UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF CONCEPTUAL CHANGE TEXTS ON SENIOR HIGH SCHOOL STUDENTS' COGNITIVE ACHIEVEMENTS AND ATTITUDES TOWARD ELECTROCHEMISTRY

PHILIP DORSAH

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OCTOBER, 2016

DECLARATION

STUDENT'S DECLARATION

I, **PHILIP DORSAH**, declare that this thesis, with the exception of quotations and references contained in published works which have been identified and acknowledged, is entirely my own original work and it has not been submitted either in part or whole for another degree elsewhere.

CANDIDATE'S NAME: PHILIP DORSAH

SIGNATURE: ………………………… DATE: ……………………………

SUPERVISORS DECLARATION

We hereby declare that the preparation and presentation of the dissertation were supervised in accordance with the guidelines on supervision of dissertation laid down by the University of Education, Winneba.

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DEDICATION

I dedicate this work to Eugene, my boy and to my mother, Priscilla

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LIST OF ABREVIATION

ANOVA:	Analysis of Variance
ANCOVA:	Analysis of Covariance
ATCLS:	Attitude Towards Chemistry Learning Scale
ATECS:	Attitude Towards Electrochemistry Scale
CAQ:	Chemistry Attitude Questionnaire
CCM:	Conceptual Change Model
CCT:	Conceptual Change Text
CG:	Control Group
CI:	Correct Response
DSI	Damongo Senior High School Interview
ECCT:	Electrochemistry Concept Test
EG:	Experimental Group
GSI	Ghana Senior High School Interview
IC:	Incorrect Response
M:	Mean
MC:	Misconception
MoE:	Ministry of Education
N:	Sample Size
PU:	Partial Understanding
SD:	Standard Deviation
SPSS:	Statistical Package for Social Scientists
SU:	Sound Understanding
WASSCE:	West African Senior Secondary Certificate Examination

ABSTRACT

The purpose of the study was to determine the effect of conceptual change texts on students' cognitive achievements and attitudes towards electrochemistry. The study employed a quasi-experimental design in which intact classes were used. The experimental group (N=51) was made up of SHS2 chemistry students and the control group (N=52) was also made up SHS2 chemistry students. Students' misconceptions in electrochemistry were first identified using a structured interview and an electrochemistry concept test (ECCT) as pre-test. Students attitudes towards electrochemistry were also determined using the Attitude towards Electrochemistry Scale (ATECS). Both the ECCT and the ATECS were administered to students before and after the treatment. The results from the interview showed that students have many misconceptions in electrochemistry regarding electrochemical cells. There was a significant difference in cognitive achievement of students in the experimental group (M = 12.2, SD = 3.83) and the control group (*M* = 10.0, *SD* = 3.73), *t* (101) = 2.99, *p* = .003, *d* = .59. There was no significant difference in the attitude of students in the experimental group (*M* = 56.6, SD = 8.86) and those of the control group (*M* = 58.2, SD = 7.63), *t* (49) = -1.03, *p* = .305. There was no significant difference in the cognitive achievement of males (*M* = 12.06, *SD* = 3.67) and females (*M* = 13.12, *SD* = 4.79), *t* (50) = -.711; *p* = .480. Also there was no significant difference in attitude of males (*M* = 56.6, *SD* = 8.77) and females (*M* = 56.6, SD = 9.94), *t* (49) = -.006, *p* = .995. The results revealed that conceptual change texts resulted in a better acquisition of scientific concepts and cognitive achievement of students in electrochemistry than the traditional teaching approach.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Overview

This chapter presents the background to the study, problem statement, and purpose of the study. It also outlines the objectives of the study, research questions, research hypothesis, the significance of the study, limitations and delimitations of the study. The chapter ends with the organization of the study.

1.2 Background to the Study

The task of teaching chemistry concepts meaningfully is sometimes `rather complicated and so it is very often not fulfilled resulting in poor performance of students in the subject. This is highlighted in the Chief Examiner's report on candidates' performance in the West African Senior School Certificate Examination (WASSCE, 2008), which noted that many candidates could not distinguish between oxidation and oxidizing agent as well as reduction and reducing agent. The Chief Examiners report (2006) also noted that candidates who attempted questions on electrochemistry could not arrange elements in correct order of their positions in the electrochemical series. Another WASSCE Chief Examiner's report (2013) also found that candidates could not give the practical application of the redox reaction chosen. Further analysis of the WASSCE questions by the researcher over the years revealed that electrochemistry questions formed about 20% of the questions. This number is large enough to affect students' overall achievement if they do not understand the concepts of electrochemistry well. According to the chemistry syllabus (MoE, 2010), the rationale for teaching electrochemistry is for students to understand the nature of oxidation-reduction reaction and apply its principles to electrochemical cells. They should also demonstrate awareness of corrosion as an oxidation-reduction process and its economic cost. This objective cannot be achieved if the concepts in electrochemistry are not communicated well to students for conceptual understanding. Thus the broader rationale for teaching chemistry, which is to provide knowledge, understanding and appreciation of the scientific methods, their potential and limitations, will not also be achieved.

According to Gabel (1996), the complexity of chemistry has implications for the teaching of chemistry. From eight years' experience as a chemistry teacher, I realized that students possess misconceptions in chemistry especially in electrochemistry. According to Johnstone cited in Sheeban and Childs (2008) chemistry is a difficult subject for students. Yet according to Chiu (2005), chemistry, though it is complex, is a world filled with interesting phenomena, appealing experimental activities, and fruitful knowledge for understanding the natural and manufactured world. As a result of the difficult and complex nature of chemistry and also the fact that it is one of the most conceptually difficult subjects on the school curriculum, it is of major importance that anyone teaching chemistry is aware of the areas of difficulty in the subject (Sheeban & Childs, 2008).

Studies on students' conception have revealed that students have many alternatives conception in chemistry (Osman & Sukor, 2013). Some of the concepts include: chemical bonding (Ozmen, 2004); electrochemistry (Schmidt *et al.,* 2007); acids and bases (Demircioglu, Ayas & Demircioglu, 2005).

Electrochemistry is an important topic in chemistry as it has many applications from battery development to neuroscience and brain research (Miller, 2014). It also underpins later topics in the curriculum and consolidates earlier ones, having links to such topics as thermodynamics, rate of reaction and chemical equilibrium. Yet it has been found that students find the topics in electrochemistry difficult to learn as evidenced by the many misconceptions the students possess in this area (Ozkaya, 2002). For example, some students hold the misconception that in an electrochemical cell the anode goes to the left and the cathode goes to the right (Ozkaya, 2002).

Students enter and finally leave school with misconceptions regarding electrochemistry because they missed the opportunity to modify their pre-existing knowledge to fit the new information (Sewell, 2002). With their misconceptions clouding their potential learning success, chemistry students may conclude that electrochemistry is indeed one of the most difficult topics to learn.

Agung and Schwartz (2007) reported that educators and researchers have acknowledged that students' alternative conceptions in science present an important educational problem. To overcome this problem, Chung (2011) suggested that diagnostic assessment should be used as an effective tool by teachers to determine student readiness before instruction. According to Sheeban and Childs (2008), it is beneficial to identify students' alternative conceptions so that teachers can be able to formulate strategies which will enable students' to conceptualize more appropriately and enable them to improve their achievement in chemistry as a whole. This statement is in agreement with Ozmen (2004) who stated that one of the most fruitful outcomes of the studies on children's misconceptions is to alert teachers to students' difficulties in conceptualizing scientific knowledge to suggest more effective strategies for improving their teaching and learning approaches. Johnstone (2000) recognized that what may be coherent and simple to the chemistry teacher, may not be so for the learner. To teach for understanding, teachers therefore need to have an accurate awareness of their pupils' prior knowledge, misconceptions and level of cognitive development. If teachers have a better understanding of their pupils' opinions and attitudes, they may be better able to adapt their lessons to facilitate a deeper and more holistic understanding of the subject.

Many studies have reported that traditional instruction is not sufficient to promote conceptual change (Kaya, 2007; Hsu, 2008; Tarhan & Acar-Sesen, 2012). Student-centred learning environments, which are enriched by effective methods and techniques, are needed in order to help students understand challenging concepts. They therefore suggested that many teaching strategies based on the conceptual change approach, such as conceptual change texts, cooperative learning methods, concept maps, demonstration, analogies, hands-on activities, were developed as an alternative strategy to traditional instruction.

To promote meaningful learning various instructional methods that are based on constructivist theory of learning have been used to identify and remediate misconceptions students have about electrochemistry. Some of these methods reported in literature include computer animations (Doymus, Karacop & Simsek, 2010; Sanger & Greenbowe, 2000; Yang, Andre & Greenbowe, 2003), computer-assisted learning (Talib, Matthews & Secombe, 2005), conceptual change instruction (e.g. Huddle, White & Rogers, 2000; Sanger & Greenbowe, 2000), cooperative learning strategies (Acar & Tarhan, 2007), conceptual change text (Yuruk, 2007) and jigsaw puzzle techniques (Doymus, Karacop & Simsek, 2010).

One of these methods is the use of conceptual change approach in which students' preexisting conceptions are restructured or changed. Conceptual change occurs when a learner changes his/her misconceptions with that of scientifically accepted ones, but changing misconceptions requires modifying or restructuring existing schemata (Onder & Geban 2006). Conceptual change text is a text that identifies misconceptions, and disproves these misconceptions and is designed according to conceptual change process which illustrates inconsistencies between the misconceptions and scientific knowledge. Conceptual change text activates students' preconceptions and warns them about possible misconceptions about the topic of interest as some of the misconceptions are juxtaposed with the scientifically accepted conceptions by providing examples and explanations.

Uzuntiryaki and Geban (2005) explored the effect of conceptual change texts accompanied with concept mapping instruction on 8th grade students' understanding of concept of solution. The results revealed that conceptual change text accompanied with concept mapping instruction caused a significantly better acquisition of scientific conceptions about the concept of solution.

Şeker (2006) in her study compared the effectiveness of conceptual change text oriented instruction accompanied with analogies over traditionally designed science instruction on 7th grade students' understanding of atom, molecule, ion and matter concepts and their attitudes toward science as a school subject. The result of the study showed that the conceptual change text oriented instruction accompanied with analogies provided better conceptual understanding of atom, molecule, ion and matter concepts than the traditional instruction in science. The research also indicated that conceptual change text oriented instruction had a significant importance as a teaching strategy to identify the misconceptions in science concepts.

Attitude towards chemistry is essential; it denotes interests or feelings towards studying chemistry. Willingness to give out one's misconception will lead to meaningful learning and as such the attitude of students towards chemistry cannot be overlooked since attitude and academic achievement are important outcomes of science education in secondary schools, students' attitude and interests tend to play substantial roles in their decision to study science (Abulude, 2009). Attitudes have been demonstrated to influence and be influenced by achievement and by cognition respectively. Researchers demonstrate that there is a link between the cognitive and the affective components of learning and that chemistry education goals should embrace the two and not treat them as mutually exclusive domains (Mbajiorgu & Reid, 2006). Research has also confirmed that attitudes are linked with academic achievement as demonstrated in a study by Salta and Tzougraki (2004).

1.3 Statement of the Problem

Students' poor achievement in Chemistry has been attributed to several factors. One of such factors is that most students experience much difficulty in their effort to learn many Chemistry topics and concepts (Sirhan, 2007). One of such difficult concepts in the Chemistry syllabus is electrochemistry. Previous studies (Lee & Kamisah, 2010) showed that the topic is difficult to learn because the concepts are abstract. Generally, some common misconceptions or problems faced by students in learning Electrochemistry are:

1. Students are always confused between the flow of current in the conductors and in the electrolytes;
2. They cannot identify the anode and cathode/positive and negative terminals of the cell;
3. They cannot describe and explain the processes happening at the anode and cathode;
4. They mix up the oxidation and reduction processes at the electrodes; and
5. They are unclear about the concept of electrolyte.

According to Kirsten (2007), misconceptions in science are common in students and affect how they learn, and how they view life. Changing these misconceptions should be a primary role of the science educator. Through student-centered instruction like guided inquiry and problem solving strategies, students are forced to take ownership of their learning and restructure their frameworks to fit new science concepts. Student's attitudes through active participation will hopefully be positive, as they become better life-long learners. Learning about science in a meaningful way involves realizing, reorganizing or replacing existing conceptions to accommodate new ideas (Smith & Blakeslee, 1993).

To improve students' achievement in electrochemistry, it is pertinent that the aspects of the concept which pose learning difficulties for students should be empirically and accurately identified, and teachers' attention drawn to it for proper handling during classroom interactions. Several strategies based on conceptual change approach were developed to overcome misconceptions that students have. One of these strategies involves the use of conceptual change texts. Conceptual change texts identify the misconceptions about electrochemistry concepts and correct them by giving analogies, examples, figures and scientific explanations.

Conceptual learning within a subject needs to be approached in a relevant manner, but the teaching must not lose sight of the fact that the attitudes of students need to be developed (Holbrook, 2005). Ramsay and Howe cited in Al-Abri, (2010) stated that a student's attitude towards science may well be more important than his understanding of science, since his attitude will determine how he will use his knowledge.

Bennett, Rollnick, Green and White (2001) also found that undergraduate students who had a less positive attitude to chemistry almost invariably obtained lower examination marks. Attitudes associated with science appear to affect students' participation in science subjects (Linn, cited in Salome, 2013). According to Keeves and Morgenstern as cited in Salome (2013), students' anxiety towards the learning of chemistry makes them lose interest in the subject. On the other hand, Deboer cited in Salome (2013) points out that students' achievement is influenced by favourable attitudes towards oneself (positive self-concept) as well as the subject.

It is therefore necessary to conduct research on misconceptions students have related to some chemistry concepts and use instructional models that would eliminate these misconceptions. In this study, conceptual change text was used as a teaching strategy to promote meaningful understanding of electrochemistry among students. The study also intended to investigate the effect of conceptual change texts oriented instruction on students' achievement and attitude toward electrochemistry.

1.4 Purpose of the Study

The purpose of this study is to determine the effect of conceptual change texts on students' attitude and achievement in electrochemistry.

1.5 Objectives

The objectives of the study were to:

1. determine the effect of conceptual change texts on students' cognitive achievements in electrochemistry.
2. determine the effect of conceptual change texts on students' attitudes toward electrochemistry.
3. ascertain the effect of conceptual change text instruction compared with the conventional method on students' attitudes and achievements in electrochemistry.

4. find out the difference in cognitive achievements of male and female students in electrochemistry before and after the treatments.
5. find out the difference in attitudes of male and female students toward electrochemistry before and after the treatments.

