Comparison of the effects of conceptual change texts implemented after and before instruction on secondary school students' understanding of acid-base concepts

Gökhan DEMİRCİOĞLU

**Karadeniz Technical University, Fatih Faculty of Education
Trabzon, TURKEY**

Email:demircig73@hotmail.com

Received 17 Sept., 2009
Revised 10 Dec., 2009

Contents

Abstract

This study examined whether the application of conceptual change texts are effective before or after the instruction on 10th grade students' conceptual understanding and alternative conceptions about acids and bases. The study was conducted with 76 10th grade students from three classes of a chemistry course taught by the same teacher. One of the classes was randomly assigned to the control group (N=25), who were taught with traditional teaching methods, and another class was randomly assigned as experimental group 1 (N=26), who studied the conceptual change texts before the traditional teaching. The other class was randomly assigned as experimental group 2 (N=25), and studied the conceptual change texts after receiving traditional teaching. The data was collected by the Concept Achievement Test, administered as pre-test and post-test. The analysis of covariance (ANCOVA) is used to analyze the data. The analysis revealed that the differences between the results in both the experimental groups and in the control group were statistically significant.

Keywords: chemistry education, conceptual change text, acids and bases, conceptual change

Introduction

Acids and bases cover an important part of the 10th grade chemistry curriculum. The mastery of concepts in this unit requires the mastery of other fundamental chemistry concepts, such as chemical bonding, chemical equilibrium, mole, nature of solutions, particulate nature of matter, chemical reactions and chemical change. Therefore, students have difficulty understanding acid-base chemistry and have held serious alternative conceptions at various grade levels (Bradley & Mosimege, 1998; Cross et al., 1986; Cros et al., 1988; Demerouti et al, 2004; Demircioğlu et al., 2004; Demircioğlu et al., 2005; Hand & Treagust, 1991; Nakhleh & Krajcik, 1993, 1994; Özmen et al., 2009a; Ross & Munby, 1991; Schmidt, 1991; Sisovic & Bojovic, 2000; Shappard, 2006; Toplis, 1998). Although there are many studies identifying students' alternative conceptions of acids and bases in science education literature, studies on how these alternative conceptions can be treated are rare (Hand & Treagust, 1991; Demircioğlu et al., 2005; Özmen et al., 2009b). Christianson & Fisher (1999) emphasized that identifying students' alternative conceptions are very important, but undoubtedly, finding ways to eliminate or prevent these conceptions is more important. Hence, researchers in science education have focused on developing alternative methods for changing students' alternative conceptions into scientific ones (Pfundt & Duit, 1991). The best-known conceptual change model originated with Posner et al. (1982) and was refined by Hewson (1981) and Hewson and Hewson (1984). The model has been accepted as an effective instructional model to restructure learners' alternative conceptions. The model describes four necessary conditions (dissatisfaction, intelligibility, plausibility and fruitfulness) for conceptual change. Only after these conditions have been met can students experience conceptual change. Cognitive conflict is often considered an important factor in conceptual change (Hewson & Hewson, 1984).

Several researchers have shown that the conceptual change approach can be effective at changing students' chemistry conceptions (Basili & Sanford, 1991; Ebenezer & Gaskell, 1995). However, the original theory of Posner et al. (1982) has been criticized for ignoring the learners' motivational beliefs including goals, purposes, intentions and metacognitive awareness (Niaz et al., 2002; Pintrich et al., 1993; Sinatra and Pintrich, 2003). Sinatra and Pintrich (2003) suggested these factors may also promote or obstruct conceptual change. Another criticism, from a socio-cultural perspective, is that conceptual change is not only an internal cognitive process but one that happens in wider situational, cultural and educational contexts (e.g. Saljo, 1999; Vosniadou, 2008a, p.XIX; Duit et al. 2008; Treagust & Duit, 2008). Moreover, many researchers suggest that conceptual change is a slow and gradual process rather than a dramatic, gestalt shift that happens over a short period of time (Vosniadou, 2007; 2008). Vosniadou (2007) also criticized the conceptual change theory because it overemphasized the effect of cognitive conflict. Despite these criticisms, teaching methods such as analogies, concept mapping, worksheets, hands on activities and conceptual change texts (CCTs), based on Posner et al.'s (1982) conceptual change model, have still been affective in eliminating alternative conceptions (Hynd et al. 1997; Özmen and Yıldırım, 2005; Özmen et al., 2009b; Taştan et al., 2008). From these, CCTs are designed to make students aware of their inaccurate preconceptions and help them change their non-scientific conceptions toward more scientific ones through the use of explanations and examples (Hynd et.a1.1994; Pabuçcu & Geban, 2006). In the CCTs, a challenging question which was prepared to activate students' preconceptions and to provide dissatisfaction with their own ideas is first presented. Then, the identified alternative conceptions of the students are directly mentioned. Next, students' alternative conceptions are challenged by introducing common alternative conceptions followed by evidence that they are wrong (Roth, 1985). Finally, correct scientific explanations supported by examples are presented (Başer & Geban, 2007). Science education literature contains several studies conducted to determine the effect of CCTs on students' conceptual understanding (e.g., Canpolat et al., 2006; Chambers & Andre, 1997; Çakır et al., 2002; Özmen, 2007; Qian and Alverman, 1995; Skopeliti & Vosniadou, 2006). The results from these studies showed that the strategy was effective in creating conceptual conflict and meaningful learning for students. In these studies, CCTs were commonly used after regular classroom teaching and were compared with the traditional teaching. On the other hand, there are no studies trying to determine the effects of CCTs implemented before regular instruction.

There has been a shift from a teacher-centered to a student-centered teaching strategy in Turkish schools based on the reconstruction the Faculties of Education implemented in 1998. However, the success of the project is less than the expected level so far (Ayvacı & Devecioğlu, 2009; Çakan, 2004; Çakır & Çimer, 2007). Therefore, the use of CCTs and other conceptual change strategies as a supplement to classroom instruction seems to be necessary. Educational research suggests that alternative conceptions may interfere with students' learning of other scientific concepts (Özmen et al., 2009a; Palmer, 1999). Therefore, it is believed that the application of CCTs before instruction may decrease the formation of new alternative conceptions growing out of the instruction. It is crucial for students to discover and remedy their alternative conceptions so they have an accurate perception of the chemistry content. Moreover, the author believes that it may be more effective in eliminating students' existing alternative conceptions and acquiring new understandings on the concepts of acids and bases than compared to the implementation of CCTs after instruction. He also believes that instruction based only on CCTs may not be sufficient as a sound understanding of acid and base concepts. However, the instruction should be supported with CCTs or contemporary teaching techniques including various laboratory activities. With this in mind, this study attempts to examine whether the application of CCTs are effective in 10th grade students' conceptual understanding and alternative conceptions about acids and bases before or after the instruction.

The purpose of the study

The main purpose of this study was to investigate and compare the effect of conceptual change texts implemented before and after the traditional teaching on students' conceptual understanding and alternative conceptions of acids and bases. The specific research questions in this study were:

1. Are there statistically significant differences between students in the control group and students in experimental groups in terms of their understanding of the concepts of acids and bases?

