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High school chemistry students' alternative conceptions of H_2O, OH-, and H+ in balancing redox reactions

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Abstract

There are a number of research works into alternative conceptions for the purposes of identifying, categorising, and designing instructional approaches to help address them. The current study sought to find out high school students' alternative conceptions in the introduction of H_2O, H^+, and OH^- in oxidation-reduction reactions in acidic and basic media when balancing the chemical equations using the ion-electron method. Two of the 20 two-tier diagnostic test items were used to survey the conceptions of 213 students in balancing oxidation-reduction reactions. The 213 students were randomly selected from three of the seven elective science schools in three districts assemblies of the Ashanti Region of Ghana. The findings from the descriptive quantitative data analysis show that the students have conceptual difficulties in the concept. Qualitatively, the identified students' alternative conceptions included introduction of H_2O molecules in acidic medium is to dilute the system; H^+ ions in a basic medium is to neutralise the OH^- ions of the base; and OH^- ions is to make the system basic. It is therefore recommended that the chemical instructional designers should design a pedagogical content knowledge for the teaching and learning of balancing oxidation-reduction reactions.

Keywords: Acidic medium; Alternative conceptions; Basic medium; Balancing; Oxidation-reduction reactions

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1. Introduction

Oxidation-reduction (redox) reactions are one of the reactions given prominence in Chemistry Education from high school through to the university level. There are various aspects to the concept of oxidation-reduction reactions and the planners of the Ghanaian Chemistry Curriculum for senior high school (SHS) have identified some of the aspects as: oxidation-reduction processes, types of oxidation-reduction reactions, half reactions, reactivity of metals and halogens, oxidising and reducing agents, balancing oxidation-reduction reactions, and oxidation-reduction titrations. The rest are electrochemistry, standard electropotential, electrochemical cells, electrolytic cells, electroplating, and corrosion of metals (Ministry of Education [MOE], 2010; 2012). Chemistry students' conception in the various aspects of oxidation-reduction reactions is important at the high school level as experiences in the concept are needed for pursuing courses relating to oxidation-reduction reactions at the tertiary level.

The current study was delimited to the aspect of balancing of oxidation-reduction reactions; and specifically the introduction of species H_2O, H^+, and OH^- in the ionic equation. There are two approaches to balancing oxidation-reduction reactions. These are oxidation number method and half reaction method (Romero, 2009). The half reaction method is also referred to as the ion-electron method for reactions occurring in both acidic and basic media (Chang, 2003). The H_2O, H^+, and OH^- species are introduced at the fourth stage of the procedure. In an acidic medium, O atoms are balanced with H_2O and H atoms are balanced with H^+. In a basic medium, H^+ ions are balanced with OH^- on both sides of the equations to neutralise any H^+ ions to form H_2O molecules (Chang, 2003; Romero, 2009).

Chiu (2005) explained that students enter into classrooms with a number of experiences that may impede their correct conception of scientific concepts. Alternative conceptions are ideas students have about scientific concepts which are contrary to those generally accepted by mainstream scientists (Yip, 1998). That is the improper students' interpretations of scientific concepts are simply the students' alternative conceptions (Wenning, 2008). Students' alternative conceptions can also be explained as different viewpoint which cannot be considered as correct or incorrect (Hewson, 1992). Mdachi (2012) described students' alternative conceptions as incorrect student responses to teachers' questions. In the current study students' alternative conceptions are the conceptual difficulties students could have in explaining chemical concepts which end up not being in line with what is accepted in the scientific community.

From the science education literature, students' conceptions of scientific concepts are given different names by different authors. Gaitano et al. (2013); Osman and Sukor (2013); Unal et al. (2010); Yip (1998) identified some of the names as preconceptions, pre-scientific conceptions, alternative conceptions, misconceptions, alternative frameworks, common-sense concepts, initial conceptions, and everyday conceptions. Aside these names for students' conceptions, Demircioglu et al. (2013); Gonzalez-Espada (2003) added naïve conceptions and naïve theories (Cakir, 2008) as well as children's science, spontaneous knowledge, preconceived notions, and factual misconceptions (Unal et al., 2010).

