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Remediating Pre-Service Integrated Science Teachers' Misconceptions About Acid-Base Concepts Using Cognitive Conflict Instructional Strategy

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Abstract: This study explored misconceptions prospective Integrated Science teachers' hold about acid-base concepts and assessed the extent to which these misconceptions can be remediated using cognitive conflict instructional strategy. The framework for the study was hinged on conceptual change theory. One-group pretest-posttest quasi-experimental design was employed for the study. Convenience sampling technique was utilised to obtain 55 participants for the study. A pre-test comprising 20 Multiple-Choice Questions (MCQ) and 5 short answer questions was used to explore participants' misconceptions. The participants were taught using cognitive conflict instructional strategy for a period of 4 weeks. Afterwards, the same test (post-test) was administered to the participants to identify the differences in their academic achievements. The responses of the participants were analysed and catogorised into three levels of conceptions to establish their misconceptions. Analysis of pre-test results revealed that the pre-service Integrated Science teachers' lacked content knowledge and had gross misconceptions about acid-base concepts with an average misconception level of 46.9%. However, a deliberate use of cognitive conflict teaching approach remediated their misconceptions by 36.2% to promote conceptual change. Statistically, there was a significant difference between the mean misconception levels of pre-service Integrated Science teachers' in the pre and post-tests, $t(54)=9.7$, $\rho=.00001$. It is recommended that Chemistry Lecturers should identify students' initial conceptions before teaching and remediate misconceptions about acid-base concepts using cognitive conflict instructional strategy.

Keywords: Acid-Base Concepts, Cognitive Conflict Strategy, Content Knowledge, Misconceptions, Pre-service Integrated Science Teachers (Student Teachers), Remediate

1. Introduction

Acid-base concepts are major concepts in Chemistry that need to be taught comprehensively and coherently, as it is central to a wide range of reactions [1]. Students who understand acid-base concepts would be able to predict and explain the outcomes of a wide range of apparently unrelated reactions. They would be able to connect and integrate seemingly diverse phenomena such as proton-transfer, transition metal coordination complexes, and organic reactions involving nucleophilic and electrophilic attack [2]. Nonetheless, there are difficulties or problems students face as they learn acid-base concepts such as their misconceptions, use of surface level features to identify acids and bases and difficulties with understanding how to use and move flexibly between acid-base models. The ideas students have about acids and bases concepts that are contrary to those accepted by chemical educators constitute misconceptions.

Misconceptions are old and bad ideas, knowledge or conceptions that learners have [3]. Again, misconceptions are beliefs about events, which do not conform to accepted scientific knowledge and are formed when a learner's prior knowledge required for processing new information is not well articulated due to poor bridging which results in confusion and poor reasoning [4]. Some causes of students' misconceptions include lack of information, incorrect strategies being applied during instruction and memorisation of concepts [5]. Misconceptions originate from an inaccurate mental structure that underlines one's ideas of a group of related concepts [6]. Students' background, experiences and the environment in which they have lived including what they perceive, make them coin their own knowledge or conception that may not be accepted by the scientific community. As a result, it makes it difficult for them to learn new concepts. The brain files new data by making connections to existing information. If this new information does not fit the learners' established patterns of thinking, it is refashioned to fit their existing pattern [7]. This is how misconceptions are unknowingly created and reinforces the learners' explanations.

Studies have shown that learners at all levels of education have misconceptions [8-10]. Chemistry includes a number of abstract concepts; therefore, most students have difficulties in understanding and learning these concepts [10]. Students' difficulties in understanding acids and bases concepts are due to not only the abstract and complex nature of the concepts, but also problems understanding the three levels of representations (macroscopic, submicroscopic and symbolic) and deviation of students from scientific conception [1]. A research work conducted among undergraduate students in Chemistry Education in State University of Malang, Indonesia showed that 28.6% of the students had the same pattern of misconception in learning acid-base Chemistry [11]. Similarly, it was identified that students in Kudus city of Indonesia held on to 45 misconceptions about acid-base Chemistry [1]. Again, a study carried out among undergraduate science teacher trainees in a state university in Turkey showed that the teacher trainees had general misconceptions on the concepts of acid-base Chemistry [12] whilst a research work conducted in Ghana among pre-service Chemistry teachers revealed that the teacher trainees had gross misconceptions about atomic orbitals and hybridisation [4]. The initial conception of pre-service Integrated Science teachers about acid-base concepts therefore cannot be undermined and they need to be determined.

Students' prior experiences, background and environment could affect their interpretation of observations and concepts. As a result, they may come to the classroom with some misconceptions toward instructional subjects to be taught [13], which may impede their correct conception of scientific concepts [14]. Furthermore, if the learners' knowledge is erroneous, it would cause further faulty reasoning and wrong formation of concepts [15]. That is, pre-service Integrated Science teachers' misconceptions could disrupt their understanding of learning acid-base concepts. Almost half of the Ghanaian students who entered tertiary teacher education had several misconceptions about chemical phenomena [6]. Notwithstanding, a study which investigated misconceptions student teachers' hold about acid-base concepts revealed that the understanding of the student teachers' was generally disappointing [16]. Most undergraduate students have their own concepts of basic chemistry, which they obtain in high school before they study at the university [11]. This prior chemical knowledge makes students relate to current chemical concepts inaccurately and as a result, creates misleading concepts, as compared to the experts' concepts. This justifies why it is imperative to explore misconceptions that pre-service Integrated Science teachers hold about acid-base concepts. If not so, their formation of new concepts can be inhibited [17] and they may impart the misconceptions to their future students.

To overcome pre-service Integrated Science teachers' misconceptions about acid-base concepts and promote conceptual change, there is the need to diagnose the misconceptions that these student teachers' hold about acid-base concepts and develop an effective instructional strategy that will help them change their conceptual framework [11]. Traditional instructional methods may have a significant effect on students' misconceptions, but they are far from being sufficient in remediation of students' misconceptions that are resistant to change [3, 11]. Based on this premise, alternative teaching strategies that make students active in learning should be used in classroom teaching. Learning process for conceptual change requires a constructivist approach where students can play an active role in reorganising their knowledge [18]. Teaching strategy that accommodate the changes of students' concept is required to remediate misconception [1].

In this study, cognitive conflict instructional strategy was used to remediate student teachers' misconceptions about acid-base concepts. Cognitive conflict strategy is part of psychological theories of conceptual change [19], which makes stability of students misconceptions falter toward scientific conceptions by giving counterpoint, analogies, demonstrations and experiments [18]. The implementation strategy of cognitive conflict in learning is through four stages: identifying students' misconceptions, the creation of conditions of conflict, provision of assistance to equilibrate and reconstruct students understanding [20]. Cognitive conflict strategy destabilises students' confidence in their existing conceptions through contradictory experiences such as discrepant events and then enable students to replace their inaccurate preconceptions with scientifically accepted conceptions [21, 22]. Studies have shown that cognitive conflict instructional strategy reduces student's misconceptions and promotes conceptual change [18, 23]. A study carried out among undergraduate students in Indonesia about effect of cognitive conflict strategy to chemical conceptual change showed a description of the misunderstanding profile of students, where before treatment there was a misunderstanding of concepts, but after exposing students to cognitive conflict treatment, the level of misunderstanding of students decreased [18]. Difference in the pre and post- test mean scores indicated that there was a conceptual change. Based on the results, it was concluded that cognitive conflict strategy had effect on students' conceptual change. Cognitive conflict instructional strategy improves students' critical thinking and academic achievements [23]. Again, cognitive conflict instructional strategy is effective in remediating misconceptions as well as improving academic performance of students [19].