2. Is there a statistically significant difference between experimental group 1 (EG1), which studied conceptual change texts before the traditional teaching, and experimental group 2 (EG2), which studied conceptual change texts after the traditional teaching, in terms of students' conceptual understanding of the acid and base concepts?
3. Which alternative conceptions concerning the concepts about acids and bases are held by the students before and after the treatment?

Research design

A quasi-experimental design, which is a form of experimental research, was used in the study (Robson, 1998). One control and two experimental groups were used in the study. A summary of the methods used in each group is given in Table 1.

Table 1. *The methods used in each group*

Groups	1th week	2th week	3th week	4th week	5th week
EG1	CCTs		Traditional teaching		
EG2	Traditional teaching			CCTs	
CG	Traditional teaching (more exercises, examples)				

As can be seen in Table 1, each group was exposed to traditional teaching in different durations. The groups were taught by the same teacher who had twenty-one years of chemistry teaching experience and has a master's degree in chemistry education. The conceptual change text sessions for both experimental groups was conducted by the researcher and lasted for 6 hours. The time devoted to traditional teaching sessions was 9 hours. Each group was given the pre-test and post-test to measure the effects of the treatment, both before and after exposure to the independent variable observed during the treatment.

Participants

76 10thgrade students from three chemistry classes in a secondary school voluntarily participated in the study. Two of the classes were randomly assigned as the experimental groups and the other as the control group. Each teaching approach used in the study was randomly assigned to each class. Experimental group 1 (EG1)

studied the conceptual change texts before the traditional teaching and consisted of 26 students (16 boys and 10 girls) while the experimental group 2 (EG2) studied the conceptual change texts after the traditional teaching and consisted of 25 students (18 boys and 7 girls). The control group (CG) was taught using only traditional approach and consisted of 25 students (14 boys and 11 girls). There were four chemistry teachers in the school where the study was conducted, and only teacher volunteered to participate in the study. The chemistry course in the school was taught in three 45-minute periods per-week.

Instrumentation

The Concept Achievement Test (CAT): First 15 items in the CAT were taken from the previous studies (Demircioğlu et al., 2005; Özmen et al., 2009a). The other items were developed by the researcher according to the instructional objectives and students' alternative conceptions reported in the literature. Each item on the CAT was constructed based on a methodology used by Peterson, Treagust and Garnett (1986) and Treagust (1988). To confirm content validity, the CAT was examined by a group of experts comprising two university chemistry educators and two high school chemistry teachers who have been teaching for over twenty years at the central lycées in the city of Trabzon. Its reliability coefficient (KR20) for the pilot study was found to be 0.83 using the Cronbach Alpha formula, whilst this value was 0.87 for the real study. The final version of the CAT consists of twenty-five questions and the conceptual areas covered by the test are presented in Table 2.

Table 2. *The topic the each test item attempts to measure*

Covered areas	Definitions of acids and bases: 1, 2, 3
	Characteristics of acids and bases: items 4, 5, 6, 7, 8
	Titration and neutralization: items 9, 10 ,11, 12
	Weak acid and base ionizations: items 13, 14, 15, 16
	pH scale: items 17, 18, 19
	Indicators: items 20, 21, 22
	Hydrolysis and buffer solutions: items 23, 24, 25

Development of conceptual change texts

Twelve conceptual change texts were prepared by the researcher based on information gathered from a review of literature about students' learning difficulties in acid-base chemistry and alternative conceptions determined by the CAT. Conceptual change texts used in the study were comprised four main parts. The first part contained a question about the concept to be studied in order to activate preconceptions of students and cause dissatisfaction with their current conceptions. The students were expected to respond the question and explain their answer individually. In the second part, students' alternative conceptions were directly mentioned. In this way, the students were expected to be dissatisfied with their existing ideas. In the third part, scientifically acceptable explanations related to concepts were given. These explanations were supported with concrete examples and figures to help students' understanding of the concept. In the final part, the students were provided with different statements related to the concept in order to prove that the new concept is more fruitful than their preconceptions. In this way, students' alternative conceptions tried to be changed into scientific ones. Each text aimed to remedy alternative conceptions determined by the literature and the CAT. In the study, twenty alternative conceptions, which were listed and coded in Table 5, were taken into account in six conceptual areas. In each text, one, two or three alternative conceptions were dealt with. Conceptual areas covered by the CCTs were: (a) properties of acids and bases (two texts, one for A1 and A2, the other for A3 and B3 in Table 5); (b) salts (one text for C1 and C2 in Table 5); (c) hydrolysis (one text for G1 and G2 in Table 5); (d) neutralization and titration (three texts, one for D1, another for D2, and the other 3 for E1 and E2 in Table 5;, (e) pH scale (two texts, one for B1 and B4, the other for B2 and B3); and (f) strength of acids and bases (three texts, one for F1, one for F2, F4, and F5, and the other for F3 in Table 5). The texts were validated by a panel of five experts, consisting of three experienced chemistry teachers and two chemistry education professors. One of the texts used in the study was given in Appendix A, as an example.

Teaching intervention

Three groups, two EGs and one CG, one chemistry teacher and the researcher participated in the study. Firstly, the CAT was administered to the groups as the pretest two months before the intervention. In the intervention phase, EG1 students were taught by the researcher using the CCTs for two weeks (6 hours). Afterwards, the teacher taught using the traditional approach for three weeks (9 hours). On the other hand, the teacher taught EG2 students first using traditional approaches for three weeks (9 hours), and then the researcher taught them by using CCTs for two weeks (6 hours). Both EG1 and EG2 students took a total of a 15 hours course related to acids and bases. The CG students were taught by the teacher using only the traditional approach for five weeks (15 hours in total). Table 1 summarizes the teaching procedure throughout the study.

Teaching approach used for the control group

The teacher mainly used lectures and wrote notes on the chalkboard to teach the concepts of acids and bases. During the first week, the teacher explained the *Arrhenius*definition of *acids and bases, the formation of the hydronium ion, limitations of t*he Arrhenius definition, the Bronsted-Lowry acid-base theory and Lewis' definition and then wrote examples for each definition on the chalkboard. The students listened to the teacher's lecture, took notes and gave examples of acids and bases. After the teacher's explanations, some of the concepts were discussed. In the second week, he explained the characteristics of acids and bases and gave examples for each of the properties. Then the teacher demonstrated two experiments in the classroom involving the effect of acids on metals (magnesium and zinc) and electricity conductivity of acids and bases (NaOH, HCl, lemon). The students observed and took notes. He passed out the worksheets, including conceptual questions about the definitions and characteristics of acids and bases. While the students were studying on the worksheets requiring written responses, the teacher walked around inside the classroom and helped the students when they needed. During this activity, the students had the opportunity to ask questions. The worksheets were collected and corrected by the teacher, and the students reviewed their responses after correction In the third week, the teacher explained the pH concept and showed how to solve algorithmic problems related to the pH concept and to test the pH of soft drinks, dish washing liquids, lime juice, etc. by using pH paper and litmus. The students took notes and solved algorithmic problems. In the fourth week, the teacher explained the neutralization and titration concepts by demonstrating an experiment in the classroom involving the titration of a strong acid (HCl) with a strong base (NaOH) and showed how to perform the titration calculations. In the final week, he summarized all the concepts in the acid-base unit and passed out the worksheets including algorithmic and conceptual questions about all the concepts of acids and bases. They were collected and corrected by the teacher. The students in the control group did more exercises (generally procedural questions) about each concept in the acids and bases unit than those in the experimental groups because they had more time. On the other hand, students in the experimental groups did not perform the worksheets.