Wenning (2008) emphasized that students' alternative conceptions are not naïve viewpoint but are incorrect meanings or generalisations which were built under certain conditions. In such cases Wenning

(2008) referred to the students' conceptions as paraconception. Tan et al. (2001) reported that students' alternative conceptions are formed from their strive to make meaning of chemical concepts.

In addition, students develop alternative conceptions through (personal) experiences (Chiu, 2005; Gaitano et al., 2013; Gonzalez-Espada, 2003; Sunal and Sunal, 2002; Talanquer, 2006; Wenning, 2008, Yip; 1998). Alternative conceptions are formed whenever students attempt to interpret new experience in the light of the previous experience (Wenning, 2008). Other sources of students' alternative conceptions include gender, peer interaction, media, language, symbolic representation, textbook, and laboratory work (Chiu, 2005; Kay and Yiin, 2010; Pedrosa and Dias, 2000; Wenning, 2008). These sources of students' alternative conceptions could be inside classroom-related or outside classroom-related (Osman and Sukor, 2013).

According Wenning (2008, p. 12), "misunderstanding, miscommunication, miseducation, and even a misapplication of well-established physical principles lead to the formation of alternative conceptions." This is where teachers (Gonzalez-Espada, 2003; Mdachi, 2012; Yip, 1998) as well as peers and family (Kay and Yiin, 2010) come in as source of students' alternative conceptions. Yip (1998) explained that some students' alternative conception is formed as a result of lack of prerequisite concepts from which a new concept can be connected into; and others are also formed from inaccurate teaching of teachers with fragmented understanding of scientific concepts.

Wandersee, Mintzes, and Novak claimed that students' alternative conceptions are difficult to change (Wenning, 2008). This is because students' alternative conceptions can be integrated into the cognitive structures and this can impede the learning of new scientific concepts (Sunal and Sunal, 2002; Treagust, 2006). When this happens, students find it difficult to integrate new knowledge into existing cognitive structures. From Wandersee et al., not only can students' alternative conceptions impede meaning making but can interact with new meanings resulting in mixed outcomes (Wenning, 2008).

Notwithstanding the age differences of students at different levels, students' alternative conceptions are similar and can impede their understanding in more complex concepts (Chiu, 2005; Wenning, 2008). Students' alternative conceptions are deeply seated and have the tendency of remaining even after instruction (Cakir, 2008). It is therefore expected that students need to change their alternative conceptions and reconstruct them in order to acquire the new knowledge (Chi et al., 1994).

According to Talanquer (2006, p. 813), "many students' alternative conceptions in Chemistry seem to result from the confident and impulsive application of crude, incomplete, limited, and superficial explanatory framework about chemical substances and phenomena." Some students' alternative conceptions are caused by heuristic association of ideas and concepts. That is the use of simple association rules. In some associations, students select the factor that is usually present as the cause of a phenomenon; assume that cause and effect are in a causal relationship where they share similar characteristics; associate events that are close in space and time, where students give preference to the presence of physical contact between cause and effect; think that effects are usually linear and equally distributed among equivalent parts in a system; and select important causes based upon the number of times they occur (Talanquer, 2006).

The role of teachers is to guide students to conceptualise chemical concepts. Chemical educators and researchers therefore need to explore students' alternative conceptions in chemical concepts in order to develop instructional strategies to better enhance students' conception in such concepts (Mdachi, 2012; Osman and Sukor, 2013; Park et al., 2009; Salame et al., 2011; Tan et al., 2001). And the instructional strategies developed by the chemical educators and researchers out of the identified students' alternative conceptions could help pre-service teachers develop their pedagogical content knowledge in teaching Chemistry as novice teachers (Talanquer, 2006).

There have been a number of research works in the area of Chemistry Education investigating into students' alternative conceptions in chemical concepts (Kay and Yiin, 2010; Pabuccu and Geban, 2012; Sendur et al., 2010; Topal et al., 2007). Salame et al. (2011) found one of the students' alternative conceptions in Chemistry as "hydrogen is a gas so it is smaller than all metals, it only has one orbital *1s* and it has the smallest molecular mass" (p. 192). Students some of the time consider H in chemical formula as an acid (Chiu, 2005) and that H^+ and OH^- ions respectively are donated by all acidic and basic substances (Kay and Yiin, 2010). Some students conceptualised hydrogen as a metal as it can be located on the left side of the periodic table (Unal et al., 2010).