Pre-service Integrated Science teachers' (student teachers) at the University of Education, Winneba undertake acid-bases

Chemistry as a course in the second year of their Integrated Science Education programme. Most of these student teachers' came from the senior high schools and have been introduced to acid-base concepts before. Nevertheless, some of these prospective teachers have completed College of Education and have been teachers before, and have come to the University to improve on their academic and or professional qualifications. The ideas of these prospective teachers' in the concepts of acids and bases could differ from scientific acceptable conceptions and may cause difficulty in their understanding in the new concepts of acids and bases, especially when the new concepts are not aligned with their experiences or conceptual framework. Any misconceptions that pre-service Integrated Science teachers' may have are going to be imparted to their students when they start working after school as teachers and in the process induct further generations of pupils into the familiar misconceptions [16]. This study explored the misconceptions prospective Integrated Science teachers' hold about acid-base concepts and assessed the extent to which these misconceptions could be remediated using cognitive conflict instructional strategy.

The specific research questions addressed in this study were:

1. What misconceptions do pre-service Integrated Science teachers' at University of Education, Winneba hold about acid-base concepts?
2. To what extent will cognitive conflict instructional strategy remediate pre-service Integrated Science teachers' misconceptions' about acid-base concepts?

2. Method

2.1. Research Design and Sampling Technique

One-group pretest-posttest quasi-experimental research design was employed for the study. A total of 55 second year undergraduate Integrated Science Education students (pre-service Integrated Science teachers) in the University of Education, Winneba were used for the study. Convenience sampling technique was used to obtain the participants for the study. The participants (student teachers) registered for an acid-base Chemistry course in the first semester of 2019/2020 academic year and were been handled by the researcher. The participants consisted of students who came to the University directly from the senior high school and those who had completed College of Education with Diploma in Science Education and had been teachers before. This implies that participants used for the study had studied acid-base concepts before especially at the secondary level in elective Chemistry. Notwithstanding, participants who did Science Education at the College of Education, again, studied acid-base concepts.

2.2. Research Instrument

A test comprising 20 multiple-choice items and 5 short answer questions was administered to 55 participants to explore their misconceptions about acid-base concepts. Test items developed by Bradley and Mosimege (1998) for identifying students' misconceptions about acid-base concepts [16] were employed in constructing the test items for this study. The test items used for the study (Appendix A) were developed from topics on acid-base concepts: acid-base models, properties of acids and bases, acid-base strength, pH concepts and molecular representation of acids and bases. The test instrument was made up of two sections, section A and section B. Section A comprised 20 Multiple-Choice Questions (MCQ) whilst section B comprised 5 short answer questions. Each short answer question had sub-questions and carried a total score of 10. The 20 MCQ have five options or alternatives. The options comprised one correct answer and four plausible distractors (incorrect answers). These plausible incorrect answers were considered as misconceptions. All the questions were given equal weight. Although, the weighing does not necessarily give the extent of difficulty experienced by each student teacher in the different concepts of acids and bases, it was done because the study seeks to determine the extent of student teachers' knowledge in the topic. Each correct answer circled or chosen for each question in section A was awarded one mark resulting in a total score of 20. Again, correct written response for each question in section B was awarded one mark. In all, a total mark of 30 was awarded for participants that had all the questions correct. The incorrect answers chosen by participants in the MCQ including wrong responses to short answer questions were considered as misconceptions.

The instrument was reviewed by experts in the Department of Integrated Science Education of the University of Education, Winneba to ensure its face and content validity. Afterwards, it was pilot tested on second year Chemistry Education students at the Department of Chemistry Education of the University of Education, Winneba. The data obtained from the pilot test was statistically analysed to determine the reliability of the test instrument using Spearman-Brown prediction formula. The analysis yielded reliability coefficient of 0.54. Reliability coefficient within the range of 0.5 to 0.6 is taken to depict an agreeable level of reliability for test instruments [24]. Thus, the items of the instrument were deemed reliable.

2.3. Data Collection and Analysis

The participants were pre-informed two days earlier for them to prepare for a test on acid-base concepts before the acid-base chemistry lecture began. On the third day, which was the first meeting day of the acid-base lecture, the pre-test was administered to the participants after the course outline of the acid-base Chemistry was introduced. A period of 50 minutes was given to participants to answer the questions. All the answered questions were collected just after the 50 minutes period. The participants' misconceptions were identified and treated for a period of four weeks using cognitive conflict instructional strategy embedded with demonstrations and experiments on the acid-base concepts. Firstly, conflicting facts about acid-base concepts were introduced to the student teachers' to create a mismatch or dissimilarities of their preconception held about acid-base concepts. Secondly, the participants' were introduced to demonstration and experiments about acid-base concepts to help them equilibrate and reconstruct concepts to overcome the conflict. After the four weeks period of treatment, the same test items (post-test) were administered to the participants' for a period of 50 minutes to evaluate their conceptual understanding of the acid-base concepts taught. That is, to find out whether the misconceptions the participants' had before the treatment have been alleviated. The responses of the participants' were scored out of 30 and analysed using frequency counts, percentages and paired t-test. The levels of conception shown in Table 1 [4] were used to classify the participants' responses into three levels of conceptual understanding. For easy interpretation of the data gathered, the MCQ were numbered from A1 to A20, starting from item 1 whilst short answer questions were numbered from B1 to B5, starting from item 1.

Table 1. *Criteria for classifying levels of conception [4].*

Degree of conceptual Understanding	Criteria for selecting responses
Concepts that demonstrate sound and partially sound understanding	Correct responses
True misconceptions	Responses that are unclear, illogical, irrelevant or incorrect
No response to items	No responses

3. Results

3.1. Analysis of Research Question One

Q1. What misconceptions do pre-service Integrated Science teachers' at University of Education, Winneba hold about acid-base concepts?

Table 2 summarises the responses of the participants' in MCQ. The number of respondents who had the options correct is marked by asterisks (*).