1.6 Research Questions

The research was guided by the following research questions:

1. What is the effect of the use of conceptual change text oriented instruction on students' achievements in electrochemistry before and after the intervention?
2. What is the effect of the use of conceptual change text oriented instruction on students' attitude toward electrochemistry before and after the intervention?
3. What is the effect of conceptual change text oriented instruction as compared to the conventional method of instruction on students' cognitive achievement?

1.7 Null Hypotheses

Five hypotheses were formulated from the research questions and tested at $p < 0.05$ level.

H_0 1: There is no significant difference between post-test scores of the students taught with conceptual change texts instruction and those taught with traditional instruction with respect to cognitive achievement in electrochemistry.

H_0 2: There is no significant difference between the post-test scores of students taught with the conceptual change text and those taught with the traditional method with respect to their attitude towards electrochemistry.

H_0 3: There is no significant difference between the post-test scores of students taught with the conventional method and those taught with conceptual change texts instruction.

H_0 4: There is no significant difference in cognitive achievement of male and female students in electrochemistry.

H_0 5: There is no significant difference in attitude of male and female students towards electrochemistry.

1.8 Alternative Hypothesis

H_A 1: There is a significant difference between post-test scores of the students taught with conceptual change texts instruction and those taught with traditional instruction with respect to cognitive achievements in electrochemistry.

H_A 2: There is a significant difference between the post-test and pre-test scores of students taught with the conceptual change text.

H_A 3: There is a significant difference between the post-test and pre-test scores of students taught with the conventional method.

H_A 4: There is a difference in cognitive achievement of male and female students in electrochemistry.

H_A 5: There is a difference in attitude of male and female students in electrochemistry.

1.9 Significance of the Study

Understanding the misconceptions and the preconceptions that the students hold prior to beginning their teaching, teachers may be able to better prepare their lessons in order to facilitate student success. This study will also allow teachers to better understand how students learn chemistry especially within the context of electrochemistry. The findings will assist teachers to develop programs that facilitate learning and meaningful conceptual change.

Being aware of the students' misconceptions, the teacher can focus on assisting learning to overcome these barriers to students' learning and foster the development of the students' cognitive processes.

This study would contribute to existing body of empirical research information in chemistry education at the Senior High School level.

1.10 Delimitation of the Study

This study was limited to only SHS 2 students of Damongo Senior High School and Ghana Senior High School.

There are many conceptual change models that can be used in science instruction to effect conceptual change, such as cooperative learning methods, concept maps, concept cartoons, mind maps, computer simulations, demonstration, analogies, and hands-on activities. However, this study is also limited to only conceptual change texts and how it can improve students' understanding of electrochemistry concepts. Also the study is limited to addressing only some misconceptions and conceptual change in electrochemistry.

1.11 Limitation of the Study

The design of the study is a quasi-experimental design, therefore there are some effects which may threaten the external validity of the study. One of them is the novelty effect. The novelty effect refers to the increased interest, motivation, or participation of the students because they are doing something different (Gay & Airasian, 2000). The other effect is diffusion of treatment which could occur when new instruction given to the experimental group is shared with the control group. This is a limitation because it may decrease the differences between the experimental and control groups in their pre-test and post-test scores.

1.12 Organization of the Study

The rest of the study is organized into five chapters. Chapter two presents a review of literature related to the major themes of this study and the theoretical framework guiding the study. Literature is reviewed about perspectives of conceptual change, alternative conceptions, and sources of misconceptions, conceptual change texts and the concept of attitude. The chapter ends with a review of misconceptions and difficulties in electrochemistry. The main focus of chapter three is the research methodology used in this study. This includes the quasi-experimental design, population and sampling, instruments used to collect data, data analysis methods, issues of validity and reliability of instrument, data collection procedures and data analysis.

Chapter four focuses on the presentation of the results obtained from the study. Chapter five discussed the findings of the study and draws connections, implications from previous studies on the topic. Chapter six provides a summary of the study, answers to the research questions, and then discusses the finding alongside with the implications. The conclusions are drawn upon which recommendations are made.

1.13 Operational Definition of Terms

Electrochemistry: the study of chemical reactions that produce electricity and how to use electricity to produce chemical reactions.

Conceptual Change Model (CCM): Model of science instruction created by Edward Posner (1982) is based on identifying and addressing student held misconceptions. It is a student based model that guides the learner through activities that directly challenge his/her personal misconceptions.

Conceptual change: Conceptual change is the process whereby concepts and relationships between them change over the course of an individual person's lifetime or over the course of history.

Misconception: Conceptual and propositional knowledge that is inconsistent with or different from the commonly accepted scientific consensus.

Conceptual change text (CCT): Conceptual change text is the text that identifies and analyses misconceptions, and it refutes these misconceptions that students have in their mind.

Conceptual understanding: to be able to interpret verbal or pictorial representations of scientific ideas.

Attitude: a predisposition either positively or negatively towards an object, thing or a person.

Cognitive Achievement: test scores as achieved in an examination or test.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

The literature review focused on the conceptual framework, conceptual change model, conceptual change texts, misconceptions in electrochemistry, empirical framework, difficulty in learning electrochemistry, concepts and conceptual change instruction, and the concept attitude. It also discussed the topics electrochemistry, oxidation and reduction reactions and balancing oxidation-reduction reactions.

2.2 Theoretical Framework

According to constructivist theory, learning can be viewed as a process of conceptual change. Conceptual change, within this realm, implies that a learner actively replaces existing pre scientific conceptions with scientifically acceptable explanations as new propositional linkages are formed in her/his conceptual framework (Kirsten, 2007).

The classical conceptual change model in science education arose from the work of Posner, Strike, Hewson and Gertzog (1982) based on students' epistemologies, that is, how students think about their world. In this conceptual change model (CCM), a student's dissatisfaction with a prior conception was believed to initiate dramatic or revolutionary conceptual change and was embedded in constructivist epistemological views with an emphasis on the individual's conceptions and his/her conceptual development. An important aspect of conceptual change is a learner's conceptual status. When a competing conception does not generate dissatisfaction, the new conception may be assimilated alongside the old. When dissatisfaction between competing conceptions reveals their incompatibility, two things may happen. If the new conception achieves higher status than the prior conception, conceptual exchange, may occur. On the other hand, if the old conception retains higher status, conceptual exchange will not proceed for the time being (Treagust & Duit, 2009). There are two major theoretical components of CCM:

1. The conditions that need to be fulfilled for an individual to experience accommodation. That is the four conditions proposed by Posner et al (1982);
    a. Dissatisfaction with the new concept,
    b. intelligibility of the new concept,
    c. plausibility of the new concept and
    d. the new concept must be fruitful.
2. Individual's conceptual ecology that provides the context in which the conceptual change occurs and has meaning (Hewson & Thorley, 1989). According to Posner *et al.,* a learner's conceptual ecology consists of their conceptions and ideas rooted in their epistemological beliefs.

The four conditions are graphically presented in figure 1.

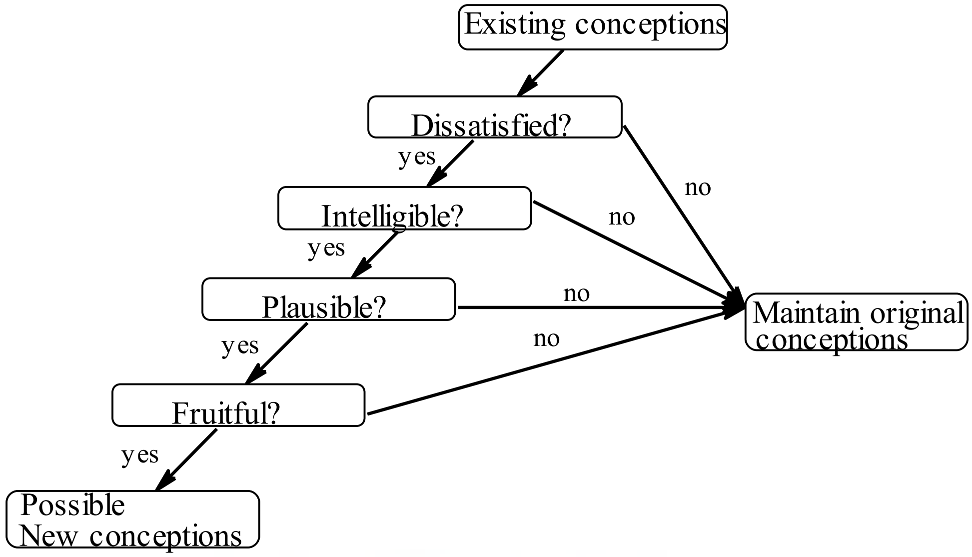

***Fig 2.1*: Posner et al's (1982) Conceptual Change Model**

Firstly, students have to collect a pile of contradictory information from the teacher or text and to conclude that their current concepts are not capable to explain these anomalies (Reads, 2004). In other words, they have to perceive a cognitive conflict which makes them dissatisfied with their present concepts (Beerenwinkel, 2014). Secondly, the students have to see how the puzzling information can be structured by the new concept. Thirdly, they have to trust in the capacity of the new concept, especially, that it can solve the problems caused by their prior concepts. Finally, the new concept should foster inquiry by opening new research areas (Posner *et al.* 1982).

The other theoretical component of CCM is learner's conceptual ecology that deals with the different kinds of knowledge the learner holds. The learner's conceptual ecology provides the context in which conceptual change occurs and has meaning (Hewson &Thorley, 1989). Posner *et al*. (1982) identified the components of conceptual ecology as;

1. anomalies,
2. analogies and metaphors,
3. epistemological commitments,
4. metaphysical beliefs and concepts, and
5. other knowledge.

Acceptance or rejection of a conception happens within the realm of conceptual ecology. The components of conceptual ecology provide a framework for determining the extent to which the conditions are met (Yuruk, Ozdemir & Beeth, 2003). Hewson (1981) expanded the CCM by building the idea of status. Hewson and Thorley (1989) defined status as the extent to which the conception is intelligible, plausible, and fruitful. Yuruk, Ozdemir and Beeth (2003) claimed that conceptual change is about raising and lowering the status of the conditions. Thus, learning a new conception means that its status rises. Strike and Posner cited in Yuruk, Ozdemir and Beeth (2003) also maintained that the initial CCM viewed conceptions or misconceptions as cognitive objects that are acted on by the pieces of conceptual ecology but are not part of it. According to them, this assumption ignores the influence of current conception on new perceptions and new ideas. Our current conceptions influence how we perceive the world. They claimed that misconceptions should also be considered as a piece in the conceptual ecology. Strike and Posner emphasized the interdependence and interconnectedness of past experiences, epistemological views of science, competing conceptions, analogies and metaphors. They argued for a developmental and interactionist view of conceptual ecology and conclude that the CCM must be more dynamic and developmental, emphasizing the shifting patterns of mutual influence between the various components of an evolving conceptual ecology (Yuruk, Ozdemir & Beeth, 2003).

The theory of Posner *et al.* cited in Beerenwinkel (2014) assumes that learning is a rational activity. In other words, humans comprehend and accept ideas because they are seen as intelligible and rational. The verification of these characteristics is done based on the available evidence. Despite this rational focus, Posner *et al.* cited in Beerenwinkel (2014) conceded that motivational and affective aspects are also important factors for effective learning. The view of learning presented in CCM is based on an analogy between knowledge construction in scientific communities and in individual learner, a view derived from the work of philosophers and historians of science, such as Kuhn (1970), Lakatos (1970), and Toulmin (1972). Thus, the initial CCM suggests that learners behave like scientists when confronted with new information (Yuruk *et al.,* 2003).

Conceptual change involves techniques of accommodation, restructuring, replacing, or reorganizing a concept (Taylor, 2001). Conceptual change points to the development and transformation of students understanding from their naive conceptions to scientific explanation (Uzuntiryaki, 2003). The model is based on constructivist theory in which knowledge acquisition is viewed as a constructive process that involves active generation and testing of alternative propositions (Cobern, 1996). The model has direct implications regarding how to construct instruction to achieve conceptual change (Read, 2004). Instruction should be designed to present anomalies so as to create cognitive conflict. This will create a disequilibrium, which leads to dissatisfaction with the existing concept, and ultimately to a willingness to accommodate a new concept. Teaching science should therefore focus on providing students with opportunities in which they have cognitive conflict and develop different structures based on their experience. Conceptual change can be accomplished if students are given opportunity to be aware of their ideas, to encounter ideas other than their own and to realize the deficiency in their reasoning. This can be promoted by group discussions which allow students to construct their own knowledge out of exchanges with their friends and the teacher. In this way, students can control their learning process (Uzuntiryaki, (2003). Conceptual change theory takes constructivism as its foundation, and addresses how thoughts must be altered in order to coincide with scientific theory (Meyers, 2007). Based on conceptual change theory, one of the first steps in remedying misconceptions is the identification of the misconception by the learner and the teacher. It is important to identify a misconception, because there is then a better chance at changing it (Uzuntiryaki & Geban, 2005).

Again conceptual change approach to science instruction represents an alternative approach designed to encourage students to alter preconceptions and it is based on Piaget's notions of assimilation, accommodation, and disequilibrium (Wang & Andre, 1991).

Posner *et al*. (1982) also defined conceptual change in terms of assimilation and accommodation. If a student uses existing concepts to deal with new phenomena, this is called assimilation. When the students' current concepts are inadequate to allow him to grasp a new phenomenon, then he replaces or reorganizes his central concepts.

Vosniadou cited in Yuruk *et al.* (2003) presented a different view about the nature of learners' preconceptions. Her theoretical framework suggests that learners' alternative conceptions do not result from the incoherent and inconsistent knowledge pieces, but result from learners' attempts to create coherent mental models. According to Vosniadou, concepts are embedded in larger theoretical structures that constrain them. She distinguished between naive framework theories and specific theories.

Vosniadou (1994) claimed that during cognitive functioning, individuals generate or retrieve mental models to provide causal explanations of physical phenomena or to predict the state of affairs in the physical world. Mental models are dynamic and generative representations which can constrain the knowledge acquisition process in a similar way to beliefs and presuppositions. According to Vosniadou (1994), conceptual change involves gradual changes in learner's ''synthetic" mental models with scientifically accepted mental models.

Vosniadou cited in Reads (2004) studied the mental models students construct about the shape of the Earth in grades 1, 3 and 5 in a number of countries. She found that young children seem to start with a mental model of the Earth as a flat or rectangular disc, which is supported from below by the ground, and is surrounded by the sky and other objects (such as the sun and moon) above its flat top. These models seem consistent with a child's everyday experience, and so are termed initial models, as they do not show any influence from instruction about a spherical Earth (Reads, 2004). Vosniadou termed them 'synthetic models'. Vosniadou described children as having a pre-existing framework theory which is derived from their observation of the world. She therefore describes conceptual change as a change of presuppositions and beliefs. Students are assumed to construct mental models to solve problems, and the formation of these models is supposed to be constrained by the individual's prior knowledge (Beerenwinkel, 2014).