Students have weak understanding of concepts under chemical equilibrium such as oxidation-reduction reactions (Demircioglu et al., 2013; Sendur et al., 2010). In the area of oxidation-reduction reactions, Chiu (2005) reported that students have little or no knowledge about the conditions of combustion. This is because students in his study thought that the presence of water in a wet wood will prevent it from burning.

Taiwan elementary school students explained that iron lost weight because it rusted and reduction of substances occurred only when such materials are transformed from their respective compounds to elements and that oxygen is a combustion gas but it is not involved in the process of combustion (Chiu, 2005). In an electrochemical cell the electropotential is the sum of the individual potentials (Kay and Yiin, 2010) and electrons flow in solution from one electrode to another. This explains the fact that students understand that only electrons can flow in solution (Osman and Sukor, 2013).

Though there are number of research works in the area of alternative conceptions in Chemistry, the current study has become necessary as it sought to find out the students' conceptions in specific aspect of redox reaction using a mixed method approach. The purpose of the study therefore was to find out high school students' alternative conceptions in the introduction of species; H_2O, OH^-, and H^+ in balancing oxidation-reduction reactions in both acidic and basic media using the ion-electron method. In order to find out the students' alternative conceptions, two of the 20 items on a two-tier diagnostic test were used. The following research question was formulated to help achieve the purpose of the study:

What alternative conceptions and other conceptual difficulties do students have in the introduction of H_2O, OH^-, and H^+ in balancing oxidation-reduction reactions?

2. Research methodology

2.1. Research design

A cross-sectional survey design was employed as the main design for the study. The survey helped to obtain information in the form of quantitative and qualitative data for the purposes of answering the research question in order to achieve the purpose of the study. This means that a mixed method approach was employed to collect and analyse data on the students' alternative conceptions in the introduction of the species; H_2O, H^+, and OH^- in balancing oxidation-reduction reactions (using a two-tier diagnostic test).

2.2. Sample and sampling procedure

The students from the high schools in Mampong Municipality, Sekyere Central, and Kwabre East Districts of the Ashanti Region of Ghana participated in the study. There were 15 schools in the three district assemblies and the schools were stratified into science elective schools and non-science elective schools. Out of the 15 schools, there were seven elective science schools. The elective science students in Ghana all the time offer Biology, Chemistry, Physics, and E-mathematics for their stay in the high school. The SHS 3 Chemistry students were the target population for the study. The third year students were the target as the probability that they have covered topics in oxidation-reduction reactions outlined in the Chemistry Teaching Syllabus (MOE, 2010; 2012) was almost one.

The students from three out of the seven schools from the three district assemblies were randomly selected to participate in the study. The students who were present on the day of the data collection responded to the diagnostic test. Involving all the students present on the day of the data collection helped to minimize the impact of the non-response attrition on the study. From the three schools, 83, 69, and 61 students totaling 213 participated in the study.

2.3. Research instrument

The research instrument used for the study was two-tier diagnostic test. The purpose of the two-tier diagnostic test was in part to obtain the students' scores in the test and to ascertain the students' reasons for selecting some of the options. The test was a two-tier multiple-choice test with three options. After each option selected, the students were expected to explain why the option selected was the best answer to the test. The test items were:

1. In balancing redox reaction in "acidic" medium, which of the following species is first added to the equation?

- *a.* H^+
- *b.* OH^-
- *c.* H_2O

GIVE REASON FOR YOUR ANSWER: ……………………………………………

2. In balancing redox reaction in a "basic" medium, which of the following species is added at both sides of the equation?

- *a.* H^+
- *b.* OH^-
- *c.* H_2O

GIVE REASON FOR YOUR ANSWER: ………………………………………

The use of the diagnostic test of this characteristic became necessary as Pabuccu and Geban (2012) recommended that teachers can use various methods such as multiple-choice test to diagnose students' alternative conceptions in chemical concepts. They appreciated that a two-tier multiple-choice test can be just an effective as an interview to find out students' alternative conceptions in chemical concepts.