Table 2. *Summary of participants' responses to MQQ (N=55).*

Alternatives (%)						
Item	A	B	C	D	E	No response
A1	5.5	18.2	3.6	65.5*	3.6	3.6
A2	34.5*	7.3	21.8	23.6	7.3	5.5
A3	3.6	16.4	10.9	25.4	36.4*	7.3
A4	12.7	27.2	5.5	41.8*	5.5	7.3
A5	51.0	0	34.5*	10.9	0	3.6
A6	5.5	18.2	41.8*	21.8	1.8	10.9
A7	0	58.2*	40.0	0	0	1.8
A8	52.8*	27.2	12.7	5.5	0	1.8
A9	23.6	3.6	5.5	56.3*	5.5	5.5
A10	40.0*	10.9	18.2	14.5	9.1	7.3
A11	79.9*	0	7.3	0	7.3	5.5
A12	20.0	3.6	38.2	1.8	30.9*	5.5
A13	9.1	18.2	34.5	16.4	18.2*	3.6
A14	16.4	9.1	32.7	21.8*	9.1	10.9
A15	20.0	23.6	36.4*	7.3	3.6	9.1
A16	16.4	27.3	9.1	14.5*	14.5	18.2
A17	12.7	16.4*	41.8	12.7	14.5	1.8
A18	21.8	7.3	20.0	21.8*	18.2	10.9
A19	12.7	20.0	5.5	32.7	21.8*	7.3
A20	34.5	16.4	34.5*	3.6	1.8	9.1

Analysis of results shown in Table 2 indicates that on the average, about 7.0% of the participants did not attempt to answer the MCQ. This clearly indicates that some participants had difficulties answering the MCQ. Most participants (65.5%) intimated that $H_2O_{(l)}$ could act either as a base or acid as a response to A1. However, when participants were asked to indicate the role of $H_2O_{(l)}$ in the reaction: $HCl_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+_{(aq)}$ (item A2), only 34.5% of the participants correctly indicated that $H_2O_{(l)}$ in the above reaction acts as a base towards $HCl_{(aq)}$. Instead, some participants (23.6%) wrongly indicated that $H_2O_{(l)}$ does not act as an acid or a base but act as solvent in the reaction whilst other participants (21.8%) saw $H_2O_{(l)}$ to be a conjugate base of $HCl_{(aq)}$. Again, about half of the participants could not identify $NH_4^+{}_{(aq)}$ and $H_3O^+_{(aq)}$ in the reaction: $NH_{4(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+_{(aq)}$ as Bronsted Lowry acids (item A4). However, about 27.0% of the participants (27.2%) identified $NH_4^+{}_{(aq)}$ and $NH_{3(g)}$ as Bronsted-Lowry acids. In addition, few participants (12.7%) identified $NH_{3(g)}$ and $H_3O^+_{(aq)}$ as Bronsted-Lowry acids in response to question A4. About 27.0% of the participants wrongly indicated that the conjugate base of $HCl_{(aq)}$ is hydroxide ion as a response to question A8. This implies that participants inadequately understood the Bronsted-Lowry acid-base concepts. Furthermore, about 47.0% of the participants failed to identify the most vital objection against Arrhenius acid-base model in the MCQ (item A6). Instead, some participants (21.8%) wrongly intimated that hydrogen ion (H^+) forming hydronium ions (H_3O^+) as a result of the dissociation of acids in aqueous solution can be objected as far as Arrhenius acid-base theory is concerned. This creates an impression that participants barely understood the Arrhenius acid-base theory.

A high proportion of participants could not recognise that $CH_3COO^-_{(aq)}$ and $HCOO^-_{(aq)}$ are not acid-base conjugate pairs (item A13). Instead, about 34.0% of the participants claimed that $H_2O_{(l)}$ and $H_3O^+_{(aq)}$ are not acid-base conjugate pairs whilst few participants (18.2%) indicated that $H_2O_{(l)}$ and $OH^-_{(aq)}$ are not acid-base conjugate pairs in response to question A13. Notwithstanding, about 42.0% of the participants wrongly pointed out that Bronsted-Lowry acid-base model is limited to aqueous solution as in case of Arrhenius model (item A17). Furthermore, about 20.0 to 22.0% of the participants claimed that deficiencies in Bronsted-Lowry acid-base model are not corrected by Lewis acid-base model, and molecules short of electron pair do not act as Lewis acids (item A18). Critical analysis of the participants' responses to questions A1, A2, A4, A5, A6, A8, A13, A17 and A18 clearly showed that participants had misconceptions about concepts of acid-base model and they poorly understood acid-base reactions.

From Table 2, most participants (61.9%) failed to identify acidic solution as a solution that conducts electricity (item A5). Instead, about half of the participants (51.0%) wrongly identified an acidic solution as a solution that turns red litmus paper blue (item A5). The difficulties participants had identifying the properties of acids and bases was also shown in their responses to item A7 since 40.0% of the participants claimed red litmus paper does not change to blue in alkaline solutions. In addition, participants (32.7%) indicated that reaction of acids and bases always results in a neutral product in response to question A19. This assertion was reiterated as part of participants' responses in item A20 since about 35.0% of the participants posited that neutralisation reaction of acids and bases always gives neutral product. Furthermore, few participants (16.4%) claimed that in a neutralisation reaction, when either the acid or the base is weak, neutralisation does not completely take place. About 24.0% of the participants identified $Al(OH)_{3(aq)}$ as diprotic instead of amphiprotic. Critical analysis of participants' responses to item A5, A7, A9, A14 and A19 revealed that participants had misconceptions about acid-base properties especially the effect of acidic or alkaline solution on litmus paper, the electrolytic nature of acids and the concepts of neutralisation.

Analysis of participants' responses to question A15 showed that only about 36.0% of the participants knew that the strength of an acid depends on its ability to transfer proton to a base. On the contrary, some participants (23.6%) wrongly identified acid strength as a measure of the acid to react faster with a base whilst few participants (20.0%) claimed all concentrated acids have high acid strengths (item A15). In addition, 27.0% of the participants wrongly indicated that K_a of weak acid and K_b of it conjugate base are related by the mathematical expression, $KaKw=K_b$ (item A16). Notwithstanding, few participants (16.4%) claimed that in pure water, $[H_3O^+]=[OH^-]=1x10^{-14}$ M in response to question A16. Analysis of participants' responses to item A12 revealed that participants had it difficult to arrange $NH_{3(g)}$, $H_2O_{(l)}$, $NH_4^+{}_{(aq)}$, $CH_3COOH_{(aq)}$ and $HNO_{3(aq)}$ in order of increasing acid strength. Only about 31.0% the participants had the arrangement of these acids in order of increasing strength correct ($NH_{3(g)}$, $H_2O_{(l)}$, $NH_4^+{}_{(aq)}$, $CH_3COOH_{(aq)}$, $HNO_{3(aq)}$). Nevertheless, about 38.0% of the participants wrongly arranged these acids in order increasing strength as $H_2O_{(l)}$, $CH_3COOH_{(aq)}$, $NH_4^+{}_{(aq)}$, $HNO_{3(aq)}$ and $NH_{3(aq)}$. Again, 32.7% of the participants wrongly identified pyridine (C_6H_5N) as a weak acid instead of a weak base in response to item A14. The number of participants (67.3%) who wrongly identified $HSO_4^-{}_{(aq)}$ as a weak acid was greater than the number of participants (21.8%) who correctly identity $HSO_4^-{}_{(aq)}$ as a weak acid. Critical analysis of participants' responses to question A12, A15 and A16 clearly showed that participants had misconceptions about the concepts of acid-base strength.