According to Piaget, conceptual change occurs as a result of development of a child's logical capabilities and involves the domain-general modification of cognitive structures that affect the knowledge acquisition process (Schnotz *et al.,* 1999, cited in Reads, 2004). Piaget suggested that changes in these structures should influence reasoning ability and knowledge acquisition in all domains (Vosniadou, as cited in Reads (2004).

Vygotsky believed that the tools acquired from everyday experiences were closely related to real phenomena, but lacked coherence, whereas those acquired in a school environment were coherent but isolated from real phenomena by the context in which they were acquired. Thus, the purpose of instruction is to help bring these tools together, so that concepts acquired from everyday experience could be integrated into a coherent framework, and the tools acquired from school instruction become usable in everyday situations (Reads, 2004).

Chi, Slotta, and Leeuw (1994) viewed conceptual change based on the assumption that there are categorical differences between science concepts. Chi *et al.* as cited in Yuruk *et al*., (2003) proposed that entities in the word belong to three different ontological categories: matter (or things), processes and mental states. A category differs from the other in terms of some ontological attributes. For instance, entities within the matter category such as sand, paint, and human being have ontological attributes as ''being containable,'' ''storable,'' ''having volume and mass,'' and ''being colored.'' On the other hand, processes own their own set of ontological attributes. Chi *et al.* cited in Yuruk *et al*., (2003) argued that students have difficulty in encountering science concepts due to the existence of mismatch or incompatibility between categorical representation that students bring to an individual context, and the ontological category to which the science concepts truly belongs. According to this approach, misconceptions arise when the learner assigns a concept to a wrong ontological category. For example, students frequently assume that the force concept is under the category of matter rather than the subcategory of constraint-based interaction. As a result, they consider force as a kind of substance that an object possesses and consumes. When students who categorize force as matter are presented with new information about the concept of force, the new information will be assimilated into the matter category as well. Thus, students cannot understand the concept completely if the ontological category of the concept is not changed. According to this theoretical framework, conceptual change involves the reassignment of a concept to the appropriate category within the existing structure.

Chi *et al.* (1994*)* assumes that humans assign concepts into different categories. A wrong categorization according to the scientific view is called misconception. Conceptual change means reassigning concepts across ontologically different trees (Beerenwinkel, 2014).

Mortimer cited in Yuruk *et al* (2003) constructed another theoretical context that did not only consider ontological differences but took into account the ordered and context-reliant nature of epistemological and ontological distinctions among different usage of a single concept. Mortimer pointed out that a new concept does not necessarily replace alternative conceptions; instead individuals keep using their alternative conceptions in their daily life. His model is based on the notion of conceptual profile consisting of hierarchical zones, each of which is ontologically and epistemologically different from the others.

The conceptual profile of a concept differs from one learner to the other since the zones are strongly influenced by different personal experiences and have different cultural roots. Mortimer distinguished experts from novice students in that the experts are conscious of their conceptual profile and can use each concept in their profile in the appropriate contexts. The aim of teaching should be to help students become conscious of their conceptual profile and decide where each concept is applicable (Yuruk, *et al.,* 2003).

Categorization of concepts as espoused by Chi is supported by DiSessa (1993) view of intuitive concepts of learners as pieces. DiSessa (1993) claimed that learners' innate conceptions acquired from everyday experiences of the physical world do not possess a coherent structure, but rather they are isolated, fragmented "knowledge in pieces". These knowledges in pieces is called phenomenological primitives (p-prims). DiSessa (1993) went on to say that these knowledge pieces are primitive schemata constructed as a result of shallow interpretation of the physical reality. This means that, conceptual change occurs when there is a change in the functions of phenomenological primitives from relatively isolated, self-explanatory entities to the pieces of a larger system. In other words, conceptual change takes place when collection of phenomenological primitives can provide an internally coherent and systematic explanation for the complex conceptual structure.

DiSessa interprets conceptual change as the connection of various mental entities in complex ways. The learner has to integrate existing fragmented pieces of knowledge by reorganization and restructuring (Yuruk, Ozdemir & Beeth, 2003).

2.2.1 Instructional implications of different perspectives on conceptual change

Yuruk, Ozdemir, and Beeth (2003) summarized the instructional implications of the different perspectives on conceptual change as shown in Table 2.1.

Table 2.1: Instructional Implications of Different Perspectives on Conceptual Change

Theoretical perspective	View on conceptual change	Instructional implication
Knowledge in pieces (DiSessa,1993)	A change in the functions of p-prims from relatively isolated, self-explanatory entities to the pieces of internally coherent complex systems.	Helping students to become aware of their fragmented and isolated pieces of knowledge namely, their phenomenological everyday experiences and form more functional, complex and coherent mental models.
Concepts as Mental Models (Vosniadou,1994)	A gradual change in the coherent 'synthetic' mental structures constrained by their naive epistemological and ontological presuppositions.	Helping students to differentiate between their presuppositions and scientific ones, namely, helping them to be aware of their mental models and the presuppositions and beliefs that constrain their mental models.
Ontological Categories (Chi *et al*., 1994)	Reassignment of a conception in a scientifically appropriate ontological category.	Helping students to be aware of the ontological category to which they assign their conception.
Profile Change (Mortimer, 1995)	Changing the conceptual profile and acquiring the capability to distinguish the different zones of the profile.	Fostering students' consciousness about the zones of their profile, the associated epistemological and ontological commitments, and the functional differences of ideas in each zone among different contexts.

Instructional implications of conceptual change views (adopted from Yuruk, Ozdemir, & Beeth, (2003)

2.2.2 Alternative Conceptions

The terms alternative conceptions and misconceptions have the same meaning that can be used to refer to students' conceptions that are different from scientifically accepted ones (Ozmen, 2007; Taber & Tan, 2011). Conceptions that are inconsistent with the accepted scientific conceptions are defined as misconceptions. Researchers have used various terms for misconceptions, such as alternative conceptions, alternative frameworks, and preconceptions (Novick & Nussbaum, 1982; Nakleh, 1992).

Misconceptions are generally firmly established in student's schemata, thus, the students are reluctant to transform them (Sungur, Tekkay, & Geban, 2001; Balci, 2006) and as a result, students' learning difficulties often persist even after formal instruction in science classes. This is because misconceptions are integrated into their cognitive structure and interfere with students' subsequent learning. According to Ndlovu (2014), alternative conceptions in science are often deeply held, largely unexplained, and sometimes strongly defended. He stated that teachers frequently under estimate the importance and the persistence of these barriers to true understanding. This makes conceptual change a difficult task for teachers.

Following an extensive review of the research literature, Wandersee, Mintzes, & Novak cited in Wenning (2008) generated eight emerging research-based claims relating to alternative conceptions in science.

Claim 1: Learners come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events. Alternative conceptions span the fields from physics, and earth and space science to biology, chemistry, and environmental science. Each associated subfield within the disciplines seems to have its alternative conceptions.

Claim 2: The alternative conceptions that learners bring to formal science instruction cut across age, ability, gender, and cultural boundaries. No matter how gifted the group of students concerned, each group will have students with alternative conceptions regardless of their background.

Claim 3: Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies. Students' alternative conceptions are very difficult to change; only very specific teaching approaches have shown promise of getting students to accept new explanations.

Claim 4: Alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers. Students often hold to the same views as those held by very early scientists that are frequently referred to as "Aristotelian" in nature.

Claim 5: Alternative conceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture, and language, as well as in teachers' explanations and instructional materials. The many sources of alternative conceptions are at best speculative, but research and inference suggest that a student's worldview is strongly influenced by his or her social environment.

Claim 6: Teachers often subscribe to the same alternative conceptions as their students. It is not at all uncommon for science teacher educators to see alternative conceptions in their teacher candidates; likewise, even experienced science teachers and scientists with advanced degrees will sometimes cling to alternative conceptions that are also held by their students.

Claim 7: Learners' prior knowledge interacts with knowledge presented in formal instruction, resulting in a diverse variety of unintended learning outcomes. Not only can alternative conceptions be a hindrance to new learning; they can also interact with new learning resulting in "mixed" outcomes. It is not unusual to see different students draw different conclusions from the same experiences and observations.

Claim 8: Instructional approaches that facilitate conceptual change can be effective classroom tools. Several conceptual change approaches have been developed to identify, confront, and resolve problems associated with alternative conceptions.

2.2.3 Types of Misconceptions

According to Balci (2006) there are five major types of misconceptions namely preconceived notions, non-scientific beliefs, conceptual misunderstandings, vernacular misconceptions and factual misconceptions.

Preconceived notions are popular conceptions rooted in everyday experiences. For example, the thought that underground water must flow in streams may come from our daily experiences since people see the water flowing in streams in everyday life.

Nonscientific beliefs include views learned by students from sources other than scientific education, such as religious, culture and mythical teachings.

Conceptual misunderstandings arise when scientific information is taught in a way that does not challenge students' prior knowledge and result in conflicting situations. As an example for this type of misconception, students may know the definition of matter but do not accept air as matter.

Vernacular misconceptions arise from the use of words that mean one thing in everyday life and another in a scientific context. For example, the meaning of the term "work" in science classes is different from its meaning in everyday life (Vosniadou, 1994).

Factual misconceptions are inaccuracies often learned at an early age and retained unchallenged into adulthood. For example, lightning never strikes twice in the same place is an idea which is embedded in one's mind at an early age, but not true.

2.2.4 Sources of Misconceptions

Tentatively, students' conceptions are built from their interactions with other people or learning media. Demircioglu *et al*. (2005) gathered reports from previous researches and stated that sources of misconceptions in chemistry are due to daily life experience, traditional instructional language, teachers, mismatches between teacher and students' knowledge of science, changes in the meaning of chemical terms and textbooks. Schmidt *et al*. (2007) stated that previous researches reported that alternative conception is caused by students receiving misleading or erroneous concepts and information. Sanger and Greenbowe (1999) revealed that textbooks may contain misleading statements that would justify students' developing alternatives conception. Griffiths and Preston (1992) concurred with Driver and Easley (1978) that these conceptions are often strongly resistant to traditional teaching and form coherent, though mistaken, conceptual structures within the students' learning experience.

Misconceptions can occur when the learner is trying to make sense of a situation or phenomena in his/her environment (Balci, 2006). Often, these misconceptions happen at a very early age as the child interacts with the environment. Misconceptions can be formed due to several reasons such as cultural beliefs, encounters with other people including family members, and observations of others (Chin & Chia, 2004). According to Vosniadou cited in Balci (2006), children begin to acquire knowledge by organizing their sensory experiences under the influence of everyday culture and language into narrow, but coherent, explanatory frameworks and these frameworks may not be the same as currently accepted in science. This indicates the importance of children's experiences, everyday culture and language in knowledge construction. This implies that children's background and their previous knowledge play an important role in their understanding of new concepts and so they cannot be ignored during classroom instruction.

Haidar and Abraham cited in Balci (2006) found that formal reasoning and pre-existing knowledge plays an important role in the development of students' conceptions. They stated possible sources of misconceptions as:

1. Macroscopic reasoning: The students may have difficulty in translating observable behaviour of matter to the scale of atoms and molecules.
2. Instruction: the students may misinterpret instructional devices.

According to Uzuntiryaki (2003), another possible source of students' misconceptions is everyday knowledge. Students' interaction with their peer in social environment leads to certain misconceptions. Prieto *et al.* cited in Uzuntiryaki (2003) suggested that students' ideas were as a result of the interaction between their social and school knowledge.

According to Balci (2006), teachers themselves may be the cause of misconceptions. This happens when the teacher is unable to explain concepts well to students or when he uses complex language to confuse students. This can also be as a result of inadequate content knowledge held by the teacher. Students may misunderstand some concepts due to inadequate prerequisite knowledge of the teacher on the subject matter (Taber, 1995).

2.2.5 Techniques for Teaching Electrochemistry

Thompson and Soyibo cited in Corriveau (2011), reported that the addition of practical work to the usual combination of lecture, teacher demonstrations and class discussions improved students' test score and attitudes. Chemistry is a practical subject and many of the topics cannot be taught without practical. Practical lessons help students to see and appreciate many of the abstract things they learn in chemistry class and also underscored the macroscopic level of Johnstone's chemistry learning. Ozkaya and colleagues (2006) used conceptual change texts that evoke learners' preconceptions, caution learners about common misconceptions and contrast the misconceptions with scientifically accepted conceptions by using examples and explanations. These conceptual change texts were immediately followed by two tier assertion-reason style questions to better assess learning and uncover misconceptions. Improved post-test scores were noted on both conceptual and algorithmic test questions, which the researchers attributed to improved understanding of how electrochemistry concepts are related and an ability to organize relevant concepts in related categories. Conceptual change texts were proven by researchers to be an effective way of teaching chemistry to bring about conceptual change. Acar and Tarhan (2006) reported success with using student cooperative learning groups and computer animations. Other researchers also reported improved understanding with the use of computer simulations (Ceyhun & Karagolge, 2005; Sanger & Greenbowe, 1997b).

2.2.6 Instructions for Changing Alternative Conceptions

Conceptual change in learning can be viewed from the words assimilation-which here means when a student uses existing ideas to explain a new phenomenon-and accommodation, when a student uses inadequate current conceptions to explain a new phenomenon, thus needing to reorganize and replace current conceptions (Posner, Strike, Hewson & Gertzog, 1982).

To promote conceptual understanding and eliminate learners' misconceptions, various conceptual change approaches were suggested by some researchers (Treagust & Duit, 2008; Vosniadou, 2007; Taslidere, 2013). These approaches and strategies were derived from Kuhn's philosophy of science and Piaget's cognitive developmental theory (Zhou, 2010; Taslidere, 2013).

Different researchers proposed different strategies of remedying or overcoming these misconceptions and learning difficulties of learners (Ndlovu, 2014). These include Computer animations/simulations (Yang, Andre & Greenbowe, 2003, 2004; Doymus, Karacop, & Simsek, 2010), computer assisted-learning (Talib, Matthews, & Secombe, 2005; Hartley, Treagust, & Ogunniyi, 2008) and models (Huddle *et al*., 2000; Sanger & Greenbowe, 2000). Other researchers also suggested co-operative learning (Acar &Tarhan, 2007) and the use of conceptual change text and jigsaw puzzle technique as well (Yuruk, 2007).

Building on this idea of promoting conceptual change, Karsli and Ayas (2011) combined different conceptual change techniques such as computer animations, conceptual change text, worksheet and hands-on activities to build a 5E learning model. In this model, the 5 Es' represent: engagement, exploration, explanation, elaboration, and evaluation. Research has shown that conceptual change text proved to be effective in changing students' misconceptions. Thus this study used conceptual change texts approach to teach electrochemistry to ascertain its effect on students' cognitive achievement and attitude.