The diagnostic test of which the two test items used in this study were part of was constructed by the authors. The content validity of the test was ascertained by two experts in Chemistry Education. The test items were later shown to three Chemistry teachers who have been teaching high school Chemistry for more than five years to further validate the instrument. To establish the reliability of the instrument, it was pilot-tested with 10 high school students of similar characteristics from the Central Region of Ghana. After the pilot test, the test items were subjected to item analysis and items identified as too easy or difficult were deleted from among the test items for the study. The Cronbach's alpha coefficient of reliability was calculated as 0.8. The Cronbach's alpha coefficient of reliability was calculated for the instrument as the test items were not scored right or wrong.

2.4. Data collection procedure

The author 1 sought permission from the Headteachers of the three schools for the conduct of the study in the schools. The purpose of the study was explained to the Headteachers and later the Chemistry teachers. The purpose was to receive the needed assistance from the Headteachers and the Chemistry teachers. Thereafter the students were briefed on the purpose of the study and the need for the students to sincerely respond to the diagnostic test on oxidation-reduction reactions.

In each of the three schools, author 1 administered the research instrument on his own to the students in the presence of the school's Chemistry teachers. The presence of the Chemistry teachers helped to eliminate any form of nervousness that they may have had experienced being with author 1 alone in the classroom. The students took between 30 to 60 minutes to complete the diagnostic test.

2.5. Data analysis

The data collected with the research instrument was analysed using descriptive statistics as well as open coding and constant comparison. The research question was answered by using percentages. In the analysis of the two test items on the introduction of the species; H_2O, H^+, and OH^-, the percentages of the students' correct responses as well as incorrect responses to each test item was presented and discussed. The explanations given by the students for each of the options selected was open coded and constantly compared. The themes used were introduction of H_2O in balancing oxidation-reduction reaction; introduction of H^+ in balancing oxidation-reduction reactions; and introduction of OH^- in balancing oxidation-reduction reactions. Codes and samples of students' explanations were used to support the conceptions identified.

3. Results

3.1. Students' alternative conceptions and other conceptual difficulties

The research question sought to find out the students' alternative conceptions and other conceptual difficulties in the introduction of H_2O, H^+, and OH^- in balancing oxidation-reduction reactions. To be able to achieve this, the percentages of the students who selected each of the species under each item are presented and discussed. The students' alternative conceptions could be seen in the second part of the presentation. The performance of the students on Item 2 was quite good to that of Item 1. The calculated item difficult index for Item 2 was 0.7 and for Item 1 was 0.4. This is because under Item 1, 36.6% of the students identified H_2O as the specie that is first added to an equation of oxidation-reduction reaction in an acidic medium to help balance the number of oxygen atoms. This implies that 63.4% of the students found it very difficult to identify that H_2O is the first specie to be added. Out of the 63.4% students, 42.7% identified H^+ and 9.4% identified OH^- whereas 11.3% could not provide any response as to what specie should be first added to balance some of the atoms in an equation of oxidation-reduction reaction in acidic medium.

Under Item 2, 67.1% of the students identified OH^- as the specie needed to initially neutralise hydrogen ions in the chemical equation of oxidation-reduction reaction in a basic medium. However, 32.9% of the students found it difficult to identify OH^- as the initial specie needed to help balance the number of atoms and charges in oxidation-reduction reaction in basic medium. This is because 10.8% of the students identified H^+ as the specie and 14.1% identified H_2O as the specie. The rest of the 32.9% students who were 8.0% failed to provide any specie needed to help balance atoms and charges of species in oxidation-reduction reaction in basic medium.