Teaching approach used for the experimental groups

The same instructional procedure was used in EG1 and EG2, except for the implementation time of the CCTs. While the CCTs were implemented before the traditional instruction in EG1, it was applied after the traditional instruction in EG2 (see in Table 1). In a typical instructional sequence, the CCT was handed out to students and they were asked to read the question at top of it carefully and silently. Then, students were asked to stop reading and were given time to think. Then, they were asked to write their answer in blank area under the question. This step attempted to activate students' alternative conceptions if they existed. After this process finished, students verbally stated their beliefs and were discussed with the whole classroom. Then, they were asked to read common alternative conception(s) in the text and to compare with ideas they had just written. On one hand, students who had alternative beliefs were helped to recognize the weakness or lack of their conceptions and to develop cognitive conflict; on the other hand, all of the students were encouraged to notice the different alternative beliefs. After the classroom discussion, scientific explanations related to concept were presented to provide intelligibility and plausibility. A few willing students were asked to assess the text. Finally, the researcher summarized it for all students. After the CCTs, the students in EG1 were exposed to the traditional teaching. During this period, the students were taught by the teacher and dealt with the concepts of acids and bases. The students in the experimental groups (EG1 and EG2) studied the concepts in the acid and base unit twice.

Data analysis

In the analysis of the results from the CAT, the total scores of each student in the group and then the mean score of each group were first computed for each test.

The pre-CAT scores of the groups were compared by using one-way analysis of variance (ANOVA) to determine whether a statistically significant mean difference existed between the CG, EG_1 and EG_2. The post-test results were also compared using the analysis of covariance (ANCOVA) to see the effects of intervention on students' understanding of the concepts of acids and bases. In the analysis of covariance, pre-CAT was used as a covariate to control the probable initial group differences.

Results

The descriptive measures of the tests for the experimental groups and the control group are given in Table 3. It is seen that students' mean scores of pre-CAT were similar in the experimental and control groups. A one-way analysis of variance (ANOVA) was used to determine whether statistically significant differences existed among the mean scores of EG_1, EG_2 and CG for the results of the pre-CAT at the 0.05 level. The findings showed that there were no differences among the groups with respect to the students' initial understandings of the concepts of acids and bases ($F_{(2;73)}$=0,042; p>0.05) before the treatment. These results indicated that students in all groups were similar in respect to the initial understandings of the concepts of acids and bases before the intervention.

Table 3. *Comparison of performance of experimental and control groups on pre-tests and post-tests*

		Pre-CAT		Post-CAT		Pre-Post mean difference (CAT)
Group	N	Mean	SD	Mean	SD	
EG_1	26	34.62	17.72	77.88	12.50	43.26
EG_2	25	35.40	17.55	70.60	13.17	35.20
CG	25	36.00	16.14	60.00	15.74	24

Note: SD: Standard Deviation; EG: Experimental group; CG: Control group

After the treatment, the analysis of covariance (ANCOVA) was run to compare the effects of intervention on students' understanding of acid-base concepts in post-CAT. The adjusted mean scores of EG_1, EG_2, and CG were 79.1, 70.1 and 58.2, respectively. Although the students in each group increased their achievement scores from pre-test to post-test, these gains were not too high. While the mean score of students in EG_1 had risen from 34.62 to 77.88 with a gain score of 43.3, in EG_2 it had risen from 35.40 to 70.6 with a gain score of 35.2 and in the control group it had risen from 36 to 60.2 with a gain score of 24.2 after the treatment. As seen in Table 4, the results of ANCOVA showed that the treatments resulted in significant effects on the mean scores ($F_{(2;71)}$= 24,84, p<0.01). When the marginal mean scores of the groups were compared by using the Tukey test, statistically significant differences were found between the experimental groups and the control group (p<0. 01), and a remarkably significant difference was also found between the experimental groups in favor of EG_1 (P<0.05). The alternative conceptions concerning the acid and base concepts were determined by the students' responses to the multiple choice items in the CAT. Ratios of the alternative conceptions held by more than 20% of students in each group were presented in Table 5. The alternative conceptions, as reflected by the distracters in multiple-choice items, are the most common in a certain conceptual area.

Table 4. *Summary of the analysis of covariance comparing the mean post-CAT scores of students in the experimental and control groups*

Source of Variance	*df*	Mean Square	F	p	Eta-Square η^2	Differences (Tukey HSD)*
Pre-CAT (cov)	1	3880.89	24.84	0.000	0.256	EG1-CG; EG2-CG; EG1-EG2
Treatment	2	1562.69	10.00	0.000	0.217	
Error	72	156.388				

*significant differences among the groups according to Tukey test (at the 0.05 level)

Twenty alternative conceptions were identified and were grouped under the headings of the application of properties of acids and bases (A), pH scale (B), salts solutions (C), neutralization and titration (D), indicators (E), strength of acids and bases (F) and hydrolysis (G). While the percentages of students' alternative conceptions in pre-test ranged from 26.29% to 80.77% in EG_1, the students in EG_2 ranged from 24% to 84% and those in the control group ranged from 24% to 80% (Table 5). The students in each group held almost the same alternative conceptions in the pre-test at about the same percentages. Each group showed progress in changing their alternative conceptions to the scientifically acceptable ones, but the experimental groups performed better overall. Although the experimental groups performed better, this does not mean that all alternative conceptions were remedied. The reasons for this are discussed in detail below.

Discussion and Implications

In this study, as mentioned above, the three groups (the EG_1, EG_2 and CG) were used to answer to the proposed research questions. The results showed that there was no significant difference among three groups concerning their understanding of the concepts before the treatment. The first research question in the study was whether there were significant differences between the post-test mean scores of students in the experimental groups who received the CCTs as an adjunct to traditional teaching, compared to the control group students who only received traditional instruction. The results showed that students in the EGs performed much better in the post-test than the students in the CG. This finding showed that the learning approaches based on the combination of conceptual change and traditional approach resulted in a significantly better acquisition of the scientific conceptions and the elimination of alternative conceptions than traditional instruction alone. This result is consistent with the findings from the previous studies on conceptual change texts (Chambers and Andre, 1997; Guzzetti et al., 1997; Hynd et al., 1997; Özmen, 2007; Wang and Andre, 1991). However, the way the CCTs were used in this study was different from the related studies in the literature. In the present study, they were used to support the traditional teaching in the Turkish schools, but not as the main method of teaching. The reason why the students in the experimental groups were more successful than the students in the control group may be that the author (in the CCTs sessions) dealt with students' existing ideas and alternative conceptions and provided a learning environment for them to think about their own ideas and to compare their existing concepts with new ones. Also, he provided opportunities for students to become involved in discussions while studying with the CCTs. For example, in the conceptual change texts used in this study, emphasis was given to students' alternative conceptions. As they struggle with these alternative conceptions, the students became dissatisfied with their preconceptions. This enabled them to accept better explanations to the problems that were introduced. In this way, students were allowed to think about prior knowledge. Consequently, they were convinced that the alternative conception was incorrect and the scientifically acceptable new conception was correct. In contrast, in the control group and in the sessions of traditional teaching of the EG_1 and EG_2, the teacher did not consider students' prior knowledge and alternative conceptions. He used lecture and discussion methods to transfer knowledge, wrote notes on the chalkboard about the definition of concepts covered, and gave students worksheets requiring written responses. Also, he demonstrated four experiments concerning titration, electrical conductivity of acids and bases, properties of acid and bases and effects of acids on different kinds of metal. The main difference between the two approaches was that the conceptual change approach explicitly dealt with alternative conceptions.