2.3 Conceptual Change Texts

According to Balci (2014), conceptual change texts are texts designed to change students' alternative conceptions and focus on strategies to promote conceptual change by challenging students' alternative conceptions, producing dissatisfaction, followed by a correct explanation which is both understandable and plausible to the students. In these texts, the identified alternative conceptions of the students are given and then activated by presenting them with situations designed to elicit a prediction based on them. Alternative conceptions are challenged by introducing common alternative conceptions followed by evidence that they are wrong. Finally, students are informed of the correct explanations supported by examples.

Conceptual change texts are also referred to as refutational texts since they usually try to produce a cognitive conflict by refuting an alternative idea held by the student. They generally adhere to the following pattern (Chambliss 2002; Beerenwinkel, 2014).

1. Presentation of the naive ideas based on everyday experiences
2. Demonstration of the limitations of the naive ideas
3. Presentation of the scientific concept
4. Highlighting how the scientific concept addresses the limitations

Conceptual change texts seem to be an important medium to support instruction which aims at fostering conceptual change. Conceptual texts present students with information that directly conflicts with their current beliefs (Hynd, 2001). This conflict that conceptual change texts provide is essential in motivating students to improve their conceptual models. The teacher should frequently pause to stimulate whole class discussion on what is being covered by the text. This discussion allows for students to voice their misconceptions and also ensures that all students comprehend the text, regardless of their reading ability (Guzzetti, 2000).

Conceptual change texts are different from traditional textbooks because they target the reader's specific misconceptions (Cetingul & Geban, 2011). Conceptual change text styles may vary from author to author but the overall format remains the same. The reader is first asked a question or asked to make a prediction about a scientific concept. Secondly, the reader is presented with commonly held misconceptions about the concept. When the reader sees similarity in his or her thinking, cognitive dissonance takes place and the need for correction is realized (Durmus & Bayraktar, 2010). Thirdly, the reader is given a correct explanation of the concept if his/her idea is scientifically incorrect. Finally, the reader is asked to answer questions that solidify understanding and demonstrate accurate remediation of his/her prior misconceptions (Ozkan & Selcuk, 2013). This process of the conceptual change text successfully fulfills Posner's requirements for conceptual change: creates dissatisfaction with the original misconception and provide the reader with an explanation that is intelligible, plausible, and fruitful (Posner et al, 1982). Research suggests that it is most effective to allow students to read each section silently and then to pause for class discussion after each section (Cetingul & Geban, 2011). During discussion, students can express their thoughts and clarify their own thinking through social constructivism (Sungur, Tekkaya, & Geban, 2001). Another benefit of pausing is that it allows the teacher to provide clarification and summarize key points for struggling readers.

2.3.1 Related literature

Chambers and Andre (1997) investigated the effect of conceptual change texts on students' understanding of concepts in electrochemistry and showed that students who received a conceptual change text instruction significantly improved their performance in their understanding of electricity concepts as compared to traditional texts. In another study, Hynd, McWhorter, Phares and Suttles (1994) reported the effectiveness of conceptual change texts on bringing about conceptual change and promoting meaningful learning in students regarding Newton's laws of motion. Yuruk and Geban (2001) as well as Cakir, Uzuntiryaki, and Geban (2002) reported that instruction based on conceptual change texts resulted in a significantly better acquisition of scientific conceptions related to electrochemical cells, and acids and bases as compared to a traditional style instruction.

Chambers and Andre cited in Balci (2006) investigated the effect of conceptual change texts on students' understanding and showed that subjects who received a conceptual change text instruction significantly improved their performance in their understanding of electricity concepts as compared to traditional texts. In addition, Tekkaya (2003) who investigated the effectiveness of combining conceptual change texts and concept mapping strategy on students' understanding of diffusion and osmosis found out that there was a statistically significant difference between the experimental and control groups in favor of the experimental group after treatment. Sungur, Tekkaya and Geban (2001) investigated the contribution of conceptual change oriented instruction to students' understanding of the human circulatory system. They used conceptual change texts accompanying by concept mapping in order to teach the concepts. The results of this study revealed that conceptual change texts accompanied by concept mapping instruction produced a positive effect on students' understanding of the concepts.

Gunay (2005) investigated the effectiveness of conceptual change text oriented instruction accompanied with analogies over traditionally designed chemistry instruction on 10th grade students' misconceptions, their understanding of atoms and molecules concepts. The result of the study showed that the conceptual change text oriented instruction accompanied with analogies provided better conceptual understanding of atoms and molecules and gave more opportunities to eliminate the misconceptions about atoms and molecules concepts than the traditional instruction in chemistry.

Geban and Bayir (2000) conducted a research to investigate the effectiveness of conceptual change texts instruction over the traditionally designed chemistry instruction on students' understanding of chemical change. The result of the study showed that students in conceptual change text instruction group had a significantly higher score with respect to achievement than students in the traditionally designed instruction group. Uzuntiryaki and Geban (2005) explored the effect of conceptual change texts accompanied with concept mapping instruction on 8th grade students' understanding of solution concepts. The results revealed that conceptual change text accompanied with concept mapping instruction caused a significantly better acquisition of scientific conceptions about the solution concepts.

Cakir, Uzunkiyati and Geban (2002) compared the effects of concept mapping and conceptual change texts instruction over the traditional instruction on tenth grade students' understanding acid and base concepts. 110 students from 6 classes of a chemistry course taught by the same teacher were enrolled in the study. There were four experimental group classes and two control group classes. Two experimental groups classes were instructed with concept mapping instruction; and the other two experimental groups were taught with conceptual change texts instruction and the next two classes were assigned as control group and instructed with traditional method. All students were then administered an acids and bases concept pre-test and post-test. When two-way ANOVA was used for statistical analyses, the results showed that concept mapping instruction and the conceptual change texts instruction caused a significantly better acquisition of scientific conceptions related to acids and bases than the traditional instruction.

Sungur, Tekkaya, and Geban (2001) determine the results of promoting conceptual change through the use of conceptual change text and concept mapping. The result of the study indicated support for facilitation of environment consisting of debate, discussion, and increased participation. The students realized and became dissatisfied with their misconceptions and were more receptive to the new correct information. They realized the new concept was more meaningful through active involvement.

Guzetti, Snyder, Glass and Gamas cited in Gunay (2005), found that refutational text was more effective than regular or traditional text for conceptual change, and concluded that these texts are, at least, more effective to support conditions suggested by Posner, Strike, Hewson and Gertszog. Canpolat, Pinarbasi, Bayrakceken, & Geban (2006) investigated the effect of a conceptual change approach over traditional instruction on students' understanding of chemical equilibrium concepts. The results showed that the students in the experimental group performed better than those in the control group.

2.3.2 Difficulty in Learning Redox Reactions

Redox reactions are perceived to be one of the most difficult areas both to learn (de Jong and Treagust, 2002) and to teach (de Jong *et al.,* 1995). Three important difficulties that students have were identified as:

- difficulties in comprehending oxidation and reduction as complementary reactions (de Jong and Treagust, 2002);
- difficulties in identifying oxidizing and reducing agents (imprecise terminology and complex language use) (de Jong and Treagust, 2002);

- the undersatanding that a redox reaction is defined as a loss and a gain of oxygen (Garnett & Treagust, 1992; Osterlund & Ekborg, 2009).

According to de Jong and Treagust (2002), teachers perceive redox as one of the most difficult topics to teach and research has shown that students have difficulties in conceptualizing redox reactions (Osterlund, 2003). One of the problems noted by the teachers, and reported in De Jong *et al.* (1995) is how the teachers explain the transfer of electrons in such a way as to enable students to adopt the electron model correctly. These difficulties faced by teachers led to creating more misconceptions for students. de Jong and Treagust cited in Osterlund (2003) noted that students regard oxidation and reduction as independent reactions; they have problems with the meaning and assignment of oxidation numbers and the identification of reactants as oxidizing or reducing agents.

Gilbert (2006) described a list of problems that challenge the teaching of chemistry. Amongst these are the students' difficulties with solving problems where the same concept is used but in different contexts. Soudani, Cros and Medimagh (2000) showed in their study that university students have problems in the use of associated redox concepts in everyday contexts. As the concepts oxidation and reduction are found in various redox models, this can sometimes lead to mistaken interpretations of what is oxidized and what is reduced (Osterlund, 2003).

Literature shows that teachers perceive redox as one of the most difficult topics to teach. According to de Jong et al. (1995), teachers experience difficulties in making students adopt the electron model over the oxygen model. Ringnes (1995) on the other hand reported that most students define an oxidation as a loss of electrons, while only few are able to demonstrate the electron transfer in equations. In a study by Garnett and Treagust (1992), students were asked to explain which inorganic equations represented oxidation-reduction reactions. Many students explained the reaction in which oxygen was a participator as a redox reaction. Schmidt (1997) stated that students identify oxidation as an addition of oxygen, and reduction as the removal of oxygen and suggest that this could be due to the syllable "ox" in redox. Soudani, *et al.* (2000) explained that though university students relate the words oxidation and reduction to electron transfer, the students, however, fail to use theoretical redox knowledge in everyday situations such as the combustion of petroleum.

2.3.3 Understanding Electrochemistry

Research has shown that algorithmic understanding of a topic does not necessarily translate into conceptual understanding in chemistry (Nakhleh, 1993; Corriveau, 2011). Regarding student difficulties with electrochemistry, Niaz (2002) reported that the ability to solve routine problems based on memorized formulae does not transfer readily to problems that require conceptual understanding. Ceyhun and Karagolge (2005) also reported that students who held misconceptions regarding electrochemical concepts were still able to calculate cell potentials correctly. Ozkaya (2002) attributes learning difficulties in electrochemistry to a general lack of conceptual understanding and attributes this to insufficient textbook explanations of these concepts. Research has shown that students have difficulties in conceptualizing redox reactions (de Jong & Treagust, cited in Osterlund, 2009). They found that students regard oxidation and reduction as independent reactions; students have problems with the meaning and assignment of oxidation numbers and the identification of reactants as oxidizing or reducing agents. Schmidt as cited in Osterlund (2009) found that many students believe that oxygen always takes part in all redox reactions and that oxygen is a pre-requisite for a redox reaction. According to Sirhan (2007), numerous reports supported the view that the interplay between macroscopic and microscopic worlds is a source of difficulty for many chemistry learners. Examples such difficult topics include electrochemistry, chemical change and reactivity, balancing redox equations. According to Bradley and Brand, as cited in Sirhan (2007), one of the essential characteristics of chemistry is the constant interplay between the macroscopic and microscopic levels of thought, and it is this aspect of chemistry learning that represents a significant challenge to novices. Real understanding of chemistry demands the bringing together of conceptual understandings in a meaningful way. According to Johnstone and Bodner as cited in Sirhan (2007), what is taught by teachers is not always what is learned by students. They added that while students show some evidence of learning and understanding in examination papers, research showed evidence of misconceptions and rote learning of certain areas of basic chemistry which are still not understood. Johnstone (1984, 1991) indicated that the nature of chemistry concepts and the way the concepts are represented (macroscopic, microscopic, or representational) make chemistry difficult to learn.

2.3.4 Perception and misconceptions in electrochemistry

Electrochemistry is the study of the inter-conversion of electrical and chemical energies which involves many examples of chemical observations, chemical reactions and symbols. According to Ahmad and Che-Lah, (2012), there are two main electrochemical cells: the electrolytic and voltaic (galvanic) cells. These two cells have similar related features such as having two electrodes that are dipped into a solution known as electrolyte, and these two electrodes are connected to positive and negative terminals. Even though both electrochemical cells have similar terminologies, the outcomes for their chemical changes and reactions are different from one another. For example, in the electrolytic cell, the 'positive terminal' is known as the anode, whilst in the voltaic cell, the negative terminal is similarly known as the anode (Ahmad & Che-Lah, 2012). In electrolytic cells, electricity introduced from an outside source is used to push nonspontaneous, but desired, chemical reactions to occur. For example, electrolysis is used to produce pure sodium metal and chlorine gas from common table salt. Electrolysis is also the principle employed in electroplating, a process that is used to cover a cheaper metal with a second metal that is more resistant to corrosion, such as chromium. Electrochemical cells of both types involve movement of electrons and ions (Corriveau, 2011). Electrochemistry has been widely reported as being one of the most difficult topics in chemistry because it contains many ambiguous and abstract terms and has an apparent lack of consistency and logic in its representation (Sanger & Greenbowe, 1997a & 1997b; Ozmen, 2004; Ozkaya *et al.,* 2006; Schmidt *et al.,* 2007; Ahmad & Che-Lah, 2012).

Electrochemistry is regarded as one of the most difficult chemistry concepts in which both pre-service teachers and students have learning difficulties (Ozkaya, 2002; Akram, Bin Surif, & Ali, 2014; Ndlovu, 2014). Huddle, White and Rogers (2000) found that a few students in their study had a coherent concept of the purpose of the salt-bridge. On redox reactions, they found that learners think that electrons are lost and thus reduction takes place. Garnett and Treagust (1992a) administered questions on concentration cells to introductory college students after electrochemistry teaching to determine misconceptions. The misconceptions include: the notion that water is not reactive in the electrolysis of aqueous solutions, students believed that electrons flow through the electrolyte and salt bridge to complete a circuit and the negative sign which are assigned to electrodes represent net electron charges. Students also had the notion that cell potentials are absolute and can be used to predict if the half-cell reactions are spontaneous or not and the cell potential are independent of ion concentrations (Ozmen, 2004). The results showed that students lacking an understanding of the electrochemical concepts were still able to solve quantitative examination questions. These results were confirmed by Schmidt et al. (2007, p.258) who argued that learners' alternative conceptions arise from the teaching method in which the learners first experience and learn about electrochemistry concepts and the lack of understanding of the concept terms used.

Hamza and Wickman (2007) found that learners had misconception about the electrode processes as portrayed by one learner's response who said that ''the anode should be positive because it loses electrons''. Learners seem to think that the cathode is always on the right and the anode on the left. Linked to this misconception, many learners interpret a negative electrode to imply that the electrode is negatively charged. The report also indicated that learners struggle with questions that require the use of the Table of standard reduction potentials. Sanger and Greenbowe (1997) in a study found that many learners think that the first half cell is always the anode and the other is the cathode. Garnett and Treagust (1992a) concluded that students holding misconceptions about the way electricity is conducted in metallic conductors and electrolytes are highly unlikely to understand the operation of electrochemical cells. In a subsequent study, Garnett and Treagust (1992) found that students holding the misconceptions that “an electric current only involves drifting electrons” and that “the anode and cathode are charged” were unable to explain the movement of charges in electrochemical cells correctly.

