that a majority of the students expressed specific alternative conceptions (SA) in four concepts: acid-base theory, dissociation of weak acids, weak bases, and water. List of specific alternative conceptions are summarized in Table 1.

Table 1 List of specific alternative conceptions identified in this study.

Alternative conceptions	Percentage of specific alternative conceptions held by the students
Acid-base theory	
- NH_3 was a Brønsted-Lowry acid.	36.5%
- Both NH_3 and BH_3 were Lewis bases.	34.9%
Dissociation of weak acids	
- The dissociation of weak acids was not at equilibrium.	34.9%
- At the equilibrium and constant temperature, K_a was calculated by a ratio of reactant and product concentrations. Therefore, the acid dissociation constant was given by $K_a = [HF]/[H^+][F^-]$.	31.7%
Dissociation of weak bases	
- When the initial concentration of two bases was the same, the concentration of these bases at the equilibrium was the same.	31.0%
- BOH solution could completely dissociate into ions to yield B^+ whose concentration was 0.1mol/dm^3. At the equilibrium, the BOH concentration did not affect the calculation of K_b. K_b was calculated by the product of the concentrations of B^+ and OH^-. Therefore, $[OH^-] = Kb/[B^+] = 2.6 \times 10^{-8}/0.1 = 2.6 \times 10^{-7}$ mol/dm^3	28.6%
Dissociation of water	
- At the equilibrium, water highly ionized.	31.7%
- At any temperature, H_3O^+ and OH^- concentration of pure water were equal to 1.0×10^{-4} mol/dm^3 and 1.0×10^{-3} mol/dm^3 respectively. Therefore, the K_w was equal to 1.0×10^{-7}.	28.6%

Acid-base theory

The data in Table 1 suggested that most students were unable to identify the difference between Brønsted-Lowry acids and bases. They misunderstood that NH_3 was a Brønsted-Lowry acid. In fact, the Brønsted-Lowry model defines acids as particles that donate protons, while bases are defined as particles that accept protons. When an acid donates a proton, it becomes a base. In addition, students needed to identify which substances can act as Lewis base for the given reaction.

$$NH_3(g) + BH_3(g) \longrightarrow H_3B\text{-}NH_3(g)$$

The students incorrectly considered that both NH_3 and BH_3 were Lewis bases. Indeed, Lewis acid is the species that can accept an electron pair and Lewis base is the species that can donate an electron pair. According to Kousathana, Demerouti, and Tsaparlis (2005), the students had difficulty in understanding acid-base theory.

Dissociation of weak acids

This concept needed students to understand that weak acid (e.g., HF) partially dissociates in aqueous solution. As a result, an equilibrium is formed between the acid and its ions. As can be seen in Table 1, the students incorrectly thought that the dissociation of weak acids was not at equilibrium, since it was the irreversible reaction. The equilibrium did not occur. An unclear understanding of the dissociation of weak acid had affected to the calculation of the acid dissociation constant (K_a). The students seemed to believe that K_a was calculated by a ratio of reactant and product concentrations at the equilibrium and constant temperature. Therefore, the acid dissociation constant was given by $K_a = [HF]/[H^+][F^-]$. The scientific conception is that K_a is the equilibrium ratio of products to reactants.

Dissociation of weak bases

Based on the results in Table 1, it was found that most students held specific alternative conceptions on this concept, similar to the dissociation of weak acids. The test required students to compare the concentration of two bases (AOH and BOH) at equilibrium, when the concentrations of AOH and BOH are equal and the base dissociation constant (K_b) of AOH is less than BOH. The findings indicated that the students poorly understood the meaning for the K_b. The specific alternative conception was that when the initial concentration of two bases was the same, the concentration of AOH at the equilibrium was equal to that of BOH. Also, the students were confused between strong bases and weak bases. They could not calculate the concentration of OH^-, when provided with the base dissociation constant (K_b) of BOH (2.6×10^{-8} mol/dm^3) and the concentration of BOH (0.1 mol/dm^3).

Dissociation of water

On the concept of dissociation of water, students needed to understand that water can act either as an acid or a base. This refers to the auto-ionization of water. Water is a weak electrolyte, and pure water is a non-electrolyte. However, most students incorrectly understood that, at the equilibrium, water highly ionized. They seemed to think that pure water was a strong electrolyte. In addition, they had an unclear understanding how to calculate the water dissociation constant (K_w). They believed that, at any temperature, H_3O^+ and OH^- concentration of pure water were equal to 1.0 $x10^{-4}$ mol/dm^3 and 1.0 $x10^{-3}$ mol/dm^3 respectively. Therefore, the K_w was equal to 1.0 $x10^{-7}$. Indeed, K_w is equal to 1.0 x 10^{-14} mol/dm^3.

As presented in Table 1, most students poorly understood three concepts above (i.e., dissociation of weak acids, weak bases, and water). The data suggested that chemical equilibrium is an essential concept to help students clearly understand acid-base chemistry.

Conclusion

The results of this study showed that acid-base chemistry is a concept which is problematic in learning chemistry for high school students. Alternative conceptions held by most students were acid-base theory, dissociation of weak acids, weak bases, and water. Particularly acid-base theory, the students seemed to experience considerable difficulty in understanding. These results were supported by other previous studies in literature (Demerouti, Kousathana, & Tsaparlis, 2004; Sheppard, 2006). By knowing students' alternative conceptions, teachers gain greater insight into the content to be taught and design teaching strategies to develop students' conceptions which are consistent with currently accepted scientific explanations.

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