Participants had in mind that a solution with pH above 7 is a basic solution whilst a solution with pH below 7 is acidic as about 80.0% of the participants intimated that a solution with a pH of 3 is more acidic than solutions with pH 4, 6, 7 and 9 respectively for question A11. In addition, 40.0% of the participants correctly revealed that both $NaOH_{(aq)}$ and $Na_2CO_{3(aq)}$ have a pH above 7 (item A10). On the contrary, a little above half of the participants (52.0%) had question A10 incorrect, among them were those (18.2%) who revealed that NaCl(s) has no pH whatsoever and participants (14.5%) who indicated that the pH of $HCl_{(aq)}$ is the highest as compared to the pH of $NaOH_{(aq)}$, $Na_2CO_{3(aq)}$, $NH_4Cl_{(aq)}$ and $NaCl_{(aq)}$ solutions. This implies that even though, it appeared participants knew that pH of a solution above 7 and below 7 signifies basicity and acidity respectively, they had difficulty in the application of pH concept.

Table 3 presents participants' levels of understanding about acid-base concepts in the pre-test. As stated elsewhere, the MCQ were numbered from A1 to A20 whilst the short answer questions were numbered from B1 to B5.

Table 3. *Levels of student teachers' understanding about acid-base concepts in pre-test (N=55).*

Item	Sound understanding	Misconception	No response
A1	36 (65.5%)	17 (30.9%)	2 (3.6%)
A2	19 (34.6%)	34 (61.8%)	2 (3.6%)
A3	20 (36.4%)	31 (56.4%)	4 (7.2%)
A4	23 (41.8%)	28 (51.0%)	4 (7.2%)
A5	19 (34.6%)	34 (61.8%)	2 (3.6%)
A6	23 (41.8%0)	26 (47.3%)	6 (10.9%)
A7	32 (58.2%)	22 (40.0%)	1 (1.8%)
A8	29 (52.7%)	25 (45.5%)	1 (1.8%)
A9	31 (56.4%)	21 (38.1%)	3 (5.5%)
A10	22 (40.0%)	29 (52.7%)	4 (7.3%)
A11	44 (80.0%)	8 (14.5%)	3 (5.5%)
A12	17 (30.9%)	35 (63.6%)	3 (5.5%)
A13	8 (14.5%)	45 (81.8%)	2 (3.6%)
A14	12 (21.8%)	37 (67.3%)	6 (10.9%)
A15	20 (36.4%)	31 (56.4%)	4 (7.2%)
A16	8 (14.5%)	37 (67.3%)	10 (18.2%)
A17	9 (16.4%)	45 (81.8%)	1 (1.8%)
A18	12 (21.8%)	37 (67.3%)	6 (10.9%)
A19	12 (21.8%)	39 (71.0%)	4 (7.2%)
A20	19 (34.5%)	31 (56.4%)	5 (9.1%)
B1a	8 (14.5%)	15 (27.3%)	32 (58.2%)
B1b	7 (12.7%).	16 (29.0%)	32 (58.2%)
B2a	5 (9.1%)	23 (41.8%)	27 (49.1%)
B2b	10 (18.1%)	20 (36.4%)	25 (45.5%)
B2c	5 (9.1%)	15 (27.3%)	35 (63.6%)
B3a	1 (1.8%)	15 (27.3%)	39 (70.9%)
B3b	2 (3.6%)	10 (18.1%)	43 (78.3%)
B4a	4 (7.2%)	21 (38.2%)	30 (54.5%)
B4b	10 (18.1%)	22 (40.0%)	23 (41.8%)
B5	0	6 (10.9%)	49 (89.1%)

From Table 3, participants' misconceptions about acid-base concepts on the average was 46.9%. On the average, about 61.0% of the participants did not attempt to answer the short answer questions. This gives an indication that a good number of the participants did not properly understand acid-base concepts. Participants (27.3%) who attempted question B1a wrongly wrote that Arrhenius would not have considered a solution of $CH_3COOH_{(aq)}$ to be acidic whilst few participants (14.5%) said otherwise. Besides, participants who had it correct could not give an explanation to why Arrhenius would consider a solution of $CH_3COOH_{(aq)}$ to be acidic. This implies that the participants lacked content knowledge about Arrhenius acid-base concepts. Furthermore, about 42.0% of the participants could not write a balanced chemical equation for the reaction between acetic acid and water. Furthermore, participants (36.4%) could not write a balanced chemical equation for the reaction between ammonia and water. As a result, participants could not identify the acid-base conjugate pairs in these reactions as asked in B2. Again, the few participants who attempted B3 and B4 had them wrong. Thus, participants could not compare the base strength of $Cl^{-}_{(aq)}$ and $CH_3COO^{-}_{(aq)}$. Participants (27.3%) wrongly posited that the base strength of $Cl^{-}_{(aq)}$ is greater than the base strength of $CH_3COO^{-}_{(aq)}$ in response to B3a. Furthermore, some participants (38.2%) claimed that a concentrated acid is necessarily a strong acid in response to B4a. Again, respondents (40.0%) who agreed that concentrated acid is not necessarily a strong acid could not give an explanation to that. Clearly, participants' responses to question B3a and B4 showed that participants lacked content knowledge about acid-base strength and the concepts of weak and strong acids.

From Table 3, about 78.0 – 89.0% of the participants did not attempt questions concerning pH concepts and molecular representation of acids and bases as posed in B3b and B5. The few participants (10.9%) who attempted question B5 could not draw a picture of aqueous solution of $HCl_{(aq)}$ at the molecular level. Furthermore, only about 35.0% of the participant identified the pH of distilled or deionized water to be 7 (item 20). However, participants could not comment on the pH of $NaCl_{(aq)}$ and $CH_3OONa_{(aq)}$ solutions and obviously did not attempt to give explanation to why the pH of $CH_3COONa_{(aq)}$ is greater than $NaCl_{(aq)}$, even though, they are both salt solutions (item B3b). Few participants (18.1%) claimed that both $NaCl_{(aq)}$ and $CH_3COONa_{(aq)}$ have equal pH of 7 in response to B3b.

3.2. Analysis of Research Question Two

Q2. To what extent will cognitive conflict instructional strategy remediate pre-service Integrated Science teachers' misconceptions' about acid-base concepts?

Table 4 presents student teachers' levels of understanding about acid-base concepts in the post-test.

Analysis of results presented in Table 4 shows that almost all the participants answered the questions in the post-test. On the average, only 2.2 and 7.8% of the participants did not answer the MCQ and the short answer questions respectively.