According to Schmidt, Marohn and Harrison cited in Taha (2014) in a study to identify and understand secondary-school students' problems in learning electrochemistry at an introductory chemistry level. The investigation covered four areas: electrolytes, transport of electric charges in electrolyte solutions, the anode and the cathode, and the minus and plus poles. Written tests were given to high-school students in five cycles. They found that students based their reasoning on four alternative concepts:

(a) During electrolysis, the electric current produces ions;

(b) electrons migrate through the solution from one electrode to the other;

(c) the cathode is always the minus pole, the anode the plus pole; and

(d) The plus and minus poles carry charges.

Ndlovu also identified the following misconceptions about the salt bridge:

- Learners think that ions move through the salt bridge from the one half-cell to the other half-cell.
- Ions move from the salt bridge into the half-cells to ensure that no built-up of charge takes place at the electrodes.

Common incorrect answers that students gave were that the salt bridge:

- Maintains neutrality of the cell (should be electrical neutrality);
- Completes the cell /current (instead of completes the circuit);
- Connects the half-cells
- Transfer Cu^{2+} ions to Pb^{2+} ions and Pb^{2+} ions to Cu^{2+} ions
- allows ions to move from the anode to the cathode or from the cathode to the anode
- Transfers electrons
- Separates the two electrolytes and
- Transports charge.

This was in line with observation made by Huddle, White and Rogers (2000) who found that a few students in their study had a coherent concept of the purpose of the salt-bridge.

Hamza and Wickman (2007) made a similar observation when students where asked if they know what happened at the anode and cathode electrodes.

2.3.5 Causes of misconceptions in electrochemistry

Reasons for the misconceptions are varied, including textbook authors and teachers who are guilty of making unintentional simplifications or using unclear and misleading terminologies (Acar & Tarhan, 2006; Sanger & Greenbowe, 1999; Corriveau, 2011). According to Sanger and Greenbowe cited in Corriveau (2011), over simplification of a voltaic cell with the anode on the left side, inferring that the relative location of the electrode determines the nature of the particular oxidation (or reduction) reaction that occurs there is a cause of misconception. Terms with multiple meanings add to students' general confusion. For example, electrolysis can be interpreted as chemically breaking apart by means of electricity, yet this definition does not necessarily correctly explain the purpose or action of an electrolytic cell (Schmidt, Marohn, & Harrison, 2007). The purpose of an electrolytic cell is not to break up a substance into ions, but to take existing ions out of a molten salt (or a solution) and form elemental substances from them through oxidation or reduction reactions (Corriveau, 2011).

Also, students may incorrectly reapply a term learned in another context, such as asserting that the cathode electrode should always be represented by a negative charge because they had previously learned in physics that a cathode ray was made up of negatively charged electrons. Another issue that adds to the difficulty of understanding electrochemistry is the relative nature of electrochemical cell potentials (Sanger & Greenbowe, 1997a). Like several other chemistry topics, including enthalpy and free energy, chemists cannot make absolute potential measurements of a single oxidation (or reduction) reaction but must compare each half reaction to a mutually agreed upon standard, the standard hydrogen electrode. Only in comparison to this seemingly arbitrary standard can cell potential be quantified. Another common misconception pertains to the convention of using charge symbols (i.e., + and -) to designate the anode and cathode in electrochemical cell drawings. The electrodes actually carry extremely small net charges. In a voltaic cell, the designated positive or negative signs symbolize the relative tendency to be oxidized or reduced, and thus are used to identify the anode or the cathode. But, in lieu of a thorough conceptual understanding, students will attempt to use previously acquired general knowledge, such as attempting to use the designated electrode charges and electrostatic arguments, to (incorrectly) explain how and why the various charged particles flow in particular directions in an electrochemical cell (Ozkaya et al., 2006).

2.3.6 The concept attitude

An attitude may be defined as a predisposition to respond in a favorable or unfavorable manner with respect to a given attitude object (Oskamp & Schultz, 2005; Cheung, 2011). The attitude object can be anything, such as chemistry, chemists, chemistry lessons, topics taught in school chemistry, inquiry-based chemistry laboratory experiments, chemical education research, chemical weapons, or industrial chemistry (Cheung, 2011).

Oskamp and Schultz (2005) described that there are three major theoretical viewpoints about the important nature of attitudes that have been proposed by social psychologists: the tri-component point of view, the separate entities point of view, and the latent process perspective. Affect, behaviour, and cognition are the three components of attitude which is a single entity the tri-component viewpoint holds. The thoughts and emotions one has toward an attitude object such as chemistry lessons and chemistry as a subject are referred to as affective point of view. The individual's explicit events and reactions to the attitude object is referred to as behavior component of attitude, while the cognitive factor is the thinking or belief that someone has about the attitude object. The second theoretical viewpoint about the nature of attitudes assumed that the three components, affect, behavior and cognition are unique and separate entities.

The third theoretical point of view views attitudes as a latent variable that can explain the connection between certain observable stimulus events and behaviors.

Attitudes have been demonstrated to influence and be influenced by achievement and by cognition respectively. Researches demonstrated that there is a link between the cognitive and the affective and that chemistry education goals should embrace the two and not treat them as mutually exclusive domains. According to Mbajiorgu *et al* (2006), there are four areas where attitudes are important: attitudes towards chemistry; attitudes towards topics and themes in chemistry; attitudes towards the learning of chemistry; and scientific attitudes. According to Xu (2010), given a particular object about which an attitude exists, "cognition" refers to how people think about the object, i.e. knowledge and beliefs about properties of the object (including both favorable and unfavorable judgments). "Affect" pertains to how people feel about the object (both good and bad feelings), as expressed via physiological activity or overt communication. "Behaviour" is overt actions with respect to the object as well as intentions to act (again, both positive and negative actions and intentions).

2.3.7 Empirical research on students' attitude toward chemistry

Research has confirmed that attitudes are linked with academic achievement. For example, Salta and Tzougraki (2004) found that the correlation between high school students' achievement in chemistry and their attitudes toward chemistry ranged from 0.24 to 0.41. Bennett, Rollnick, Green and White (2001) also found that undergraduate students who had a less positive attitude to chemistry almost invariably obtained lower examination marks. Attitude, motivation, and genuine interest are the most important student characteristics associated with successful studies (Dalgety et al., 2003; Berg, 2005b). Attitude towards chemistry is essential; it denotes interests or feelings towards studying chemistry. Attitude and academic achievement are important outcomes of science education in secondary schools. Students' attitude and interests could play substantial role in students' decision to study science (Abulude, 2009). Another reason why it is important to develop students' positive attitudes toward chemistry lessons is that attitudes predict behaviors (Glasman & Albarracín, 2006; Kelly, 1988). For example, Kelly cited in Cheung, 2011 reported that British students' liking for a particular science subject was a good predictor of their actual choice of physics, chemistry, or biology in schools.

Research has shown clearly that a negative attitude towards chemistry is the dominant factor affecting student willingness to study further chemistry. Based on social psychological models, it has been shown that attitudes towards topics and themes in chemistry are developed by means of interactive teaching materials. The development of students' positive attitude is necessary because attitude is linked with academic achievement (Cheung, 2009). Weinburgh, (1995) in a meta-analysis of research have summarized that the correlation between students' positive attitude towards science and academic achievement is 0.55 for girls and 0.5 for boys, indicating that an attitude can account for 25-30% of the variance for academic achievement. The correlation between high school students' achievement in chemistry and their attitudes toward chemistry ranged from 0.24 to 0.41, (Salta & Tzougraki, 2004). On the basis of attitude, the prediction of behavior is possible which is another reason why it is important to develop students' positive attitude towards chemistry, (Glasman & Albarracin 2006; Kelly 1988). According to Yara (2009) teacher attitude and the method of teaching can greatly influence students' attitude. Bennett, Rollnick, Green and White (2001) also found that undergraduate students who had developed a lower constructive attitude towards chemistry almost always got low grade in examinations. Olatoye cited in Abulude, 2009 found that students' attitude towards chemistry have significant direct effect on students' achievement in the subject.

2.4 Students Attitude towards the Study of Electrochemistry

Chemistry curricula commonly incorporate many abstract concepts, which are central to further learning in both chemistry and other sciences (Taber, 2002). Chemistry topics are generally related to or based on the structure of matter, and proved to be a difficult subject for many students (Sirhan, 2007). According to Yochum & Luoma cited in Sia, Treagust & Chandrasegaran (2012) students find electrochemistry difficult to master because they cannot observe or imagine what happens in the microscopic level in an electrochemical reaction.

According to Taber as cited in Akram *et al.* (2014), electrochemistry causes confusion in students and they did not freely assimilate their knowledge across physics and chemistry. Sanger and Greenbowe (1997) cited in Akram *et al.* (2014) found that students had learning difficulties about galvanic, electrolytic and concentration cells.

Electrochemistry has been regarded as one of the most difficult chemistry topics in which both students and teachers have difficulties (Nakhleh, 1992; Ogude and Bradley, 1994).

Ogude and Bradley as cited in Rollnick and Mavhunga (2014) showed that even college students have difficulties with the qualitative interpretation of the microscopic processes that take place in operating chemical cells.

2.5 Gender Difference in Cognitive Achievement and Attitude towards Chemistry

According to Feist as cited in Liu, Hu, Jiannong, and Adey (2010) gender has a significant influence on the development of science attitudes. Gender differences have been found in students' science-related affective attitudes, boys having a more positive attitude towards science than girls. Girls reported that science was difficult to understand, whereas more boys reported that science is destructive and dangerous, and therefore more "suitable" for boys (Jones, Carter, & Rua, 1999; Weinburgh, 1995). Gender differences in science-related affect appear to develop during the school years, with students experiencing many changes in factors such as anxiety, interest, and self-confidence.

Ajewole and Greenfield cited in Abu- Hola (2005) reported no significant differences between boys and girls in their attitudes towards science. Catsambis cited in Abu- Hola (2005) found males had a more positive attitude than females, but that no differences in science achievement were noted. Graig and Ayres cited in Zuway *et al* (2011) found that boys demonstrate a higher level of interest than girls in both physics and chemistry and that boys display less variation between subject areas than girls. They added that girls continue to express a strong interest in biology from primary through secondary school, but their interest in chemistry and physics appears to weaken considerably during the first year of secondary school. Osborne and Dillon cited in Hofstein and Mamlok-Naaman (2011) opined that girls and boys differ in their interest in science related topics.

According to them, boys showed interest in topics such as explosive chemicals, how it feels to be weightless in space, how the atom bomb functions, biological and chemical weapons and what they do to the human body. In contrast, girls showed interest in why we dream when we are sleeping and what the dreams might mean, cancer-what we know and how we can treat it, how to perform first aid and use basic medical equipment, and how to exercise the body to keep fit and strong (Hofstein & Mamlok-Naaman, 2011).

Weinburgh cited in Abu- Hola (2005) found that boys have a more positive attitude towards science than girls. Levin, Sabar and Libman cited in Abu- Hola (2005) found that the achievement of boys in all subject areas of their study (earth science, biology, chemistry and physics) was significantly better than the achievement of the girls. The results Levin, Sabar and Libman agreed with that of Cheung (2011) who found no statistically significant difference between males and females regarding attitude toward chemistry lessons. Cheung (2009) revealed that girls had a more favorable attitude towards studying chemistry than did boys. A meta-analysis conducted by Steinkamp and Maehr cited in Salta, & Tzougraki (2004) showed that girls had more positive attitudes towards chemistry compared with boys. Greenfield cited in Salta and Tzougraki (2004) found no gender differences in science-related attitudes between boys and girls. Salta and Tzougraki, (2004) found no differences between boys' and girls' attitudes regarding the interest, usefulness, and importance of chemistry and that girls, more than boys, tend to express negative attitudes regarding the difficulty of chemistry courses.

Majere, Role and Makewa (2012) found that male students had a significantly better attitude towards physics than towards chemistry. The female students, on the contrary, had a better attitude towards chemistry than towards physics, although the difference is not statistically significant. The self-concept of both female and male students in physics was much higher than they had in chemistry. With regard to attitude towards chemistry and Physics, the boys and girls had the same attitude, mixed and single-sex school students had comparable attitude towards physics and chemistry. Jones, Howe and Rua cited in Cherian and Shumba (2011) found that unlike chemistry or physics, girls expressed a more positive attitude toward biology than boys.

Many studies have agreed with the observation that male students usually outperform female students in assessments particularly in the areas of mathematics and science (Beller & Gafni, 2000; Neuschmidt, Barth, & Hastedt, 2008; Korporshoek, Kuyper, van der Werf, & Bosker, 2011).

2.6 Conceptual Framework of the Study

According to Maxwell cited in Robson (2002), conceptual framework is the system of concepts, assumptions, expectations, beliefs and theories that support and inform your research. The conceptual framework that guided the study was developed from the literature reviewed. The framework is made up of seven components and shows the relationship among the components and how they influence students' achievement and attitude towards electrochemistry.

The conceptual framework of the study is illustrated in Fig 2.2 below.

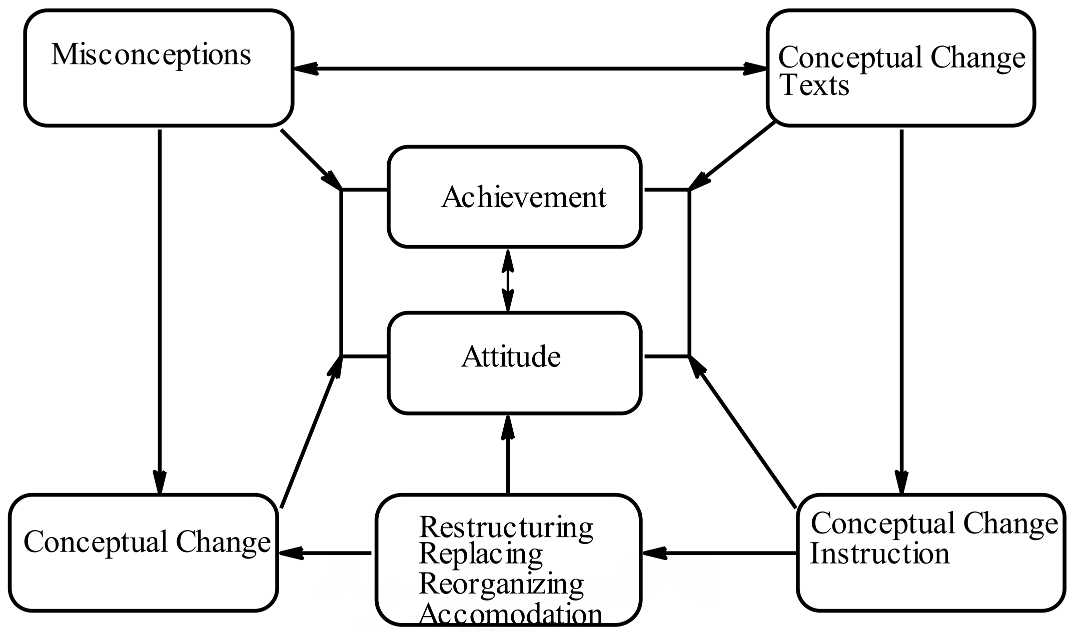

***Fig 2.2*: Conceptual Framework of the Study**

Students hold a lot of naive conceptions about electrochemistry. Conceptual change texts are used as a teaching strategy to promote meaningful understanding of electrochemistry among students. Conceptual change texts have been proven by researchers to be an effective way of teaching chemistry to bring about conceptual change. Based on conceptual change theory, one of the first steps in remedying misconceptions is the identification of the misconception by the learner and teacher. It is important to identify a misconception, because then there is a better chance at changing it. Conceptual change approach to science instruction represents an alternative approach designed to encourage students to alter preconceptions. Conceptual change involves techniques of accommodation, restructuring, replacing, or reorganizing a concept (Taylor, 2001). Conceptual change points to the development and transformation of students understanding from their naive conceptions to scientific explanation (Uzuntiryaki, 2003). The development of students' positive attitude is necessary because attitude is linked with academic achievement (Cheung, 2009). Attitudes have been demonstrated to influence and be influenced by achievement and by cognition respectively.