Table 5. *Students' alternative conceptions determined in the pre-test and post-test*

		EG1				EG2				CG			
		Pre-test		Post-test		Pre-test		Post-test		Pre-test		Post-test	
Students' alternative conceptions		f	%	f	%	f	%	f	%	f	%	f	%
1	Acids burn and melt everything (A).	15	57,69	5	19,2	13	52	6	24	12	48	8	32
2	All acids and bases are harmful and poisonous (A).	8	30,77	3	11,5	10	40	3	12	13	52	7	28
3	While bases turn blue litmus paper red, acids turns red litmus paper blue (A).	8	30,77	2	7,69	8	32	2	8	11	44	3	12
4	As the concentration of H3O+ ions in an acid solution increases, the pH of the solution increases (B).	7	26,92	0	0	9	36	0	0	7	28	4	16
5	if the pH of a solution changes, its color changes too (B)	9	34,62	1	3,85	9	36	1	4	8	32	4	16
6	pH only measures acidity (B)	11	42,31	2	7,69	11	44	4	16	13	52	6	24
7	As the value of pH increases, acidity increases (B).	10	38,46	2	7,69	10	40	3	12	6	24	2	8
8	All salts are neutral (C).	21	80,77	4	15,4	21	84	6	24	19	76	11	44
9	Salts don't have a value of pH or have pH of 0 (C).	14	53,85	0	0	6	24	0	0	8	32	4	16
10	In all neutralization reactions, acids and bases consume each other completely (D).	16	61,54	2	7,69	16	64	2	8	11	44	6	24
11	At the end of all neutralization	14	53,85	3	11,5	14	56	4	16	18	72	11	44

	reactions, there is neither H+ nor OH- ions in the resulting solutions (D).												
12	The indicator helps with neutralization (E)	18	69,23	1	3,85	18	72	2	8	14	56	5	20
13	The indicator changed color at pH of 7 (E).	7	26,92	0	0	6	24	1	4	7	28	2	8
14	A strong acid is always a concentrated acid (F).	9	34,62	4	15,4	8	32	4	16	6	24	5	20
15	Bubbles or bubbling is a sign of chemical reaction or strength of an acid or a base (F).	7	26,92	0	0	7	28	0	0	9	36	3	12
16	A strong acid doesn't dissociate in water solution because its intra-molecular bonds are very strong (F).	16	61,54	4	15,4	16	64	5	20	14	56	6	24
17	The strength of an acid depends on the number of hydrogen atoms in an acid (F).	10	38,46	2	7,69	10	40	4	16	12	48	4	16
18	Species having formulas with hydrogen are acids and those having formulas with hydroxyl are bases (F).	9	34,62	1	3,85	9	36	1	4	10	40	4	16
19	Hydrolysis is the self-ionization of water (G).	8	30,77	1	3,85	8	32	2	8	7	28	1	4
20	Hydrolysis is that water decomposes into the elements hydrogen and oxygen (G).	20	76,92	0	0	18	72	0	0	20	80	8	32

Guzzetti et al. (1997) showed that texts that deal with alternative conceptions and explicitly refute them were more effective for improving conceptual change than narrative or expository ones. Diakidoy et al. (2003) also suggested that 6th grade students who read a refutational text as an adjunct to traditional instruction performed better than students who read a simple expository text or no text at all. Moreover, in the related literature there have been a great deal of studies showing that the conceptual change approach based on CCTs was more effective for promoting instruction and remedying learners' alternative conceptions than traditional ones (Diakidoy et al., 2003; Guzzetti et al., 1997; Hynd et al., 1994; Okebukola, 1990; Horton et al., 1993; Sungur et al., 2001; Wang & Andre, 1991). Consequently, the results of the present study agreed with the previous research. In the light of these results, it can be said that conceptual change text oriented instruction is an effective teaching strategy in order to help students go through the conceptual change concerning the concepts of acids and bases.

The second research question asked whether there was a significant difference between the post-test means of the EG_1 students who received CCTs before the traditional teaching and theEG_2 students who received CCTs after the traditional teaching. When, the post-test mean scores of the EGs were compared to each other, it was found that the EG_1 students performed much better in the post-test than the students in the EG_2. In the related literature, no study examining the effect of CCTs on students' alternative conceptions before and after traditional teaching was encountered. CCTs were commonly used after the regular classroom teaching and compared with the traditional teaching in the literature. In these studies, as mentioned above, it was suggested that groups taught by CCTs were more successful than those taught by the traditional approach alone. It could be said that the present study was original from this perspective. Although the same activities were done in the both experimental groups, finding different results was amazing. In the non-formal in-class observations, during traditional teaching, most students in EG_1 were more ambitious to learn the concepts to be studied and asked more questions to the teacher than the EG_2students. The reason for this may be that EG_1students had studied the same concepts during the CCT sessions before the traditional teaching. For example, when the teacher explained neutralization and titration concepts and demonstrated a titration of a strong acid (HCl) with a strong base (NaOH), some students in the EG_1asked the following questions: "What is the difference between the equivalence point of a titration and its end point?" "Why is pH not always 7 at the equivalence point" "Why does the equivalence point occur at a pH of 7 for titration of a strong acid with a strong base?", etc. These questions lead to classroom discussions that were similar to those in the CCTs sessions, but the teacher failed to give satisfactory explanations to the questions. He showed some alternative conceptions too. Pardhan and Bano (2001), Mellado (1997) and Trend (2001) reported that pre- and in- service science teachers held non-scientific ideas. However, EG_2 students had no questions about this concepts and found the teacher' explanations adequate. In the CCTs sessions, classroom discussions, in which the cases where alternative conceptions in the texts seemed to be inconsistent with students' prior knowledge, had an important influence in student' understanding and alternative conceptions of acid and base concepts. Guzzetti (2000) argued that conceptual change/refutational texts caused cognitive conflict, but cognitive conflict was not often sufficient to cause conceptual change. Moreover, Guzzetti et al. (1995) reported that although refutational/conceptual change texts were effective on the average for groups of students, they should be supported by discussion for some students. Classroom discussions on the CCTs gave experimental group students opportunities to focus on the interpretation of phenomena and helped them build up new concepts. This finding supported the results of previous studies (Mason, 1998; Mason & Santi, 1998; Tobin et al., 1994).