Again, most participants had questions in the post-test correct. This implies that student teachers' content knowledge in acid-base concepts improved after they have been taught using cognitive conflict instructional strategy. Participants' conception shifted from misconception to sound understanding. That is, cognitive conflict instructional strategy improved student teachers' conceptual understanding about acid-base concepts. Participants' misconception level in the post-test on the average was 10.7%.

Table 4. *Levels of student teachers' understanding about acid-base concepts in post-test (N=55).*

Item	Sound understanding	Misconception	No response
A1	51 (92.7%)	4 (7.3%)	0
A2	45 (81.8%)	10 (18.2%)	0
A3	49 (89.1%)	6 (10.9%)	0
A4	41 (74.5%)	14 (25.5%)	0
A5	49 (89.1%)	6 (10.9%)	0
A6	46 (83.6%)	9 (16.4%)	0
A7	44 (80.0%)	11 (20.0%)	0
A8	41 (74.5%)	14 (25.5%)	0
A9	47 (85.5%)	8 (14.5%)	0
A10	54 (98.2%)	1 (1.8%)	0
A11	54 (98.2%)	1 (1.8%)	0
A12	47 (85.5%)	8 (14.4%)	0
A13	44 (80.0%)	11 (20.0%)	0
A14	50 (90.9%)	4 (7.3%)	1 (1.8%)
A15	45 (81.8%)	10 (18.2%)	0
A16	48 (87.3%)	5 (9.1%)	2 (3.6%)
A17	51 (92.7%)	4 (7.3%)	0
A18	46 (83.6%)	8 (14.5%)	1 (1.8%)
A19	50 (90.9%)	5 (9.1%)	0
A20	50 (90.9%)	4 (7.3%)	1 (1.8%)
B1a	51 (92.7%)	2 (3.6%)	2 (3.6%)
B1b	42 (76.3%)	11 (20.0%)	2 (3.6%)
B2a	51 (92.7%)	1 (1.8%)	3 (5.5%)
B2b	47 (85.4%)	5 (9.1%)	3 (5.5%)
B2c	51 (92.7%)	1 (1.8%)	3 (5.5%)
B3a	46 (83.6%)	4 (7.3%)	5 (9.1%)
B3b	47 (85.5%)	2 (3.6%)	6 (10.9%)
B4a	44 (80.0%)	5 (9.1%)	6 (10.9%)
B4b	48 (87.3%)	2 (3.6%)	5 (9.1%)
B5	45 (81.8%)	2 (3.6%)	8 (14.5%)

Table 5 presents the paired t-test results on the mean misconception levels of students teachers' in pre and post-tests.

Table 5. *T-test analysis of student teachers' mean misconception levels (%) in pre and post-tests (N=55).*

Misconception level (%) Variable	Max	Mean÷SD	Min	t-value	ρ-value
Pre-test	81.80	46.97±19.11	10.90	9.7155	.00001
Post-test	25.50	10.78±7.12	1.80		

From Table 5, the mean misconception level (46.9%) of participants' in the pre-test was significantly higher than the mean misconception level (10.7%) recorded in the post-test. In addition, the pre-test recorded a significant higher maximum misconception level (81.8%) than the maximum misconception level (25.5%) recorded in the post-test. Again, the minimum level of misconception recorded in the pre-test was higher than the minimum misconception level recorded in the post-test. On the average, the misconception level was reduced from 46.9% to 10.7% with a difference mean misconception level of 36.2%. This implies that students' teachers' misconception about acid-base concepts was reduced after they have been exposed to cognitive conflict treatment. The paired t-test results showed that statistically, there was a significant difference between the mean misconception levels of student teachers' in the pre and post-tests, t (54)=9.7, ρ=.00001. The analysis of results in Table 5 shows that cognitive conflict instructional strategy had a positive effect on the conceptual understanding of the student teachers'. Student teachers' misconceptions about acid-base concepts was about 36.2% remediated after they have been taught using cognitive conflict instructional strategy.

4. Discussion

A critical analysis of participants' responses to both multiple choice and short answer questions in pre-test revealed that participants lacked content knowledge in acid-base concepts. On the average, about 7.0 and 61.0% of the participants did not attempt to answer the multiple-choice and short answer questions respectively in the pre-test. The few participants who attempted answering the short answer questions in the pre-test had most of them wrong. The fact that most student teachers' did not attempt to answer the questions and those who answered the short answer questions in the pre-test had most of them wrong implies that the student teachers' conceptual understanding prior to the learning of acid-base concepts was low. This confirms the assertion that Chemistry includes a number of abstract concepts; therefore, most students have difficulties in understanding and learning these concepts [10]. Participants' difficulties in understanding acid-base concepts was not only due to the abstract and complex nature of the concepts but also problems understanding the three levels of representations (macroscopic, submicroscopic and symbolic) and deviation from scientific conception [1]. Thus, the lack of understanding of pre-service Integrated Science teachers' in acid-base concepts made it difficult for them to deduce conjugate acid-base pairs, write equations for acid-base reactions and explain acid-base concepts [1]. The finding of this study is at par with the study carried out in a university and a college of education, which revealed that the understanding of student teachers' in acid-base concepts was generally disappointing [16].

The study revealed that participants' (42.0%) could not write a balanced chemical equation for the reaction between $CH_3COOH_{(aq)}$ and $H_2O_{(l)}$ and between $NH_{3(g)}$ and $H_2O_{(l)}$. As a result, participants (27.3%) could not identify the acid-base conjugate pairs in these reactions as requested in question B2 in the pre-test. Participants wrote a balanced chemical equation between $CH_3COOH_{(aq)}$ and $H_2O_{(l)}$ as $CH_3COOH + H_2O \rightarrow CH_3COOO + H_3O^+$ and a reaction between $NH_{3(g)}$ and $H_2O_{(l)}$ as $NH_3^+\ H_2O \rightarrow 2NH + H_2$ in response to question B2. In addition, most participants (62.0%) did not know that $H_2O_{(l)}$ acts as a base in the reaction: $NH_{4(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+_{(aq)}$. Instead, participants intimated that $H_2O_{(l)}$ in the reaction act as a mere solvent and not as a base. Again, about half of the participants did not know that $NH_4^+{}_{(aq)}$ and $H_3O^+{}_{(aq)}$ in the reaction: $NH_4^+{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+{}_{(aq)}$ are Bronsted-Lowry acids (item A4). Furthermore, participants (27.2%) claimed $NH_4^+{}_{(aq)}$ and $NH_{3(g)}$ are Bronsted-Lowry acids. In addition, participants (82%) failed to recognise that $CH_3COO^-{}_{(aq)}$ and $HCOO^-{}_{(aq)}$ are not acid-base conjugate pairs (item A13). This gives an indication that student teachers' lacked content knowledge and had misconceptions in Bronsted-Lowry acid-base theory prior to the learning of the acid-base concepts.