Attitudes associated with science appear to affect students' participation in science subjects and impacts in science. Attitudes influence students' achievement and their cognition. There is an association between students' achievement in chemistry and their attitudes toward chemistry.

2.7 Summary

Conceptual change involves techniques of accommodation, restructuring, replacing, or reorganizing a concept (Taylor, 2001). Conceptual change points to the development and transformation of students understanding from their naive conceptions to scientific explanation (Uzuntiryaki, 2003).

Electrochemistry has been widely reported as being one of the most difficult topics in chemistry because it contains many ambiguous and abstract terms and has an apparent lack of consistency and logic in its representation. Apart from rational focus, motivational and affective aspects are also important factors for effective learning (Beerenwinkel, 2014).

Learners' alternative conceptions do not result from the incoherent and inconsistent knowledge pieces, but they result from learners' attempts to create coherent mental models. Also, there are categorical differences between science concepts. A category differs from another in terms of some ontological attributes. Further, learners' intuitive conceptions acquired from everyday experiences of the physical world do not possess a coherent structure, but rather they are isolated, fragmented “knowledge in pieces”. These knowledge pieces are primitive schemata constructed as a result of “superficial interpretation of the physical reality. A new concept does not necessarily replace alternative conceptions; instead individuals and even experts keep using their alternative conceptions in their daily life.

Conceptions that are inconsistent with the accepted scientific conceptions are defined as misconceptions. Researchers have used various terms for misconceptions, such as alternative conceptions, alternative frameworks, and preconceptions. Misconceptions are generally firmly established in student’s schemata, thus, reluctant to transform and students’ learning difficulties often persist even after formal instruction in science classes. Previous research stated that sources of misconception in chemistry are due to daily life experience; traditional instructional language; teachers; mismatches between teacher and students’ knowledge of science; changes in the meaning of chemical terms and textbooks. The causes of misconceptions are varied, including textbook authors and teachers who are guilty of making unintentional simplifications or using unclear and misleading terminology.

Conceptual change occurs as a result of development of a child’s logical capabilities, and involves the domain-general modification of cognitive structures that affect the knowledge acquisition process.

A number of conceptual approaches are often used to correct students’ misconceptions in chemistry. One of such approaches is conceptual change texts.

Conceptual change texts are texts designed to change students' alternative conceptions and focus on strategies to promote conceptual change by challenging students' alternative conceptions, producing dissatisfaction, followed by a correct explanation which is both understandable and plausible to the students. Conceptual change texts are different from traditional textbooks because they target the reader's specific misconceptions.

An attitude may be defined as a predisposition to respond in a favorable or unfavorable manner with respect to a given attitude object. Research has confirmed that attitudes are linked with academic achievement. Studies have suggested that an individual's attitude to science is made up of a large number of components (Osborne et al., 2003; Simon, 2000). These include "perception of the teacher, anxiety towards the subject, the value of science, self-esteem in science, motivation towards the science, enjoyment of the subject, attitudes of peers and friends towards science, attitudes of parents towards science, the nature of the classroom environment, achievement in science and fear of failure in science.

There are three major theoretical viewpoints about the important nature of attitudes that have been proposed by social psychologists: the tri-component point of view, the separate entities point of view, and the latent process perspective. Affect, behavior, and cognition are the three components of attitude which is a single entity the tri-component viewpoint holds. The thoughts and emotions one has toward an attitude object such as chemistry lessons and chemistry subject are referred to as affective point of view. The individual's explicit events and reactions to the attitude object is referred to behavior component of attitude, while the cognitive factor is the thinking or belief that someone has about the attitude object. The second theoretical viewpoint about the nature of attitudes assumed that the three components that are affect, behavior and cognition are unique and separate entities. The third theoretical point of view views attitudes as a latent variable that can explain the connection between certain observable stimulus events and behaviors. Attitudes can be formed from cognitive, affective, and/or behavioral information about the attitude objects. Students' predisposition towards electrochemistry will affect their interest and motivation to study electrochemistry which will affect their overall achievement in chemistry. Gender has a significant influence on students' achievement and the development of science related attitudes.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Overview

This chapter discusses the design of the research, population and sampling procedure, instrumentation, scoring the instrument, validity and reliability of the instrument. It also looked at the data collection procedure and data analysis.

3.2 Research Design

A quasi-experimental design is used for the study. A quasi-experiment is a type of experimental design in which the researcher has limited control over the selection of study participants (Levy & Ellis, 2011). The study utilized a non-equivalent pretest-posttest control group design. According to Campbell & Stanley cited Levy, and Ellis, (2011), the pretest-posttest with control group design is the most commonly used due to its recognized strength in controlling threats to internal validity. The researcher randomly assigns participants or events to two groups. The experimental group undergoes the prescribe treatment, while the second, the control group is the group that receives no treatment at all and serves as the benchmarking point of comparison.

Two intact classes were chosen from two schools for the study. One school was assigned the control group and the other the experimental group. The control group class was at Ghana Senior High School, in Tamale and the experimental group was at Damongo

Senior High School. Damongo is about 124km South-West of Tamale, the capital of northern region.

Both schools are category ‘A’ schools and they have similar educational characteristics such as population, infrastructure and characteristics of students. The different location of the control group and experimental group was envisioned to avoid threats to the internal validity of the study such as interaction and diffusion of treatment between control group and experimental group. Diffusion of treatment is the threat that research participants in different groups will communicate with each other and learn about the others treatment (Neuman, 2007).

Each group was given a pre-test before and a post-test after the interventions. The research design is represented as follows:

Table 3.1***: Research Design Showing Groups, Tests, Intervention and Instruments***

Groups	Pre-Test	Treatment	Post-Test
Experimental Group (EG)	ECCT, ATECS	X_1	ECCT, ATECS
Control Group (CG)	ECCT, ATECS	X_2	ECCT, ATECS

EG represents the experimental group that was taught using Conceptual Change Texts (X_1) and CG represents the control group that was taught by the traditional teacher-centered approach (X_2). ECCT is electrochemistry concept test and ATECS is attitude toward electrochemistry scale.

3.3 Population

The target population was all Senior High School chemistry students in the Northern Region of Ghana. The accessible population was all SHS 2 chemistry students from Damongo Senior High School and Tamale Senior High School.

3.4 Sampling Technique

Intact classes were used for the study. This is because the study is a quasi-experiment. The two classes were General Science classes. The students offer general science programme with Chemistry, Biology, Physics and Elective Mathematics as their elective subjects. The students were not different in that the schools were category “A” schools and the students have similar characteristics. Both schools have well equipped science laboratories, achievement levels, and teachers with similar qualifications.

The experimental group consisted of 51 SHS 2 science students of Damongo Senior High School. The total number of students in the class was 56 (43 boys and 8 girls). Five did not participate in the study due to failure to take either the ATECS test or the ECCT pre-test or both. The control group consisted of 52 SHS 2 science students (41boys and 11 girls) from Ghana Senior High School in Tamale. All the students in the control group took part in the study.

The subsample for the interview consisted of 10 students, five from the experimental group and five from the control group. The subsamples were selected using stratified random sampling procedure. The samples were stratified by gender and then three males and two females each were randomly selected from the experimental and control groups for the interview. In stratified random sampling, the population is divided into distinct subpopulations called strata, and within each stratum a separate random sample is selected (Fienberg, 2003).

3.5 Instrumentation

Three instruments were used to collect data for the study. These were the Electrochemistry Concept Test [ECCT] (Appendix A), the Attitude towards Electrochemistry Scale [ATECS] (Appendix B) and a Structured Interview (Appendix C).

3.5.1 Electrochemistry Concept Test (ECCT)

In order to access students understanding of electrochemistry concepts, a test, the electrochemistry concept test [ECCT] was developed by the researcher. The first section of the ECCT consisted of 20 multiple choice tests items and two open ended questions. The second section consisted of two questions that required the students to draw both the electrochemical and electrolytic cell. Each question included a list of parts that the students were required to label in their drawings.

The construction of the items was guided by the instructional objectives associated with electrochemistry in the national curriculum. Some of the objectives are presented in Table 3.2.

Table 3.2*: Instructional Objectives on Electrochemistry (MoE, 2010)*

The student will be able to:

1. Describe Oxidation and Reduction Processes.
2. Describe an experiment to illustrate reactivity of metals.
3. Describe oxidizing and reducing agents.
4. Explain the steps involved in balancing redox equations
5. Describe the interconversion of chemical energy and electrical energy in redox reactions.
6. Describe and explain the functions of a simple electrochemical cell.
7. Explain some applications of electrochemical cells.
8. Explain the operation of electrolytic cells.
9. Illustrate the electrolysis of brine experimentally.
10. Distinguish between electrolytic and electrochemical cells.

Students' misconceptions were searched from chemistry literature. The questions of the test were developed according to these misconceptions and the curriculum instructional objectives.

The items were distributed among a set of subtopics of electrochemistry. The details are provided in Table 3.3. These subtopics form part of the syllabus of SHS chemistry in Ghana. Each item of the ECCT consisted of a question or statement followed by four options with three of them being distractors (misconception). The respondents were required to indicate the option that best represents his/her opinion on the question.

The test covered the following subtopics in electrochemistry.

Table 3.3*: Subtopics, Items and Number of Items Making the ECCT*

Subtopics/concepts	items	Number of Items
1. Oxidation and reduction	11,12,16,18	4
2. Electrochemical cell	3,6	2
3. Electrolytic cell	5,8,13	3
4. Placement of electrodes	1,2,9	3
5. Direction and flow of electrons	10	1
6. Function of salt bridge	7	1
7. Direction of ions flow	4	1
8. Writing half reactions	17	1
9. Balancing redox reactions	19,20	2
10. Electrode potentials	14,15	2

An example of a multiple choice test item is given below:

1. How do electrons move through the electrochemical cell?

   A. Throughout the entire system.

   B. From one electrode to the other through the wire.

   C. From one electrode to the other through the salt bridge

   D. They do not move

3.5.2 Attitude towards electrochemistry scale (ATECS)

The Attitude towards Electrochemistry Scale [ATECS] (Appendix B) was used to measure students' attitude towards electrochemistry. The ATECS is an adapted version of the Attitude toward Chemistry Lessons Scale (ATCLS) and the Chemistry Attitude Questionnaire (CAQ). The ATCLS was developed by Cheung (2007) to measure student's attitude towards chemistry lessons in Hong Kong. The original ATCLS consisted of 12 Likert items on a seven-point rating scale namely: strongly disagree, moderately disagree, slightly disagree, not sure, slightly agree, moderately agree and strongly agree. Also, the original scale was made of four subscales namely; liking for chemistry theory lessons, liking for chemistry laboratory work, evaluative beliefs about school chemistry and behavioral tendencies to learn chemistry. The attitude towards electrochemistry Scale (ATECS) consisted of 14 Likert-type questions on a five-point scale measuring students' attitude towards electrochemistry. Each item consisted of a statement followed by five options namely Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D) and Strongly disagree (SD). Table 3.4 presents examples of some items of the ATECS.

Table 3.4*: Sample Items in the Attitude scale (ATECS)*

S/N	Items	Responses				
1	I like electrochemistry more than any other chemistry topic.	SA	A	U	D	SD
2	Electrochemistry lessons are interesting	SA	A	U	D	SD
3	Electrochemistry is one of my favorite chemistry topics	SA	A	U	D	SD
4	I like to do electrochemistry experiments	SA	A	U	D	SD

The ATECS consists of four subscales namely;

1. Liking for electrochemistry theory lessons,
2. Evaluative beliefs about electrochemistry,
3. Chemistry anxiety.
4. Liking for chemistry experiments.

The first subscale consists of four items and focuses on the feelings a student has toward the chemistry theory lessons implemented in school. This subscale is concerned with affective attitudinal responses. Bem cited in Cheung (2009) simply defined attitudes as likes and dislikes. According to Eagly and Chaiken cited in Cheung (2009), this dimension must be included in any measures of attitude toward a school subject because psychologists have reached a consensus that people have attitudes when they love or hate things and when they approve or disapprove of them. For example, Parkinson *et al.* (1998) conducted an exploratory factor analysis and found that nine of their attitude items formed a factor labelled as enjoyment, which accounted for the greatest percentage of variance of the variables. Items used by Parkinson *et al.* included 'I think science is interesting' and 'Science is my favourite subject'.

The second subscale is cognitive in nature and refers to the evaluative beliefs that a student holds about the importance and usefulness of school chemistry. It consists of three items: 'I am willing to spend more time reading chemistry textbooks', 'when I am working in the chemistry laboratory I feel I am doing something important' and 'chemistry is one of my favorite subjects'.

Oskamp and Schultz (2005) explained that evaluative beliefs are beliefs that state a value judgement about an attitude object. According to Cheung (2009), examples of attitude items used by science educators to measure the importance or usefulness of chemistry lessons are;

1. Chemistry is a very worthwhile and necessary subject.
2. Chemistry knowledge is useful to interpret many aspects of our everyday life.
3. Every high school graduate needs some knowledge of chemistry, and
4. Chemistry is an essential prerequisite to the study of other natural sciences.

The third subscale consists of four items and it is about students feeling of fear or anxiety towards chemistry as a subject, chemistry tests, chemistry teacher or chemistry classroom environment. The fourth subscale consists of three items and it is about students liking for electrochemistry experiments. Laboratory work is a key component of school science, and research has indicated that the majority of science students like doing laboratory work in science lessons. An attitude study by Parkinson *et al.* cited in Cheung (2009) revealed that 'The most common feature that attracted students to science was the amount of practical work involved'. Chemistry practical work received the largest number of favorable comments. The internal consistency reliability of the adapted ATECS was adequate with the Cronbach alpha values of the four subscales ranging from .683 to .855. (Table 3.5).