3.1.1. Introduction of H_2O in oxidation-reduction reactions

With respect to Item 1, some of the students correctly identified that H_2O was the specie that is first introduced into an oxidation-reduction reactions in acidic medium when balancing the equations using the ion-electron method. The students conceptualised that the H_2O molecules are added to the side that is deficient in the number of the O atoms. This in effect will help to balance the number of O atoms in the chemical equations. Some of the students' explanations were: "the answer is H_2O because oxygen is balanced first and H_2O contains oxygen that can be used to balance the reaction" (001); "H_2O; this is done to balance the number of oxygen atoms by adding it to the oxygen deficient side or the side with less number of oxygen atoms" (007); "H_2O; this is to balance the side of the equation deficient in oxygen atoms" (049); and "H_2O; because in balancing redox reaction in acidic medium H_2O is first added to the side deficient in oxygen" (113).

Alternative conceptions of H_2O in acidic medium: Some of the students explained incorrectly why H_2O molecule is the specie first introduced in oxidation-reduction reactions in acidic medium when balancing using the ion-electron method. Some of the students conceptualised that the H_2O molecules are added to help balance the O and H atoms in the oxidation-reduction equations. The excerpts were: "H_2O is added to ensure the presence of H^+ and the O_2 atoms in the reaction" (016); and "H_2O; this is because oxygen and hydrogen is needed to be balanced in redox reaction" (213).

There were instances where the students explained that the H_2O molecules are introduced in the oxidation-reduction reactions when balancing the equations using the ion-electron method to simply increase the number of O atoms. The excerpts were: "H_2O; this is done to increase the number of oxygen" (019); "H_2O; is added to the number of oxygen" (115); and "H_2O; this is done to bring or introduce an oxygen atom to the compound which lacks oxygen" (117).

Other students conceptualised that the H_2O molecules are first added to oxidation-reduction reactions to take care of the H atoms when balancing the equations using the ion-electron method. Some of the students' explanations were: "H_2O; because H_2O also determine the number of H^+ which balance the reaction" (100); "H_2O; is added in order to know the number of hydrogen atoms" (132); and "H_2O to adjust the hydrogen before balancing the hydrogen" (140).

There were also instances where the students explained that the H_2O molecules are the first specie added to oxidation-reduction equations when balancing using the ion-electron method because it helps to reduce the acidic concentration of the reactions. The excerpts were: "H_2O; this is done so that the H_2O will reduce the concentration of the acid taken part in the reaction" (126); "H_2O; this is because the H_2O will reduce the concentration of the acidic medium" (136); and "H_2O; it dilutes the solution" (211).

Alternative conceptions of H_2O in basic medium: Some of the students conceptualised the H_2O molecules as the specie introduced in oxidation-reduction reactions in basic medium at both sides of the chemical equation when balancing using the ion-electron method. The students explained that the H_2O molecules are introduced at both sides of the oxidation-reduction equations to balance the oxygen atoms. The excerpts were: "balancing of oxygen is done first so H_2O is added because it contains oxygen" (054); "H_2O; because that can proceed to nullify the number of oxygen in the other part of the reaction" (101); and "H_2O; to balance the O_2" (146).

In other instances, the students explained that the H_2O molecules are introduced at both sides of oxidation-reduction reactions in basic medium because H_2O reacts with base. Some of the students' explanations were: "H_2O; this is because H_2O is in base" (093); and "H_2O; because of the reaction between base and water" (139).

Some other students further explained that H_2O molecules are introduced at both sides of oxidation-reduction reactions in basic medium as it would help release OH^- ions in balancing the chemical equations. Some of the students' explanations were: "H_2O; because hydroxide ion is added to the equation when the H_2O is added to balance it" (032); and "H_2O; in balancing redox reaction in a basic medium H_2O can be added to get OH^-" (058).

3.1.1.1. Indistinctive explanations for H_2O molecules

The explanations given by some of the students to justify why H_2O molecules are first added to oxidation-reduction equations in acidic medium when balancing using the ion-electron method ahead of H^+ and OH^- ions could not be grouped among any of the groups identified above. The excerpts of the indistinctive explanations were: "H_2O; that's what is in my textbook" (040); "H_2O; because acid is best used in water" (103); "H_2O; water is being added to make the reaction balance" (106); "H_2O; because of the neutral state of the H_2O" (139); and "H_2O; is first added to balance the charge of oxygen in the equation" (209).