The third research question asked which alternative conceptions concerning the concepts of acids and bases were held by the students who participated in this study before and after the treatment. As seen in Table 5, the results from the pre-test showed that the students in all groups held a large number of alternative conceptions before receiving formal instruction on the acids and bases. These alternative conceptions were also common among other students in many countries and well-documented in the literature (e.g., Ayas & Demircioğlu, 2002; Cros et al., 1986, 1988; Demircioğlu, 2003; Demircioğlu et al., 2004; 2005; Hand & Treagust, 1991; Nakhleh & Krajcik, 1993; 1994; Özmen et al., 2009a; Ross & Munby, 1991). After the intervention, each group showed progress in eliminating their alternative conceptions, but the experimental groups were better overall. While the students in the EG_1 had corrected five alternative conceptions completely, the EG_2 students eliminated four alternative conceptions. On the other hand, the CG students could remedy only one alternative conception. The results from this study support the notion that it is not easy to eliminate alternative conceptions just by using ordinary forms of instruction (like lectures, ordinary text, and labs) (Champagne et al, 1983; Driver & Easley, 1978). Because alternative conceptions are well embedded in learner's cognitive ecology and strongly held, they are resistant to change even with instruction designed to address them (Palmer, 1999; Vosniadou et al., 2001). From in-class observations during the treatment, it was revealed that some of the students in the experimental groups had difficulty understanding the reverse relation (e.g., as a solution becomes more acidic, its pH falls) between $[H^+]$ and pH. Even after studying the conceptual change text about the pH scale, some continued their claims. The common alternative conceptions held by the students were generally related to the concepts of hydrolysis, salts and neutralization (Table 3). As is known, these concepts are closely related to each other. However, the hydrolysis concept is explained without relating it to the concepts of neutralization and titration in the chemistry textbooks used in the science classroom in Turkey. Thus, students have difficulty in meaningfully constructing the concept, relating it to other concepts and developing alternative conceptions (Demircioğlu, 2003). The conceptual change text used in the present study (Appendix A) explained the concept of hydrolysis by correlating it to the titration concept and emphasizing alternative conceptions. Hence, as seen from Table 3, all students in the experimental groups correlated the alternative conception in item 20 in the post-test. In addition, most students in all groups appeared to confuse the hydrolysis concept with the electrolysis of water as determined by the informal in-class observations and the pre-CAT. Most likely the reason for this can be that the students were more familiar with the electrolysis concept than the hydrolysis due to the fact that the former was taught first in 6th grade science courses in Turkish primary schools. Another reason for this confusion may be that the last parts (-rolysis) of words 'hydrolysis' and 'electrolysis' have the same spelling and pronunciation. Another alternative conception, not determined in the pre-test, was revealed while students were reading the CCTs concerning the titration. The question on top of this text was, "Why is the pH at the equivalence point of a weak base titrated with a strong acid less than 7?". None of the experimental group students were able to correctly answer this question because they ignored the effect of hydrolysis. Most students in EG_1 and EG_2 indicated that a strong acid completely ionizes, and a weak base only slightly ionizes in water producing relatively few OH^- ions, and hence H_3O^+ ions are greater than OH^- ions at the equivalence point. Namely, if one of the reactants was weak, the complete neutralization does not occur and strong one determines the pH of the resulting solution. This alternative conception was reported in the study of Pınarbaşı (2007). Some suggested that the acid would be more dominant because it would be stronger than base and the resulting solution would have an acidic pH. One possible reason of common alternative conceptions concerning acid-base concepts is that they are interdisciplinary in nature. Understanding of pH and neutralization (titration) requires the understanding and application of the knowledge of physics and mathematics because learning of these concepts requires knowledge of graphing and logarithms. Another reason can be that students may have mixed up the original and the modern interpretation of some concepts. For instance, the idea that neutralization always results in a neutral solution has been found to be quite common among the students. This is an alternative conception that stems from shifting the meaning of neutralization and the ambiguous use of the term neutral in everyday context and in the chemical context (Schmidt, 1991). The historical development (from Arrhenius' theory to Bronsted-Lowry' theory) shows that the term neutralization has lost its original meaning in chemistry, and that the modern definition is incompatible with the original interpretation. The term neutral in physics is used to show that there are neither positive nor negative charges. The term "neutral" has a different meaning when a neutral solution is described. In this case neutral solution contains as many H_3O^+ ions as OH^- ions. Nakhleh (1992) pointed out the issue of language usage in science and in everyday context.

This study sought to determine whether the CCTs were more effective before or after implementing the traditional teaching on 10th grade students' conceptual understanding and alternative conceptions of acids and bases. The findings from the study suggest that studying the CCTs before the traditional teaching can enhance more students' understanding of acids and bases than both studying them after the traditional teaching and using traditional teaching alone. The study also provides further evidence that the CCTs are more effective in remedying students' alternative conceptions than traditional approaches. Unfortunately, in our country, most teachers ignore the assessment of students' prior knowledge and learning needs before the instruction, although alternative teaching strategies emphasize the importance of learner's preconceptions. As seen from the results of this study, and similar findings of other studies, a teacher who identifies students' alternative conceptions before the instruction can more easily help students gain scientifically acceptable conceptions by using alternative teaching strategies. Firstly, pre-service and practicing science teachers should understand the importance of prior knowledge in learning, which was defined by Jonassen and Gabrowski (1993) as the knowledge, skills or ability that a student brings to the learning environment, because they are strong predictors of student achievement. Then, they should be informed about the usage of strategies of conceptual change that explicitly deal with students' prior knowledge and alternative conceptions, due to the fact that much research indicates that there is a strong relationship between prior knowledge and performance of students.

Conceptual change texts used in this study and other studies in the related literature may be placed in chemistry textbooks for better learning. Also, teachers should be trained in the preparation and the usage of conceptual change texts. Most chemistry classes in our country have teacher-centered instruction. Therefore, during the transitional period from a teacher-centered instruction to student-oriented one, CCTs can be used as a supplement to classroom instruction to promote students' understanding of science concepts and eliminate their alternative ideas. Because this study was limited to 76 10th grade high school students in three intact classrooms, caution is advised with respect to generalize the findings to a wider context (Guba & Lincoln, 1994). This study may be considered as a small step on a shift from a teacher-centered to a student-centered strategy in Turkish schools. For further work, similar studies can be constructed for other topics or concepts of secondary chemistry education and with larger sample sizes. Studies on conceptual change texts accompanied by other methods such as concept mapping, laboratory activities done by students and analogies can be carried out. Teaching strategies taking students' alternative conceptions into consideration may, as suggested here, also be useful for enhancing meaningful learning. In addition, curriculum designers, textbook writers and teachers should take these strategies into consideration when developing new science curriculum. In short, when suitable conceptual change strategies are used in the teaching of the acid and base concepts, they are more likely to cause a significantly better removal of misconceptions and acquisition of scientifically sound concepts.

Acknowledgements

This work was supported by the Research Fund of Karadeniz Technical University, Project Number: 2005.116.04.3

References

Ayas, A., & Demircioğlu, G. (2002). *Student teachers. understanding and misconceptions of acids, bases and salts in chemistry*, First International Education Conference, *Changing times*, *Changing Needs*, Eastern Mediterranean University, May 8-10, 2002, Gazimagusa, North Cyprus.