On the average, about 49.0% the student teachers' had misconceptions about acid-base model. Comparatively, the finding of this study is different from a research work conducted in Tai and Indonesia, which showed that the misconceptions that Thai and Indonesian grade 12 students had about acid-base concepts were 26.6 and 23.7% respectively [25]. Similarly, this study confirms the assertion that one of the Chemistry concepts that students found most difficult and for which they exhibited alternative conceptions was acid–base model [26]. The present study also reported that participants could not explain why Arrhenius would have considered a solution containing $CH_3COOH_{(aq)}$ to be acidic (item B1). Moreover, some participants (21.8%) objected to the formation of hydronium ions from hydrogen ions as a result of dissociation of acids in aqueous solution so far as Arrhenius acid-base theory is concerned. This implies that student teachers' lacked content knowledge and had misconceptions about Arrhenius acid-base theory. The finding of this study confirms the assertion that one of the acid-base concepts, which appeared to be difficult to students, and for which they exhibited the alternative conception was acid-base model [26].

The study revealed that participants could not compare the base strength of $Cl^-{}_{(aq)}$ and $CH_3COO^-{}_{(aq)}$. This is because participants wrongly intimated that the base strength of $Cl^-{}_{(aq)}$ was greater than the base strength of $CH_3COO^-{}_{(aq)}$ in response to question B3a. Some participants (38.2%) claimed a concentrated acid was necessarily a strong acid. Furthermore, participants had difficulty arranging NH_3, $H_2O_{(l)}$, $NH_4^+{}_{(aq)}$, $CH_3COOH_{(aq)}$ and $HNO_{3(aq)}$ in order of increasing acid strength. Participants (38.2%) wrongly arranged these compounds in increasing order of acid strength as $H_2O_{(l)}$, $CH_3COOH_{(aq)}$, $NH_4^+{}_{(aq)}$, $HNO_{3(aq)}$ and $NH_{3(g)}$ (item A12). Again, the definition of acid strength was not well understood by participants as a result they intimated that acid strength was a measure of the acid to react faster with a base whilst some participants (20.0%) claimed all concentrated acids have high acid strengths in response to question A15. Participants wrongly expressed the relation between K_a of weak acid and K_b of it conjugate base as $K_aK_w=K_b$ in response to question A16 and identified pyridine (C_6H_5N) as a weak acid instead of a weak base (item A14). This implies that student teachers' had misconceptions in the concepts of acid-base strength. Participants could not comment on the pH of $NaCl_{(s)}$ and $CH_3OONa_{(aq)}$ solutions and obviously did not attempt giving explanation to why the pH of $CH_3COONa_{(aq)}$ is greater than $NaCl_{(aq)}$, even though, they are both salt solution. Notwithstanding, some participants (18.2%) claimed that both $NaCl_{(aq)}$ and $CH_3COONa_{(aq)}$ solutions had equal pH of 7 in response to B3b. Again, participants claimed that $NaCl_{(aq)}$ had no pH whatsoever and that the pH of $HCl_{(aq)}$ was highest as compared to the pH of $NaOH_{(aq)}$, $Na_2CO_{3(aq)}$, $NH_4Cl_{(aq)}$ and $NaCl_{(aq)}$ solutions in response to question A10. This implies that student teachers' lacked content knowledge and had misconceptions about pH concepts. Participants had difficulty drawing a picture of an aqueous solution of $HCl_{(aq)}$ at the molecular level, and showing the molecules and ions present (B5). Participants, who answered B5, drew a beaker with dots inside and did not show the chloride and hydrogen ions as the question demands. This indicates that student teachers' poorly understood the concepts of acids and bases at the molecular level. Again, this study is at par with a study carried out at in a university and a college of education, which revealed that student teachers' could not offer a complete satisfactory answer to the representation of acids and bases at the molecular level [16].

Critical analysis of participants' responses to question A5, A7, A9, A14 and A19 revealed that participants had misconceptions about acid-base properties. About half of the participants (51.0%) wrongly identified acidic solution as a solution that turns red litmus paper blue (item A5). Again, participants (32.7%) indicated that reaction of acids and bases always results in a neutral product in response to question A19. This assertion was reiterated as about 35.0% of the participants posited that neutralisation reaction of acids and bases always gives neutral product in response to item A20. This implies that student teachers' had misconceptions about neutralisation concepts and thought all salts are neutral. This finding is similar to the finding of a study conducted in State University in Turkey, which revealed that 35.0% of undergraduate science teacher trainees wrote that neutralisation of acid and base always gives a neutral product [12]. Again, the finding in this study is similar to a study conducted to explore students understanding in neutralisation concept, which revealed that most of the students misunderstood the concepts of neutralisation and neutrality, and that students had misconception about neutralisation concepts because they failed to realise the central role of water in neutralisation reactions [27, 28]. Furthermore, most participants (65.5%) failed to identify acidic solution as a solution that conducts electricity (A5). Participants' responses to question A 5, A7, A9, A14 and A19 showed that, they had misconceptions in the concepts of acid-base properties.

The study revealed that participants had gross misconceptions about acid-base concepts. On the average, about 46.9% of the participants had misconceptions in acid-base concepts (Table 3). This implies that the student teachers' had misleading concepts, which could have made them relate to the acid-base concepts inaccurately. The student teachers' had misconceptions about acid-base concepts because the understanding of acid–base concepts involves the comprehension of many areas of introductory Chemistry, including chemical equilibrium, chemical reactions, stoichiometry, the nature of matter, and solutions [29]. The finding of this study confirms the assertion that most undergraduate students have their own concepts of basic Chemistry, which they obtain from high school before they study at the university [11] and that learners at all levels have misconceptions [10]. Furthermore, the finding of the current study is in consonance with the findings of studies carried out in other countries, even though different assessment tools were used. For instance, a research work carried out in Thai and Indonesia showed that Thai and Indonesian grade 12 students had misconceptions about acid-base concepts [25]. Again, the finding of a study carried out to map the misconception pattern of Chemistry prospective teachers showed that 28.6% of the students had the same pattern of misconception [11]. Similarly, it has been reported that almost half of the Ghanaian students who entered tertiary teacher education had several misconceptions about chemical phenomena [6].