Some of the students' explanations for the introduction of the H_2O molecules into oxidation-reduction reactions in basic medium could not be grouped under any of the alternative conceptions given above. The excerpts were: "H_2O to neutralise/balance the excess base in the solution" (048); "because water is universal solvent in a solution" (061); and "H_2O; because in basic medium or in acidic medium water is added to make the equation stable" (076).

3.1.2. Introduction of H+ into oxidation-reduction reactions

Alternative conceptions of H^+ in acidic medium: H^+ ions are not the first specie to be introduced into oxidation-reduction reactions in acidic medium when balancing the equations using the ion-electron method. However some of the students selected and justified H^+ ions as specie introduced in oxidation-reduction reactions in acidic medium. Some of the students conceptualised that the H^+ ions are first added because the reactions occurred in acidic medium and that acids donate proton or release H^+ ions in aqueous solutions. The excerpts were: "H^+; because it donates protons" (079); "H^+; because an acid produces hydrogen ion when in aqueous solution" (148); "H^+; because H^+ means the addition of a proton and the moment H^+ is added to a solution it becomes highly concentrated and reacts fast" (170); and "H^+; because it was stated in the definition of acid that it is a substance which yield excess of H^+ in an aqueous solution" (199).

Other students conceptualised that as the reaction is occurring in an acidic medium, then H^+ ions were the first to be added ahead of any other species. Some of the students' explanations were: "H^+; balance all hydrogen atom first before balancing other element" (068); and "H^+ is an acidic medium agent it will be first added before the other agent is then added" (165).

Some of the students conceptualised that the H^+ ions are the first specie to be introduced in oxidation-reduction reactions in acidic medium when balancing using the ion-electron method as they take care of any electron in the system as it is an electron pair accepter. The excerpts were: "H^+ to account for excess electrons. It is oxidised from …" (038); "H^+ because the number of electron on the other side of the equation" (081); and "H^+ means losing an electron to attain stable charged particle" (171).

Some of the students conceptualised that the H^+ ions are first introduced in oxidation-reduction reactions in acidic medium so as to balance the number of O atoms in the chemical equations. Some of the students' explanations were: "H^+; it is added to the oxygen rich half to balance each half" (085); "H^+ because it is added to the half of the equation with less number of oxygen atoms" (091)" and "H^+; because in acidic medium H^+ is added first to the equation with the highest oxygen" (181).

There were other instances where the students conceptualised that the H^+ ions are first introduced in oxidation-reduction reactions in acidic medium when balancing using the ion-electron method as it helped to neutralised any OH^- ions in the system to form H_2O molecules. The excerpts were: "H^+; because acidic medium H^+ to the reactant side and water is the product side" (062); "H^+; because it made it neutralised and know what to add next" (104); and "H^+ because it would form the H_2O molecules because OH^- being dominant will be neutralised" (192).

Alternative conceptions of H^+ ions in basic medium: Some of the students conceptualised that the H^+ ions are introduced in oxidation-reduction reactions in basic medium to help balance the chemical equations. The students conceptualised that the H^+ ions are added to neutralise any base (OH^-) in the system. The excerpts were: "H^+; I think it is to neutralise the basic medium" (102); "H^+ ions are added to the equation to neutralise the presence of OH^- ions in the reaction in a basic medium" (125); and "H^+; because H^+ is added to neutralise the base present" (191).

There were other instances where the students explained that the H^+ ions are introduced at both sides of the oxidation-reduction reactions in basic medium because these reactions in basic medium lack positive charges in the system. The excerpts were: "H^+ because it lacks positive charges" (073); and "H^+ because it's a positive charged ion" (163).

3.1.2.1. Indistinctive Explanations for H+ Ions

With respect to the introduction of H^+ ions as the first specie when balancing oxidation-reductions in acidic medium using the ion-electron method, some of the students' explanations could not be grouped under any of the groups above. The excerpts were: "H^+; because in acidic medium it needs H^+ and H_2O but it is added first" (060); "H^+; because every corrosive acid has H^+ in its compound" (120); and "H^+; to know the number of oxidation in the reaction" (178).