Ayvacı, H. Ş. Devecioğlu, Y. (2009, 1-3 May). *The new educational program and the innovational viewpoints of teachers*, The first international congress of educational research, The association of educational research community, Çanakkale, Turkey. Retrieved december 4, 2009, from http://oc.eab.org.tr/egtconf/pdfkitap/pdf/458.pdf.

Basili, PA. & Sanford, JP. (1991). Conceptual change strategies and cooperative group work in chemistry. *Journal of Research in Science Teaching, 28*, 293-304.

Başer, M. & Geban, Ö. (2007). Effectiveness of conceptual change instruction on understanding of heat and temperature concepts, *Research in Science & Technological Education, 25*(1), 115–133.

Bradley, J.D. & Mosimege, M.D. (1998). Alternative conceptions in acids and bases: A comparative study of student teachers with different chemistry backgrounds. *South African Journal of Chemistry, 51*, 137-150.

Çakan, M. (2004). Öğretmenlerin Ölçme-Değerlendirme Uygulamaları ve Yeterlik Düzeyleri: İlk ve Ortaöğretim (In Turkish), *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi, 37*, 99–114.

Çakır, Ö. Uzuntiryaki, E., & Geban, O. (2002).*Contribution of conceptual change texts and concept mapping to students' understanding of acids and bases*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, April 6-10, 2002, New Orleans, LA.

Çakır, İ. & Çimer, S.O. (2007, 15-17 Nov.). Fen ve Teknoloji Öğretmenlerinin Alternatif Ölçme Değerlendirme Konusundaki Yeterlilikleri ve Uygulamada Karşılaşılan Problemler. *I. Ulusal İlköğretim Kongresi*. Ankara.

Canpolat, N., Pınarbaşı, T., Bayrakçeken, S. & Geban, O. (2006). The conceptual change approach to teaching chemical equilibrium. *Research in Science & Technological Education*, *24*(2), 217-235.

Chambers, S.K., & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching, 34*, 107-123.

Champagne, A.B, Gunstone, R.F., & Klopfer, L.E. (1983).Naive knowledge and science learning. *Research in Science and Technological Education, 1*, 173-183.

Christianson, R.G. & Fisher, K.M. (1999). Comparison of student learning about diffusion and osmosis in constructivist and traditional classroom. *International Journal of Science Education, 21*, 689-698.

Cros, D., Maurin, M., Amouroux, R., Chastrette, M., Leber J., & Fayol M. (1986). Conceptions of first-year university students of the constituents of matter and the notions of acids and bases. *European Journal of Science Education, 8*, 305-313.

Cros, D., Chastrette, M., & Fayol, M. (1988). Conceptions of second year university students of some fundamental notions in chemistry. *International Journal of Science Education, 10*, 331-336.

Demerouti, M., Kousathana, M., & Tsaparlis, G. (2004). Acid-base equilibria, Part I. Upper secondary students' alternative conceptions and difficulties. *The Chemical Educator, 9*, 122-131.

Demircioğlu G. (2003). *Developing and implementing teacher guide material related to the unit "acids and bases" at 10th grade level*. PhD Thesis, Graduate school of natural and applied sciences, Karadeniz Technical University, Trabzon.

Demircioğlu, G., Özmen, H. & Ayas, A. (2004). Asit ve baz kavramları üzerine bir araştırma çerçevesinde kimyada karşılaşılan kavram yanılgıları (In Turkish). *Educational Sciences: Theory & Practice, 4*(1), 73-80.

Demircioğlu, G., Ayas, A., & Demircioğlu, H. (2005). Conceptual change achieved through a new teaching program on acids and bases. *Chemistry Education Research and Practice, 6*, 36-51.

Diakidoy, I.-A.N., Kendeou, P., & Ioannides, C. (2003). Reading about energy: The effects of text structure in science learning and conceptual change. *Contemporary Educational Psychology, 28*(3), 335-356.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education, 5*, 61-84.

Duit, R., Treagust, D., & Widodo, A. (2008). Teaching science for conceptual change—Theory and practice. In S. Vosniadou, et al. (Eds.), *International handbook of research on conceptual change* (pp. 629–646). New York: Routledge.

Ebenezer, J.V. & Gaskell, P.J. (1995). Rational conceptual change in solution chemistry. *Science Education, 79*, 1-17.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research, cited in: Denzin, N.K & Lincoln, Y.S, *Handbook of Qualitative Research*, Sage:105-17.

Guzzetti, B. J., Hynd, C. R., Skeels, S. A., & Williams, W. O. (1995). Improving high school physics texts: Students speak out. *Journal of Reading*, *36*, 656–663.

Guzzetti, B. J. (2000). Learning counter intuitive science concepts: What have we learned from over a decade of research? *Reading, Writing, Quarterly*, *16*, 89-98.

Guzzetti, B.J., Williams, W.O., Skeels, S.A., & Wu, S.M. (1997). Influence of text structure on learning counterintuitive physics concepts. *Journal of Research in Science Teaching, 34*, 701-719.

Hand, B., & Treagust, D.F. (1991). Student achievement and science curriculum development using a constructivist framework. *School Science and Mathematics, 91*, 172-176.

Hewson, PW. (1981). A conceptual change approach to learning science. *European Journal of Science Education, 3*, 383-396.

Hewson, P.W. & Hewson, M.G. (1984). The role of conceptual conflict in conceptual change and the design of science education. *Instructional Science, 13*, 1-13.

Horton, P.B., McConnly, A.A., Gallo, M., Woods, A.I., Senn, G.J. & Hamelin, D. (1993). An investigation of the effectiveness of concept mapping as an instructional tool. *Science Education*, *77*(1), 95–111

Hynd, C. R., McWhorter, I. Y., Phares, V. L., & Suttles, C. W. (1994). The role ofinstmctional variables in conceptual change in high school physics topics. *Journal of Research* in *Science Teaching, 31*(9), 933-946.

Hynd, C.R., Alvermann, D., & Qian, G. (1997). Pre-service elementary school teachers' conceptual change about projectile motion: Refutation text, demonstration, affective factors, and relevance. *Science Education*, *81*, 1–27.

Jonassen, J. H., & Grabowski, B. L. (1993). *Handbook of Individual Differences, learning and instruction. Part VII, Prior knowledge.* Hillsdale: Lawrence Erlbaum Associates.

Mason, L. (1998). Sharing cognition to construct scientific knowledge in school context: the role of oral and written discourse. *Instructional Science*, *26*(5), 359–389.

Mason, L. & Santi, M. (1998). Discussing the greenhouse effect: children's collaborative discourse reasoning and conceptual change. *Environmental Education Research, 4(1),*67-85

Mellado, V. (1997). Preservice teachers' classroom practice and their conceptions of the nature of science. *Science and Education*, *6*, 331-354.

Nakhleh, MB. (1992). Why some students don't learn chemistry, *Journal of Chemical Education*, *69*, 191–196.

Nakhleh, M.B., & Krajcik, J.S. (1993). A protocol analysis of the influence of technology on students. actions, verbal commentary, and thought processes during the performance of acid-base titrations. *Journal of Research in Science Teaching, 30*, 1149-1168.