Table 3.5: ***Factors/Variables, Items and alpha values making the ATECS***

Sub-Scale	**Items Comprising Scale**	**Cronbach Alpha**
Liking for Electrochemistry	1,2,3,4	0.765
Evaluative Beliefs about Electrochemistry	5,6,7	0.683
Chemistry Anxiety	8,9,10,11	0.855
Liking for Chemistry Experiments	12,13,14	0.751

3.5.3 Structured interview

An individual, face-to-face structured interview (Appendix C) was used to obtain qualitative data for the study. According to Neuman (2007), face-to-face interviews have the advantage of high response rate and permit the interviewer to observe non-verbal communication and use extensive probes. The interview protocols developed by Sanger and Greenbowe (1995) for galvanic and electrolytic cells was adapted. The original protocol contained questions on Galvanic cells, electrolytic cells and concentration (Nernst) cells. Questions on concentration (Nernst) cells were not included in the adapted protocol because it was not covered by the SHS chemistry syllabus. Set-up 1 in the original protocol was a Ni-Ag cell with seven follow-up questions. This was modified by using Zn-Cu cell with six questions. Also, the electrolytic cell (set-up 2) in the original protocol had platinum electrodes and aluminum bromide as electrolyte with six questions. In the modified version sodium chloride was used as the electrolyte with four questions. The instrument was modified to facilitate students understanding of the questions.

3.6 Validation and Reliability of the Attitude towards Electrochemistry Scale (ATECS)

3.6.1 Reliability and Validity

A pilot test of the Attitude towards Electrochemistry Scale [ATECS] (Appendix D) was carried out with a sample of 100 SHS 2 chemistry students in Damongo Senior High School to establish the validity and reliability of the instrument. The students in the experimental and control groups were not part of this sample. The pilot test was also necessary to correct errors and identify ambiguous and difficult items. The construct validity of the items was determined using factor analysis.

The analysis was to examine if the items were internally consistent, stable, and homogenous. The Cronbach alpha (α) value of the 20-items was .866. Analysis of the corrected item-total correlations of the 20 items revealed six items with low item-total correlations below .3 (Appendix E). After deleting the six items (items 1, 6, 7, 15, 17, and 20), the reliability procedure was rerun and the Cronbach alpha increased from .866 to .906. This value is quite high and indicated that the items form a scale that has reasonable internal consistency reliability. Also, the corrected item-total correlations of the 14 items were high ranging between .530 and .760 (Appendix F). The minimum level of alpha coefficient of a good test is 0.7, which has been suggested by Nunnally (1978). Therefore, the ATECS form a reliable scale.

3.6.2 Factor analysis

A principal components factor analysis was performed on the remaining 14 items in ATECS with varimax rotation. Before the factor analysis, the Bartlett's Test of Sphericity and the value of KMO (Kaiser-Mayer-Olkin of sampling adequacy) were determined to make sure the data was suitable for factor analysis. The Bartlett's Test of Sphericity was significant χ^2 = (261.232), $p < 0.05$, indicating that correlations between items were sufficiently large for factor analysis.

Also, the KMO value was .606, above the proposed minimum values of 0.5 (Yong & Pearce, 2013) and 0.6 as proposed by Tabachnick and Fidell (2007). This means that the data sample was adequate for factor analysis. The internal consistency of each factor proved to be high, as indicated by Cronbach's alpha values that ranged between .683 and .855 (Table 3.6).

Four factors were extracted instead of the original seven factors which was based on a priori theoretical beliefs about the number of underlying constructs. The four factors accounted for 48.726%, 12.692%, 9.899% and 7.191% respectively of the variance of the 14 variables [in combination explained 78.508% of the variance] (Appendix G). Table 3.6 shows the items and factor loadings for the rotated factors, with loadings less than .30 omitted.

The scree test (Fig. 3.1) is a plot of eigenvalues and factors (Cattell, 1978).

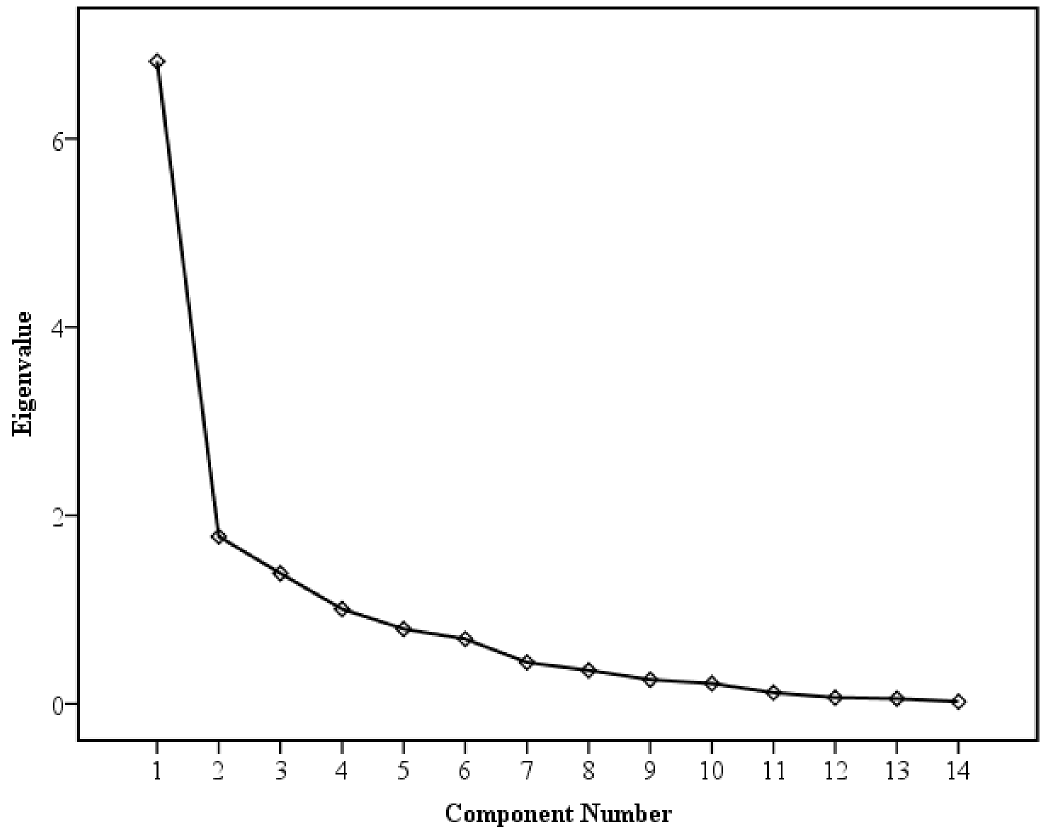

Fig 3.1: Scree Plot

An inspection of the scree plot revealed a clear break at the point of inflexion after the fourth factor. The number of factors retained is the data points that are above the break or point of inflexion (Yong & Pearce, 2013). This confirms the four factors by the Kaiser's criterion and thus four factors were retained.

After factor analysis, the items which loaded less than .30 on the relevant factors were ignored. The factor loadings were reasonable with values between .40 and .883 (Table 3.6). According to Tabachnick and Fidell (2007), only variables with loadings of .32 and above are interpreted. The greater the loading, the more the variable is a pure measure of the factor. Comrey and Lee cited in Tabachnich and Fidell (2007) suggested that loadings that exceed .71 (50% overlapping variance) are considered excellent, .63 (40% overlapping variance) very good, .55 (30% overlapping variance) good, .45 (20% overlapping variance) fair, and .32 (10% overlapping variance) poor. Based on this, the factor loadings of the variables appeared to be good.

Some of the items were loaded unto more than one factor (cross loading), and so the magnitude of factor loadings as well as the relevance of the items to the underlying constructs were taken into consideration in the analysis. Items with high factor loadings and are more relevant to the underlying construct were retained. Factors were interpreted or named by examining the largest values linking the factor to the measured variables in the rotated factor matrix (Green & Salkind, 2005). Some of the items were retained under other factors and some factors were renamed. The factors are: Liking for Electrochemistry, Evaluative Beliefs about Electrochemistry, Chemistry Anxiety and Liking for Chemistry Experiments. The original scale (ATCLS) consisted of four factors namely Liking for chemistry theory lessons (estimated α = .86), Liking for chemistry laboratory work (estimated α = .84), Evaluative beliefs about school chemistry (estimated α = .76) and Behavioural tendencies to learn chemistry (estimated α = .76). The total number of items were 14. Factor 1 and factor 3 had 4 items each whiles factor 2 and factor 4 have 3 items each.

Table 3.6: ***Item-Total Correlations, eigenvalues and Factor Loadings of items of the ATECS***

	Rotated Factor loadings (N=100)				
	Item-total correlations	Factor 1	Factor 2	Factor 3	Factor 4
Item 1	0.536	0.883			
Item 2	0.530	0.786			
Item 3	0.710	0.500			
Item 4	0.587	0.400			
Item 5	0.552		0.759		
Item 6	0.603		0.674		
Item 7	0.730		0.497		
Item 8	0.653			0.881	
Item 9	0.760			0.827	
Item 10	0.660			0.702	
Item 11	0.605			0.461	
1tem 12	0.615				0.802
Item 13	0.585				0.655
Item 14	0.688				0.560
% of variance explained		48.726%	12.692 %	9.899 %	7.191%
Eigenvalue		6.822	1.777	1.386	1.007

The factors were defined by eigenvalues greater than 1 according to the Kaiser-criterion (Tabachnick & Fidell, 2007).

The subscales of the ATECS and their corresponding items and alpha values are presented in Table 3.7.

Table 3.7: ***Cronbach alpha, corrected item-total correlations, and loadings of items of ATECS***

Subscale and item	alpha (α)	Factor Loadings	Item-total correlation
Liking for Electrochemistry	0.76		
1. I like trying to solve new problems in electrochemistry.		0.88	0.53
2. Electrochemistry lessons are interesting.		0.78	0.58
3. Electrochemistry is one of the most important subjects for people to study.		0.50	0.71
4. I consider myself a good chemistry student.		0.40	0.53
Evaluative/Behavioral Beliefs	0.68		
5. I am willing to spend more time reading chemistry books.		0.75	0.55
6. When I am working in the chemistry lab, I feel I am doing something important.		0.67	0.73
7. Chemistry is one of my favorite subjects.		0.497	0.60
Chemistry Anxiety	0.85		
8. Chemistry tests makes me afraid.		0.88	0.76
9. In electrochemistry class I feel being in control of my learning.		0.82	0.65
10. My chemistry teacher makes me feel as if I am a dumb.		0.70	0.66
11. Chemistry makes me feel as though I am lost in the bush.		0.46	0.605
Liking for Chemistry Experiments	0.75		
12. If I had a chance, I would do a project in electrochemistry.		0.80	0.68
13. I like to do chemistry experiments.		0.65	0.61
14. People must understand electrochemistry because it affects their lives.		0.56	0.58

3.6.3 Validity and Reliability of the ECCT

Validity is the extent to which an instrument measures what it purports to measure. The content and face validity of the Electrochemistry Concept Test (ECCT) items were carried out by allowing experts such as senior lecturers in chemistry and science education, including my supervisors and experienced chemistry teachers to verify the test items. The suggestions made and inputs provided were incorporated into the final test items. Also, the test was pilot tested and questions that were ambiguous, unclear and problematic were removed. The reliability of the ECCT was determined by using test re-test reliability procedure. The reliability co-efficient was found to be 0.75 which is fairly high and suggests that the ECCT was reliable. Also, item difficulty index (*p*) of the ECCT items was determined and the value was found to be .35. This indicates that the test items were quite easy. According to Ananthakrishnan cited in Karelia, Pillai and Vegada (2013) any discrimination index of 0.2 or higher is acceptable.

3.6.4 Trustworthiness of the interview

Member checks were used to ensure trustworthiness of the interview data. According to Guba and Lincoln cited in Shenton (2004) member checks is considered the single most important provision that can be made to bolster a study's credibility. Participants were asked to listen to the tape recordings and read the transcripts of the interviews in which they participated. The emphasis was on whether the participants consider that their words matched what they actually intended. It was also to ensure that the tape recorder used accurately captured participants' articulations.

The interview protocol and the transcripts were also given to peers, experience chemistry teachers and senior lecturers to check that the questions and responses were trustworthy. Samples of the transcripts were also given to two colleagues for analysis and coding. Their analysis and coding were then compared with that of the researcher to ensure trustworthiness.

3.7. Scoring the instruments

3.7.1 Electrochemistry concept test (ECCT)

The scoring rubric for the open-ended questions was the same for each question and was scored out of a total of four points. The scoring rubrics are similar the one developed by Romu (2008) in his study on demystifying misconceptions in grade 12 electrochemistry.

i. Zero (0) represents an answer that is completely incorrect or unanswered.
ii. One (1) represents a drawing with one of the four listed requirements correct.
iii. Two (2) represents a drawing with two of the four listed requirements correct.
iv. Three (3) represent a drawing with three of the four listed requirements correct.
v. A score of four (4) represents a perfect drawing with all the listed requirements included. The total score for part 2 was eight (8).

For the multiple-choice section, if a student selected the correct answer, he/she obtain a mark of one, and if the student selected any of the three incorrect answers, he/she obtained a mark of zero for that question. The total score for each of the pre-test and post-test was 28.

The scores were put into three categories according to the range of scores as in Table 3.8. Similar categories were used by Abraham *et al*. (1992), Çalık (2005), Unal *et al*. (2010), and Sendur and Toprak (2013).

Table 3.8: ***Categories of Misconceptions***

Category	Range of Scores
Sound Understanding (SU)	21-28
Partial Understanding (PU)	10-20
Misconception (MC)	0-9

3.7.2 Attitude towards Electrochemistry Scale (ATECS)

The Attitude towards Electrochemistry Scale (ATECS) consisted of Likert-type questions on a five-point scale. The scale was used to determine the extent of agreement or disagreement with a particular statement of attitudinal belief. The scale was made up of a mixture of positively worded items and negatively worded items to counteract the tendency for respondents to automatically and unthinkingly give the same answers to all questions (Tuckman, 1994). A positively worded statement, for example; chemistry is interesting, was scored as follows: SA = 5, A = 4, UD = 3, D = 2, SD = 1.

A negatively worded statement, for example; studying chemistry is a waste of time, was scored as follows: SA = 1, A = 2, UD = 3, D = 4, SD = 5. The attitude score of a student was obtained by summing up the responses for the items on the scale and dividing by the number of items to obtain mean attitude scores. The scores were summed, and categorized into positive, neutral or negative attitude.