Some of the students' explanations justifying why H^+ ions are the specie introduced at both sides of oxidation-reduction reactions in basic medium could not be grouped under the groups of the students' alternative conceptions as given above. The excerpts were: "H^+; only in the reduction half since the H^+ is added to the right hand side" (066); and "H^+ is redox reaction in a basic medium; the specie is first added at both sides in the equation" (077).

3.1.3. Introduction of OH- ions in oxidation-reduction reactions

In balancing oxidation-reduction reactions in basic medium using the ion-electron method, some of the students correctly conceptualised that OH^- ions are the specie introduced at both sides of the chemical equations to help balance the equations. The students explained that the OH^- ions are introduced at both sides of the oxidation-reduction equations to help neutralise any H^+ ions present in the system to form H_2O molecules. The excerpts were: "OH^-; this is because basic medium react with acidic medium …" (063); "OH^- is first added to the equation to react with hydrogen ions to produce water" (074); and "OH^-; because it may contain H^+, so you need to add OH^- to make it neutralised" (104).

Alternative conceptions of OH^- ions in basic medium: Some of the students conceptualised that the OH^- ions are introduced at both sides of oxidation-reduction reactions in basic medium as they are proton (H^+) accepter. The excerpts were: "OH^-; because OH^- means the accepting of proton from a different compound" (080); "OH^-; base is a proton accepter and yield excess OH^- in aqueous solution" (133); and "OH^- means gaining or accepting a proton to become stable as a charged particle" (171).

Other students also conceptualised that the OH^- ions are introduced at both sides of oxidation-reduction reactions in basic medium to help balance the number of O atoms in the system. The excerpts were: "OH^- because it is used to balance oxygen in the basic medium" (007); "OH^-; this is done to balance the number of oxygen atoms in the reaction; OH^- is added to the oxygen deficient side before H_2O is added to the other side" (017); and "OH^-; because OH^- is added to the side deficient in oxygen" (030).

There were other instances where the students explained that the OH^- ions are introduced at both sides of oxidation-reduction reactions in basic medium to help balance the number of electrons in the equations. The excerpts were: "OH^- because it will help balance the number of electrons on the other side of the equation …" (011); and "OH^-; because it accepts and balance electrons" (169).

Some of the students further explained that the OH^- ions are introduced at both sides of oxidation-reduction reactions in basic medium simply because the system is characteristically basic. The excerpts were: "OH^- because OH^- ions are the outcomes of basic substances and hence, adding them in balancing in basic medium is much more preferable" (009); "OH^-; this is because the presence of OH^- ions makes the reaction basic" (014); and "the characteristic of a basic medium is in its OH^-" (043).

Some of the students explained that the OH^- ions are introduced at both sides of oxidation-reduction reactions in basic medium because bases release OH^- ions in aqueous in solution. The excerpts were: "OH^-; because it is stated in the definition of base that it is the substance which yield more excess of OH^- in an aqueous solution" (114); and "OH^-; because base release hydroxide" (118).

Alternative conceptions of OH^- ions in acidic medium: With respect to the introduction of OH^- ions, some of the students conceptualised the OH^- ions as the first specie introduced in balancing oxidation-reduction reactions in acidic medium using the ion-electron method. The students explained that the OH^- ions were introduced to neutralise the presence of H^+ ions as the reaction was in acidic medium. Some of the students' explanations were: "OH^-; I don't know but I think it is to neutralise the acidic medium" (046); "OH^- to neutralise the excess acid in the solution" (048); "OH^-; is added to the equation to neutralise the presence of H^+ ions in the reaction in the acidic medium" (125); and "OH^-; because OH^- is added to neutralise acid present" (191).

3.1.3.1. Indistinctive explanations for OH- ions

Some of the students' explanations for the introduction of OH^- ions at both sides of oxidation-reduction reactions in basic medium could not be grouped under any of the alternative conceptions identified above. The excerpts were: "OH^- because it would neutralise the H_2O molecules here being dominant will be neutralised" (022); "OH^-; to know the number of reduction in the reaction" (088); and "OH^-; it is added first at both sides of the equation because it has an oxidation state of -1" (168).