Nakhleh, M.B., & 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*, *34*, 1077-1096.

Niaz, M., Aguilera, D., Maza, A., & Liendo, G. (2002). Arguments, contradictions, resistances and conceptual change in students' understanding of atomic structure. *Science Education, 86*, 505-525.

Okebukola, P. A.(1990). Attaining meaningful learning of concepts in genetics and ecology: An examination of thepotency of the concept mapping technique. *Journal of Research in Science Teaching*, *27*(5), 493-504.

Özmen, H. (2007). The effectiveness of conceptual change texts in remediating high school students' alternative conceptions concerning chemical equilibrium. *Asia Pacific Education Review*, *8*(3), 413-425.

Özmen, H., Demircioğlu, G., & Coll, R. (2009). A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry. *International Journal of Science and Mathematics Education*, *7*, 1-24.

Özmen, H., Demircioğlu, H. & Demircioğlu, G. (2009). The effects of conceptual change texts accompanied with animations on overcoming 11th grade students' alternative conceptions of chemical bonding, *Computers & Education*, 52, 681-695.

Özmen, H. and Yıldırım, N. (2005). Effect of work sheets on student's success: Acids and bases sample, *Journal of Turkish science education*, *2*(2), 64-67.

Pabuçcu, A. & Geban, Ö. (2006). Remediating misconceptions concerning chemical bonding through conceptual change text, *Hacettepe University Journal of Education. 30*, 184-192.

Palmer, D. (1999). Exploring the link between students' scientific and nonscientific conceptions. Science Education, *83*, 639-653.

Pardhan, H., & Bano, Y. (2001). Science teachers' alternate conceptions about direct currents. *International Journal of Science Education*, *23*(3), 301-318.

Peterson, RF, Treagust, DF., & Garnett, P. (1986). Identification of secondary student's alternative conceptions of covalent bonding and structure concepts using a diagnostic test instrument. *Research in Science Education*, *16*, 40-48.

Pfundt, H & Duit, R. (1991). Bibliography of students' alternative frameworks in science education, (Kiel, Germany:IPN).

Pintrich, P.R., Marx, R.W. & Boyle, R.W. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*, 167-199.

Pınarbaşı, T. (2007). Turkish undergraduate students' misconceptions on acids and bases. *Journal of Baltic Science Education*, *6*(1), 23-34.

Posner, G.J, Strike, K.A, Hewson, P.W., & Gertzog, W.A. (1982). Accommodation of a scientific conception: toward of conceptual change. *Science Education, 66*, 211-227.

Qian, G., & Alvermann, D. (1995). Role of epistemological beliefs and learned helplessness in secondary school students' learning science concepts from text. *Journal of Educational Psychology*, *87*, 282–292.

Robson, C. (1998). *Real Word Research*, Blackwell Publishers Ltd., Oxford, UK.

Ross, B., & Munby, H. (1991). Concept mapping and alternative conceptions: A study of high school students' understanding of acids and bases. *International Journal of Science Education, 13*, 11-23.

Roth, K. J. (1985) Conceptual change learning and students processing of science texts, paper presented at the *Annual meeting of the American Education Research Association*, Chicago, IL.

Saljo, R. (1999). Learning as the use of tools: A sociocultural perspective on the human-technology link. In K. Littleton & P. Light (Eds.), *Learning with computers: Analysing productive interaction.* London, New York: Routledge.

Schmidt, H.J. (1991). A label as a hidden persuader: chemists. Neutralization concept. *International Journal of Science Education, 13*, 459-471.

Sheppard, K. (2006). High school students' understanding of titrations and related acid-base phenomena, *Chemistry Education Research and Practice*,*7*(1), 32-45.

Sinatra, G.M. & Pintrich, P.R. (2003). *Intentional conceptual change*. Mahwah, NJ: Erlbaum.

Sisovic, D., & Bojovic, S. (2000). Approaching the concepts of acids and bases by cooperative learning. *Chemistry Education: Research and Practice in Europe, 1*, 263-275.

Skopeliti, I., & Vosniadou, S. (2006). *The Influence of Refutational Text on Children's Ideas about the Earth*. Poster submitted for publication in the *Proceedings of the 28th Annual Conference of the Cognitive Society,* Vancouver, BC Canada.

Sungur, S., Tekkaya, C., & Geban, Ö. (2001). The contribution of conceptual change texts accompanied by concept mapping to students' understanding of the human circulatory system. *School Science and Mathematics, 101*(2), 91-101.

Tobin, K., Tippins, D.J., & Gallard, A.J. (1994). Research on instructional strategies for teaching science. In Gabel, D.L. (Ed.), Handbook of Research on Science Teaching and Learning (pp. 45-93). New York: Macmillan.

Toplis, R. (1998). Ideas about acids and bases. *School Science Review, 80*, 67-70.

Treagust, DF. (1988). Development and use of diagnostic tests to evaluate students' alternative conceptions in science. *International Journal of Science Education*, *10*, 159-169.

Treagust, D. & Duit, R. (2008). Compatibility betwen cultural studies and conceptual change in science education: there is more to aknowledge than to fight straw men!. *Cultural Studies of Science Education*, *3*, 387–395.

Trend, R. (2001). Deep time framework: A preliminary study of UK primary teachers' conceptions of geological time and perceptions of geoscience. *Journal of Research in Science Teaching*, *38*(2), 191-221.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction, 11*, 381–419.

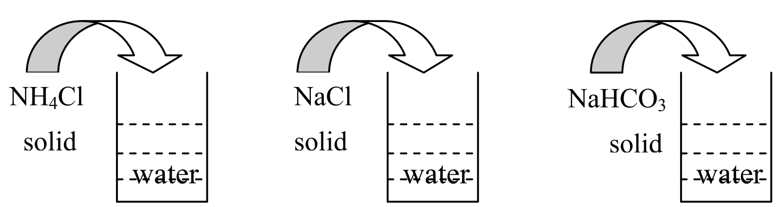
*Vosniadou, S. (2007). Re-framing*the*conceptual*change*approach*and itsre-framing*,* In*Vosniadou, S, Baltas, A* & Vamvakoussi, *X. Re-framing* the *Conceptual* Change *Approach* in *Learning* and *Instruction* (p. 2). Oxford: Elsevier.

Vosniadou, S. (2008). Bridging culture with cognition: A commentary on ''culturing conceptions: from first principles''. *Cultural Studies of Science Education*, *3*, 277–282.

Vosniadou, S. *(2008a).* Conceptual Change research: An introduction, In *Vosniadou, S. (Ed.), Internetional handbook of research on conceptual change* (p. XIX). Routhledge: New York and London.

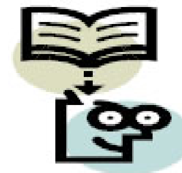
Wang, T., & Andre, T. (1991). Conceptual change text versus traditional text and application questions versus no questions in learning about electricity. *Contemporary Educational Psychology, 16*, 103-116.