The study revealed that most participants who answered the post-test questions had them correct. This implies that student teachers' content knowledge in acid-base concepts improved after treatment. Participants' conception shifted from misconception to sound understanding after treatment. On the average, participants' misconception level reduced from 46.9% (pre-test) to 10.7% (post-test) after they have been exposed to cognitive conflict treatment. That is, cognitive conflict instructional strategy remediated students' misconceptions about acid-base concepts by 36.2% to promote conceptual change. Statistically, there was a significant difference between the mean misconception levels of participants in the pre and post-tests, $t\ (54)=9.7$, $\rho=.00001$. This clearly indicates that cognitive conflict instructional strategy greatly remediated student teachers' misconceptions about acid-base concepts and improved their conceptual understanding. This confirms the assertion that cognitive conflict instructional strategy improves students' critical thinking and academic achievements [23]. Cognitive conflict instructional strategy is effective in remediating misconceptions as well as improving academic performance [19]. Again, the finding of this study is at par with the finding of a study, which showed a description of the misunderstanding profile of students, where before treatment there was a misunderstanding of the concept, but after treatment with cognitive conflict strategy, the level of misunderstanding of students decreased [18]. It was therefore revealed that cognitive conflict instructional strategy has positive effect on students' conceptual changes [18]. The cognitive conflict instructional strategy used as an intervention in this study to remediate student teachers misconceptions, firstly, destabilised the student teachers' confidence in their existing conceptions through contradictory experiences and secondly, enabled them to replace their inaccurate preconceptions with scientifically accepted conceptions [21, 22].

5. Findings

On the averagely, about 46.9% of the participants had misconceptions in acid-base concepts. The misconceptions diagnosed are summarised below:

a. Almost half of the participants (51.0%) intimated that acidic solution turns red litmus paper blue

b. About 42.0% of the participants indicated that Bronsted-Lowry acid-base model is limited to aqueous solution as in case of Arrhenius acid-base model.
c. About 24.0% of the participants claimed that water in the reaction: $NH_4^+{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+{}_{(aq)}$ does not act as acid or a base but merely a solvent in the reaction: $NH_4^+{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+{}_{(aq)}$
d. About 27.0% of the participants pointed out that $NH_4^+{}_{(aq)}$ and $NH_{3(g)}$ are Bronsted-Lowry acids in the reaction: $NH_4^+{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+{}_{(aq)}$
e. About 22.0% of the participants intimated that water in the reaction: $NH_4^+{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+{}_{(aq)}$ is a conjugate base of $HCl_{(aq)}$.
f. Participants (27.0%) revealed that the conjugate base of $HCl_{(aq)}$ is hydroxide ion.
g. About 20.0 – 22.0% of the participants indicated that deficiencies in Bronsted-Lowry acid-base model are not corrected by Lewis acid-base model and molecules short of electron pair do not act as Lewis acids.
h. About 35.0% of the participants indicated that $H_2O_{(l)}$ and $H_3O^+{}_{(aq)}$ are not acid-base conjugate pairs.
i. About 38.0% of the participants arranged $NH_{3(g)}$, $H_2O_{(aq)}$, $NH_4^+{}_{(aq)}$, $CH_3COOH_{(aq)}$ and $HNO_{3(aq)}$ in order of increasing acid strength as $H_2O_{(l)}$, $CH_3COOH_{(aq)}$, $NH_4^+{}_{(aq)}$, $HNO_{3(aq)}$ and $NH_{3(g)}$
j. About 35.0% of the participants said that neutralisation reaction of acids and bases always gives a neutral product.
k. Participants (27.0%) intimated that the base strength of $Cl^-{}_{(aq)}$ is greater than the base strength of $CH_3COO^-{}_{(aq)}$
l. Participants (38.3%) indicated that a concentrated acid is necessarily a strong acid.
m. Participants (20.0%) said that all concentrated acids have high acid strengths.
n. Participants identified $Al(OH)_{3(aq)}$ as a diprotic acid instead of amphiprotic acid.
o. Participants (32.0%) identified pyridine as a weak acid
p. Participants (27.0%) posited that the K_a of a weak acid and the K_b of it conjugate base are related by the mathematical expression, $K_a.K_w=K_b$
q. About 23.0% of the participants defined acid strength as a measure of an acid to react faster with a base.

Student teachers' content knowledge and conceptual understanding about acid-base concepts improved after they were exposed to cognitive conflict instructional strategy. Cognitive conflict instructional strategy was effective in remediating student teachers' misconception about acid-base concepts by 36.2%.

6. Implications

The study revealed that pre-service Integrated Science teachers' understanding prior to the learning of acid-base concepts was low. Critical analysis of pre-test results showed that the prospective Integrated Science teachers' lacked content knowledge and had misconceptions about acid-base concepts with an average misconception level of 46.9%. The gross misconceptions that the pre-service Integrated Science teachers hold could have inhibited the formation of the new acid-base concepts and certainly pass the misconceptions to their future students. However, a deliberate use of cognitive conflict teaching approach remediated their misconceptions about acid-base concepts by 36.2% and improved their conceptual understanding.

In light of the findings of the study and their educational implications, the following recommendations are made.

1. Chemistry Lecturers must first diagnose the initial conception of students about topics they intend to teach, as this will enable them fish out the misconceptions students hold and help them to plan properly and effectively on how to deliver their lessons.
2. Chemistry Lecturers should utilise cognitive conflict instructional strategy to teach and remediate students' misconceptions about acid-base concepts to promote conceptual change.
3. The study should be replicated using cognitive conflict instructional strategy on other difficult Chemistry concepts such as chemical thermochemistry, chemical kinetics, chemical equilibrium etc. This would provide a basis for greater generalisation of the conclusion drawn from the findings of the study.

Appendix

Test questions

Instructions. The questions consist of two sections; section A and B. Section A consists of multiple-choice questions whilst section B consist of short answer questions. Choose the most appropriate answer (option) from the list of options provided for question 1 to 20 in section A and write your answer for the questions in section B. Questions in section A carries 20 marks whilst section B carries 10 marks. Answer all questions in the answer booklet provided.

Section A (20 marks)

1. Which of the following substances can act either as an acid or as a base?
   A. $HCl_{(aq)}$
   B. $NH_4Cl_{(s)}$
   C. $HCN_{(aq)}$
   D. $H_2O_{(l)}$
   E. $H_{2(g)}$

2. Which statement regarding the reaction between hydrogen chloride and water is correct?

$$HCl_{(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

A. Water acts as a base towards $HCl_{(aq)}$
B. Water molecule is a proton donor to the chloride ion
C. Water is a conjugate base of the $HCl_{(aq)}$
D. Water does not act as an acid or base but merely a solvent in this reaction.
E. The water molecule is an electron acceptor.

3. Which statement is not correct?
A. Acids may be positive ions, neutral molecules or negative ions.
B. An acid-base reaction consists of the transfer of a proton from an acid to a base
C. Bases may be negative ions, neutral molecules or positive ions.
D. The strength of an acid depends on it tendency to donate protons
E. Aqueous solutions of salts are neutral.

4. In the equilibrium reaction:

$$NH_4^+{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3(g)} + H_3O^+_{(aq)}$$

The Bronsted-Lowry acids are
A. $NH_{3(g)}$ and $H_3O^+_{(aq)}$
B. $NH_4^+{}_{(aq)}$ and $NH_{3(g)}$
C. $H_2O_{(l)}$ and $H_3O^+_{(aq)}$
D. $NH_4^+{}_{(aq)}$ and $H_3O^+_{(aq)}$
E. $H_2O_{(l)}$ and $H_3O^+_{(aq)}$

5. Which one of the following is a property of an acid solution?
A. Solution turns red litmus paper blue
B. Solution tastes sweet
C. Solution is a good conductor of electricity
D. Solution has a hydrogen ion concentration of 10^{-3}M.
E. Solution is slippery

6. Arrhenius theory about acids maintains that acids in solution dissociate to form hydrogen ions (H^+). An important objection against this is:
A. The number of acids would be very large
B. Hydrogen ions would not react chemically
C. Hydrogen ions cannot occur freely in an aqueous solution
D. Hydrogen ions would form hydronium ion.
E. The number of acids would be very small.