Some of the students' explanations as to why in balancing oxidation-reduction reactions in acidic medium the OH^- ions are the first specie to be introduced in the chemical equations could not be considered as part of those given above. Some of the students' indistinctive explanations for the OH^- ions were: "OH^- is in acidic medium because it is negatively charged" (073); "OH^-; this is because it is base by OH^- (093); and "OH^- is first added in the equation because OH^- is add to the compound with more oxygen" (156).

4. Discussion

The findings show that the students' alternative conceptions are based upon simple association of the species, H_2O, H^+, and OH^- to other concepts learnt (Talanquer, 2006). For instance, the introduction of H_2O in balancing oxidation-reduction reactions in acidic medium is to increase the number of O atoms or to dilute the system but this not necessarily the case. It is to help balanced the number of oxygen atoms. And in basic medium H_2O molecules are introduced at both sides of the oxidation-reduction reaction to balance O atoms. The H_2O molecules though are used to balance O atoms at the side of the chemical equation deficient in O atoms but not at both sides of the equation as in the case of the OH^- ions.

The conception of acid as a proton donor, electron pair accepter, or a substance that releases hydrogen ions in solution is incorrectly conceptualised in balancing oxidation-reduction reaction in acidic medium using the ion-electron method as in other studies such as Chiu (2005). This is because the H^+ ions are not released in solution from any acid but are introduced to balance the atoms of H in the chemical equation. And in balancing oxidation-reduction in basic medium using the ion-electron method OH^- ions are incorrectly conceptualised as they are not released in solution as a base but are introduced to neutralise any H^+ ions present in the system. The students conceptualise that H^+ and OH^- ions are released respectively by acid and base as in other studies like Kay and Yiin (2010) and for that matter in balancing oxidation-reduction reactions in either acidic or basic medium, the H^+ or OH^- ions should be added accordingly. Though in balancing oxidation-reduction reaction in basic medium OH^- ions are introduced at both sides of the equation to neutralise H^+ ions but this is not the case when the reaction occurs in acidic medium. That is H^+ ions are not introduced in equations of oxidation-reduction reactions in acidic medium to neutralise any OH^- ions but to balance any H atoms in the system. This once again is simplistic association of chemical concepts (Talanquer, 2006).

The students' alternative conceptions identified by the current study could be described as inside classroom-related (Osman and Sukor, 2013) and that these could have been developed during the process of teaching and learning. This is because the students' conception of the three species, H_2O, H^+, and OH^-, are chemically correct in other context but not in balancing oxidation-reduction reactions in acidic and basic media using the ion-electron method. For instance, acids (H^+) neutralise bases (OH^-) to form water (H_2O) molecules in a neutralisation reaction but in balancing oxidation-reduction reactions in acidic medium, the H^+ ions are added to balance any H atoms in the chemical equation but not to neutralise any OH^- ions. In addition, a basic substance in solution releases OH^- ions in other instances but in balancing oxidation-reduction reactions in basic medium the OH^- ions are added at both sides of the equations to help neutralise any H^+ ions to form H_2O molecules and not because base releases OH^- ions in solution. Chemistry teachers are therefore encouraged to address any students' conception of acid and base in terms of release of ions in solution, transfer of proton and electron when balancing oxidation-reduction reactions in acidic and basic media using the ion-electron method.

5. Conclusion

The study has shown that Chemistry students have conceptual difficulties in explaining the Chemistry behind the introduction of species like H_2O, H^+, and OH^- in balancing oxidation-reduction reactions in acidic and basic media using the ion-electron method in line with what is scientifically accepted. The students' alternative conceptions in this area are as a result of the simplistic association of concepts as they attempt to explain them. This confirms the categories of Talanquer (2006) in chemical concepts where the categories are formed based upon the use of simple association rules. The current study has added to the literature on students' alternative conceptions in Chemistry by identifying some of the alternative conceptions in balancing oxidation-reduction reactions in acidic and basic media using the ion-electron method. It is therefore recommended that chemical instructional designers should study the findings from the study and come out with the appropriate pedagogical content knowledge to help students learn the Chemistry behind the introduction of H_2O, H^+, and OH^- in balancing oxidation-reduction reactions in acidic and basic media using the ion-electron method and other chemical concepts which could help eliminate students' alternative conceptions in Chemistry.

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