Appendix A: Conceptual change text on the hydrolysis of salts



Question: *The beakers above contain ammonium chlorine, sodium chlorine and sodium bicarbonate solution, respectively. What do you think about pH values of these salt solutions? Explain*

Before reading the text below, write your answer in the space given below.
………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
……………………………………………………………………………………………..



Misconceptions: While many students believe that salt solutions are all neutral or have a pH of 7, some believe that they have not any value of pH or a pH of 0.

As you know, when salts dissolve in water they dissociate into their component cations and anions. The reactions of ions from salts with the water molecules to form H_3O^+ or OH^- ions are called **salt hydrolysis reactions.**In the reaction, the water molecule takes part in the reaction as one of the reactants. From this, it is understood that salt solutions can be acidic, basic or neutral. If all salt solutions were neutral, pH at the equivalent point of all titrations would be 7. But we knows that pH at the equivalent points can be less or greater than 7. **The reason for this is that a kind of salt formed.**

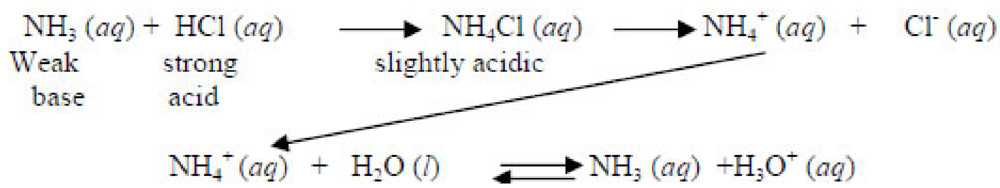
Is it possible to predict whether a salt hydrolysis reaction produces an acidic solution (containing H_3O^+ ions) or a basic solution (containing OH^- ions)?

The simplest way of this is to examine the acid and base from which the salt is formed. There are four possibilities: **(i) salts of strong acids and strong bases:** for example, NaCl is a salt formed by the neutralization reaction between NaOH and HCl.

$$\underbrace{NaOH\,(aq)}_{\text{strong base}} + \underbrace{HCl\,(aq)}_{\text{strong acid}} \longrightarrow \underbrace{NaCl\,(aq)}_{\text{neutral}} + H_2O\,(l)$$

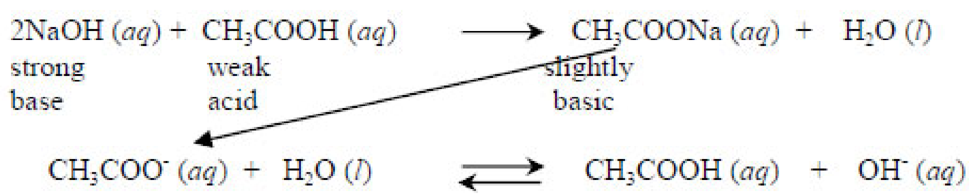
The ions in NaCl solution are Na^+ and Cl^-. Both are the ions of a strong acid (HCl) and a strong base (NaOH). Thus neither Na nor H_3O^+ hydrolyzes. A water solution of it is neutral and pH=7 at 25 ^{0}C, that is, neither acidic nor basic**.**

(ii) salts of strong acids and weak bases: for example, NH_4Cl is a salt formed by the neutralization reaction between NH_3 and HCl.



The water solution of this salt is slightly acidic or has a pH lower than 7 because the $NH4^+$ ion donates H^+ ions to water. This process is called **salt hydrolysis.** Because the Cl^- is a conjugate base of HCl (a strong acid), it has not affinity for H^+ ions. It is merely a spectator ion in this reaction

(iii) salts of weak acids and strong bases: solutions of these salts are basic and have a pH less than 7. For example, CH_3COONa is a salt formed by the neutralization reaction between CH_3COOH (weak acid) and NaOH (strong base).

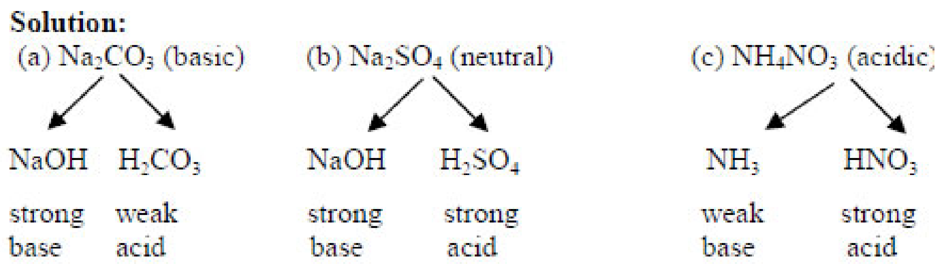


Its water solution is basic because the CH_3COO^- (ethanoate) ion in the solution is a Bronsted-Lowry base and reacts with water to form ethanoic acid (acetic acid) and hydroxide ions. The Na^+ ion is merely a spectator ion in the reaction.

and (iv) salts of weak acids and weak bases: Aqueous solutions of these salts can be neutral, acidic or basic depending on the relative strengths of the acid and base. In this case, both the cation and the anion of salt undergo hydrolysis. Whether salt solution is acidic, basic or neutral is estimated by comparing the values of Ka (the acid dissociation constant) and Kb (the base dissociation constant). If Ka(cation) > Kb(anion) the solution of the salt is acidic. If Ka(cation) = Kb(anion) the solution of the salt is neutral. If Ka(cation) < Kb(anion) the solution of the salt is basic. For example, if the base NH_3 has a $K_b = 1.6 \times 10^{-5}$ and the acid HClO has a Ka of 3.4×10^{-8}, then the aqueous solution of HClO and NH3 will be basic because the Ka of HClO is less than the Ka of NH_3.

In summary, if the acid is weak, i.e., poorly ionized and the alkali is strong, i.e., highly ionized, the aqueous solution of the salt will have an alkaline reaction as a result of the hydrolysis. In the opposite case, if the base is weak, the salt will have an acidic reaction in an aqueous solution.

Also, it can be decided from the molecular formulas of salts whether their water solutions are basic, acidic or neutral. Salts are made up of a cation (other than H^+) and an anion (other than OH^- or oxide, O^{2-}). The formula of the salt indicates the acid and base that prepare the salt. The cation is derived from the base; the anion is derived from the acid. For example, let us predict whether a water solution of each of the following salts will be acidic, basic or neutral:



(a) $NaCO_3$ is the salt of a strong base, NaOH and a weak acid, H_2CO_3. The Na^+ ion will not hydrolyze but the CO_3^{-2} ion will. A water solution of $NaCO_3$ will be basic. (b) Na_2SO_4 is the salt of a strong base, NaOH and a strong acid, H2SO4. Neither the Na^+ ion nor the SO_4^{-2} ion hydrolyzes. A water solution of Na_2SO_4 will be neutral. (c) NH_4NO_3 is the salt of a weak base, NH_3, and a strong acid, HNO_3.The NH_4^+ ion will hydrolyze but the NO_3^{-1} ion will not. A water solution of NH_4NO_3 will be acidic.

-- predict whether a water solution of each of the following salts will be acidic, basic or neutral:

(a) KNO_3 ; (b) KCl ; (c) Na_3PO_4 ; (d) KBr ; (e) NH_4Br ; (f) K_3PO_4