7. Which of the following is not a property of bases?
A. Aqueous solutions are slippery
B. Change colour of blue litmus paper to red
C. Change colour of red litmus paper to blue.
D. Taste bitter
E. React with acids to form salts.

8. The conjugate base of hydrogen chloride is
A. The chloride ion
B. The hydroxyl ion
C. Water
D. Potassium hydroxide
E. Ammonia

9. Hydroxides such as $Al(OH)_3$ which can react with strong acids or strong bases are
A. Diprotic
B. Dibasic
C. Binary

D. Amphiprotic
E. Donors

10. Five beakers contain the following solutions separately of equal concentration: $NaOH_{(aq)}$, $Na_2CO_{3(aq)}$, $HCl_{(aq)}$, $NH_4Cl_{(aq)}$ and $NaCl_{(aq)}$. If the pH of those solutions is tested with universal indicator or pH meter, it is will be found that:
A. Both the $NaOH_{(aq)}$ and $Na_2CO_{3(aq)}$ have a pH above 7
B. The $NH_4Cl_{(aq)}$ has the lowest pH value
C. The $NaCl_{(aq)}$ has no pH whatsoever
D. The $HCl_{(aq)}$ has the biggest pH above 7
E. Only the $HCl_{(aq)}$ and $NaOH_{(aq)}$ register pH values.

11. A student has been given a number of aqueous solutions and he has determined the pH of each, using the pH meter. Here are his results:

solution	**A**	**B**	**C**	**D**	**E**
pH	3	4	6	7	9

Which solution is most acidic?

12. The following substances have been arranged in an increasing order of acid strength. Which order is correct?
A. Nitric acid, acetic acid, water, ammonia, ammonium ion
B. Ammonium ion, water, acetic acid, ammonia, Nitric acid
C. Water, acetic acid, ammonium ion, nitric acid, ammonia
D. Acetic acid, water, nitric acid, ammonia, ammonium ion
E. Ammonia, water, ammonium ion, acetic acid, nitric acid.

13. Which of the following statement is not correct?
A. $HNO_{3(aq)}$ and $NO_3^-{}_{(aq)}$ are acid-base conjugate pairs
B. $H_2O_{(l)}$ and $OH^-{}_{(aq)}$ are acid-base conjugate pairs
C. $H_2O_{(l)}$ and $H_3O^+{}_{(aq)}$ are acid-base conjugate pairs
D. $H_2S_{(g)}$ and $SH^-{}_{(aq)}$ are acid-base conjugate pairs
E. $CH_3COO^-{}_{(aq)}$ and $HCOO^-{}_{(aq)}$ are acid-base conjugate pairs.

14. Which statement is correct?
A. Phosphine (PH_3) is a weak acid
B. Hydrazine (N_2H_4) is a weak acid
C. Pyridine (C_6H_5N) is a weak acid
D. HSO_4^- is a weak acid
E. Sodium citrate is a weak acid

15. Which statement concerning strength of an acid is correct?
A. All concentrated acids have high acid strength.
B. Strength of an acid is measured by tendency of the acid to react faster with a base.
C. Strength of acid depends on its ability to transfer proton to a base.
D. Acids with high temperature always have high acid strength.
E. Acids with high strengths have pH of 7.

16. Choose the correct one
A. In pure water, $[H_3O^+]=[OH^-]=1x10^{-14}M$
B. K_a of a weak acid and K_b of its conjugate base is given by the expression, $K_a.K_w=K_b$
C. The pH of NH_3 ($7x10^{-3}M$) solution is 10.54 [pKa=4.74]
D. The K_a of a weak acid is a measure of its acid strength
E. CaO is an Arrhenius base

17. Which statement is correct?
A. Most Bronsted-Lowry acid-base reactions are equilibrium reactions.
B. In Bronsted-Lowry acid-base reaction, release of OH^- ions in water is not necessary to qualify a base.
C. Bronsted-Lowry acid-base model is limited to aqueous solution as in case of Arrhenius model.
D. Electron pair acceptors are acids and sometimes bases according to Lewis theory.
E. HCOOH and H_2COO are acid base conjugate pairs.

18. All the following statements are correct, except;
    A. Deficiencies in Bronsted-Lowry acid-base model are corrected by Lewis acid-base model.
    B. Molecules having lone pair of electrons act as Lewis bases.
    C. Molecules short of an electron pair act as Lewis acids
    D. Transfer of proton is accompanied by the loss of or donation of electron-pair in both Bronsted-Lowry and Lewis acid-base reactions.
    E. Arrhenius acid dissolves in water to produce H^+.

19. Which of the following statement concerning acids and bases is correct?
    A. Only acids conduct electricity, bases do not
    B. Strong acids contain more hydrogen bonds than weak acids
    C. Strong acids react with strong bases and weak acids react with weak bases or vice versa
    D. Reaction of acids and bases always result in neutral solution
    E. A concentrated acid is corrosive

20. Which of the following statement is scientifically correct?
    A. Neutralisation reaction of acid and base always gives a neutral product
    B. In a neutralisation reaction, when one reactant (acid or base) is weak, the neutralisation does not completely take place.
    C. pH of a distilled or de-ionized water is always equal to 7
    D. A solution of 10^{-8} M has a pH of 8
    E. A solution of 0.1 M H_2SO_4 has a pOH of 13.30

Section B: Short answer questions (10 marks)

1. Ethanoic acid (CH_3COOH) is dissolved in water.
   A. Would Arrhenius have considered the resulting solution to be acidic? [1 mark]
   B. Explain [1 mark]

2. Write an equation for the chemical reaction that occurs when
   A. Acetic acid reacts with water [1 mark]
   B. Ammonia reacts with water [1 mark]
   C. Identify the acid-base conjugate pairs for the above reactions. [1 mark]

3. HCl is described as a strong acid, while ethanoic acid is described as a weak acid in an aqueous solution.
   A. What can be said about the base strength of $Cl^-_{(aq)}$ and $CH_3COO^-_{(aq)}$? [1 mark]
   B. What can be said about the pH of two salt solutions:
   $NaCl_{(aq)}$ and $CH_3COONa_{(aq)}$? Explain [1 mark]

4. A. Is a concentrated acid necessarily always a strong acid?
   B. Explain [1mark]

5. Draw your picture of an aqueous solution of hydrochloric acid at the molecular level and show the molecules and ions present. [1 marks]

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