3.8 Intervention

3.8.1 Design of the intervention

The treatment was administered for three weeks. The topic ‘’electrochemistry’’ was taught using conceptual change texts (Appendix H) in the experimental group and traditional teacher-centered method in the control groups. The texts were designed by the researcher based the instructional objectives on electrochemistry. Students in the experimental group were first asked questions that created cognitive conflict with their pre-existing conceptions. This caused them to be dissatisfied with their old conceptions. The researcher then explained to the students why their answers and ideas were incorrect. The teacher then provided the scientifically correct answers to the students. The students understanding were reinforced by providing examples, illustrations and analogies. The researcher also demonstrated the process of electrolysis and electrochemical cells to the students in the laboratory. They were made to observe the operation of a zinc-copper electrochemical cell and also the electrolysis of aqueous sodium chloride. Students in the control group were taught using the lecture method without considering their misconceptions.

3.8.2 Conceptual change text

The experimental group was instructed with the conceptual change text instruction. The conceptual change text was given to the experimental group consisting of 55 students. The texts were designed by the researcher by searching through the literature. It was developed in a way that addresses the misconceptions about electrochemistry concepts. The text contained information that illustrates the inconsistencies between misconceptions about electrochemistry and scientific knowledge. It also includes examples and figures to activate the misconceptions about electrochemistry. The texts were developed in short, clear sentences with moderate number of technical terms.

Explanations were provided for technical terms in a straightforward manner using familiar concepts. The texts also focused on the main ideas, unimportant information was neglected and important aspects highlighted (e.g., bold letters). Care was taken to ensure moderate degree of information density and a moderate degree of redundancy.

The conceptual text covered the following aspects of misconceptions about electrochemistry:

- The definition of oxidation and reduction.
- Oxidizing and reducing agents
- Balancing redox reactions
- Electrochemical cells
- Electrolytic cells
- Placement and charge on the anode and cathode,
- direction of electron flow in electrochemical cells,
- functions of the salt bridge
- the direction of ions flow in the salt bridge,
- Writing the cell reaction.

3.8.3 Implementation of the intervention

Students were given the opportunity to ask questions, discuss the topic individua1ly and with their friends, and present their understandings. In addition, students were given the opportunity to realize that some of their preconceptions are inconsistent with that of scientific explanations by the help of conflicting conditions. Conflicting conditions were presented related to electrochemistry concepts by the researcher in order to activate students' preconceptions.

In the experimental group, conceptual change texts instruction was designed to remediate students' misconceptions about electrochemistry and to replace them with scientific conceptions. During the instruction, four steps suggested by Posner *et al.* (1982) were followed. These steps are:

1. There must be dissatisfaction with the existing concepts. If the learner's current understanding or knowledge is satisfactory for understanding a given phenomenon, the learner will be less likely to accept a new concept. For conceptual change to occur, they must become dissatisfied with their existing knowledge.
2. The new concept must be intelligible. Learners must be able to understand what the new concept means.
3. The new concept must appear plausible. It should be consistent with other knowledge and solve a particular problem.
4. The new concept must appear fruitful. It should be useful in a variety of new situations.

Conceptual change texts prepared by the researcher were consistent with the four steps suggested by Posner *et al.* (1982). These texts offered a guideline to students to enable them gain experience in grasping the new concepts. These guidelines provided special learning environments such as identifying common alternative conceptions by the teacher, activating students' alternative conceptions by presenting examples and questions, presenting descriptive evidence in the text that the alternative conceptions were incorrect, and providing a scientifically correct explanation of the situation. Opportunity was provided for students to be involved in the discussions. At the beginning of each lesson, conceptual change texts were given to the students. First, the students were asked to read the questions in the texts followed by the discussion of the questions under the guidance of the teacher. Research suggests that it is most effective to allow students to read each section silently and then to pause for class discussion after reading each section (Cetingul & Geban, 2011). Also, the teacher took down notes about the students' responses since whether they are scientifically accepted or not, these responses will be used during the class discussions.

In the second and third steps, students read the scientific explanation in the text. In order to make the new concepts intelligible and plausible to them, reasons, situations and examples were provided in the text to explain why the misconceptions were incorrect and why the scientifically accepted concepts are rational. The students first read the explanations and examples in the text; then, the teacher repeated the explanations provided in the texts. In the fourth step, the teacher presented to students the new situations and examples to enhance the understanding of the new concepts about electrochemistry. Students were encouraged to use the newly learned information in explaining other examples during the class discussions. During discussions students can express their thoughts and clarify their own thinking through social constructivism (Sungur, Tekkaya, & Geban, 2001). This process helped the students to understand why the new explanation is more useful. Conceptual change texts are not meant to replace other forms of instruction such as demonstrations, laboratory activities, computer simulations, etc. (Cetingul & Geban, 2011), but are used in conjunction with these other conceptual change instructional methods.

3.8.4 Traditional teacher-centered instruction

The conventional teacher-centered instruction was guided mainly by the lecture method. At the start of each lesson, the researcher introduced the topic to the class.

During the classroom instruction, the researcher wrote the topic on the board without revealing the students' prior conceptions and misconceptions. An explanation was given by writing the main ideas, formulae and reactions on the board. After the teacher's (the researcher) explanation, the concepts were discussed with teacher-directed questions.

In this method, students were passive as they only listened, took notes, and asked questions about unclear points. The teacher wrote some questions on the board to support important concepts and reactions from the lecture. For each question, sufficient time was given to the students to answer them.

3.9 Data Collection Procedure

Formal permission was sought from the Headmasters of the two schools before administering the ECCT and ATECS. This was done through a letter of introduction (Appendix K) obtained from the Head of Department, Department of Science Education of the University of Education, Winneba. The ECCT and the ATECS were personally-administered by the researcher.

The pre-test was administered to both groups using the ECCT and the ATECS at the same time. The pre-test was to ensure that students of the two groups were not significantly different to avoid selection bias. Selection bias is the threat that research participants will not form equivalent groups (Neuman, 2007). After the administration of the pretests, a structured interview was conducted with 10 students (5 each) from both experimental and control groups to determine students' misconceptions in electrochemistry. Each interview took approximately 30-45 minutes. The interviews were conducted on a one-to-one basis. The interview was audio-taped and then transcribed (Appendix I) immediately. During each interview, the student illustrated his/her explanations with diagrams or chemical equations. This provided extra information about their current understanding or existing knowledge. The interview focused on discovering areas of difficulties that students may face with galvanic cells and electrolytic cells such as;

- Identifying the anode and cathode of galvanic cells;
- Understanding the need for a standard half-cell;
- Understanding current flow in galvanic and electrolytic cells,

- Understanding the charge on the anode and cathode;
- Identifying the anode and cathode in electrolytic cells;

The experimental group and the control group did not receive the intervention at the same time. The researcher first administered the intervention to the experimental group. The experimental group received conceptual change text instruction. The entire Electrochemistry unit took three weeks to cover. The post-test was administered to the experimental group after the intervention using the ECCT and the ATECS at the same time. The researcher then moved to the control group and administered the intervention and after which the post-test was taken using the ECCT and the ATECS.

3.10 Data Analysis

3.10.1 Quantitative data analysis

The data was analyzed using IBM Statistical Package for the Social Sciences (SPSS) version 21.0, Origin 8.5 and Microsoft excel. Both descriptive and inferential statistics were used to analyze the data collected.

3.10.1.1 Descriptive statistics

The descriptive statistics included means, standard deviation and variance. These were used to answer research questions 1 and 2. Demographic characteristics of respondents such as their ages were also presented using descriptive statistics.

Item analysis of the items in the ATECS was performed using descriptive statistics. The mean scores and standard deviations of students' responses to the ATECS items were determined. On a five-point scale a mean score of 3 and above means a positive attitude on the item and a mean score below three means negative attitude on the item, a mean score of three indicates a neutral position.

3.10.1.2 Inferential statistics

The inferential statistics included t-tests for independent samples, Chi-square test of independence and analysis of covariance (ANCOVA). These were used to answer research questions 1, and 2 and hypotheses 4 and 5. All research hypotheses were tested at .05 level of significance. The means of the pre-test and post-test scores of the electrochemistry concept test (ECCT) of experimental and control groups were compared using independent samples t-test. The effect-size of the differences between mean scores of control and experimental groups were computed using Cohen's *d* formula. Whereas statistical tests of significance tell us the likelihood that experimental results differ from chance expectations, effect-size measurements tell us the relative magnitude of the experimental treatment. Effect sizes are especially important because they allow us to compare the magnitude of experimental treatments from one experiment to another (Thalheimer & Cook, 2002).

According to Cohen, Manion and Morrison (2007) effect size is simply a way of quantifying the difference between two groups. It is a measure of the effectiveness of the treatment (Coe 2000; Cohen *et al*, 2007).

Students' responses on the Attitude towards Electrochemistry Scale (ATECS) were converted to scores by summing up students' responses to the 14 items. Attitude scores from the pre-test and post-test were also analyzed using independent samples t-test.

3.10.2 Qualitative data analysis

The results from the interviews were organized into five thematic areas of students' misconceptions identified from the interview. These were;

1. Identifying the anode and cathode of galvanic cells;
2. Understanding the function of the salt bridge;
3. Understanding current flow in galvanic and electrolytic cells;
4. Understanding the charge on the anode and cathode;
5. Identifying the anode and cathode in electrolytic cells;

The interview was analysed based on percentage of respondents who held certain misconceptions in electrochemistry. Item analysis was used to determine the percentage of correct and incorrect responses of the ECCT items in experimental and control groups before and after the treatment. Frequencies and percentages of students' responses to each item were analysed using SPSS. The percentage of correct and incorrect responses revealed the degree of misconceptions held by students. Students' scores in the ECCT were put into three categories according to the score ranges. The categories are: sound understanding (SU) [21-28], partial understanding (PU) [10-20] and misconception (MC) [0-9].

CHAPTER FOUR

4.0 RESULTS

4.1 Overview

This chapter presents the results of the study. Descriptive statistics were presented using means, standard deviations, frequencies and percentages. The hypotheses stated in chapter one were tested at a significance level of .05. Statistical analyses were carried out by using the IBM SPSS (Statistical Package for Social Sciences) version 20. The results are presented based on the following research questions and hypotheses:

Research questions:

1. What is the effect of conceptual change text oriented instruction on student's achievement in electrochemistry?
2. What is the effect of conceptual change text oriented instruction on student's attitude toward electrochemistry?
3. What is the effect of conceptual change text oriented instruction compared with the traditional method of instruction?

Hypotheses:

1. There is no significant difference in cognitive achievement of male and female students in electrochemistry.
2. There is no significant difference in attitude of male and female students towards electrochemistry.

4.2 Characteristics of Respondents

Table 4.1 shows the sex and age distribution of students in control and experimental groups.

Table 4.1: ***Sex and Age Distribution of Students***

Variable	Group		Frequency	Percentage
Sex	Experimental group	Male	43	84
		Female	8	16
	Total		**51**	**100**
	Control group	Male	41	79
		Female	11	21
	Total		**52**	**100**
Age	Experimental Group			
15			2	3.90
16			6	11.8
17			6	11.8
18			14	27.5
19			8	15.7
20			10	19.6
21			4	7.80
22			1	2.00
Total			**51**	**100**
Age	Control Group			
14			1	1.90
15			1	1.90
16			8	15.4
17			21	40.4
18			12	23.1
19			7	13.5
20			2	3.80
Total			**52**	**100**

EG (M = 18.3, SD = 1.67)   CG (M = 17.3, SD = 1.18)

In all 103 students took part in the study. The experimental group consists of 51 SHS 2 science students from Damongo Senior High School. The control group consists of 52 SHS 2 science students from Ghana Senior High School, Tamale. The results showed that out of 51 students of the experimental group eight students (16%) were females and 43 students (84%) were males. Also, out of 52 students of the control group, 11 students (21%) were females and 41 students (79%) were males. The age of students in the experimental group ranged from 15 to 22 with a mean age of 18.3 and the age of students in the control group ranged from 14 to 20 with a mean age of 17.3 years. The experimental group's mean age was higher than the control group's mean age.

4.3 Research question 1

What is the Effect of Conceptual Change Text Instruction on Student's Achievement in Electrochemistry?

4.4 Pre-intervention Results (data) on Research Question 1

Research question one sought to find out the effect of conceptual change texts on students' cognitive achievement in electrochemistry. The data was obtained by administering Electrochemistry Concept Test (ECCT) to the experimental and control group before the intervention.

The aim of the pre-test was to determine students' cognitive achievement in electrochemistry before the intervention. It also presented the researcher a baseline for comparison with the post-test results.

4.4.1 Results of the structured interview data

After the pre-test and before the intervention, structured interviews were conducted with a total of 10 students-five students from each group. The purpose of the interview was to find out possible misconceptions students have in electrochemistry. The interview results showed that students in both groups held some alternative conceptions about electrochemistry.

The interview data was analyzed by the researcher using an inductive analysis procedure (Patton, 2002), in which data was carefully evaluated through repeated and independent readings of the transcripts to extract general themes. Content analysis was used to interpret responses (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005). All answers provided by the 10 students were reviewed and classified by the researcher.

The results of the interview were discussed under 5 areas of students' difficulties such as; identifying cathode and anode in galvanic cells, understanding the functions of the salt bridge, understanding charge of the cathode and anode, identifying cathode and anode in electrolytic cells and understanding current flow in galvanic and electrolytic cells.

4.4.2 Identifying the anode and cathode of galvanic cells

Students have many misconceptions about identifying the anode and the cathode. Two students out of the 10 interviewed correctly used the reactivity of the metals in the electrochemical series to determine or assign anode and cathode. This is showed in the following extract:

RESEACHER: How will you determine which electrode is the anode and which is the cathode?

GSI02: …you consider the reactivity of the metals…. zinc is above copper in the activity series…. the one that is above the other is the anode……it means it has a higher concentration of electrons……electrons flow from the anode to the cathode. Copper is the cathode …. that is, it accepts electrons.

GSI04: you consider the two elements……. their positions in the electrochemical series…...the one on top will loss electrons and becomes the anode……and the one below accepts electrons and becomes the anode.

Four students (40%) used the charge/signs of the electrodes to identify the anode and cathode. This is supported by the following explanations:

RESEACHER: How will you determine which electrode is the anode and which is the cathode?

DSI04: The zinc is the anode…. because it is the negative electrode… and the copper is the cathode because it is the positive electrode.

DSI05: You look at the charge… the anode is always negative and the cathode is positive.

DSI09: Looking at the diagram…... Zinc is anode and copper is cathode…... The zinc is positive acceptor and the copper is negative acceptor.

GSI03: The zinc is the anode……. because it has a positive charge. The copper is the cathode because it has a negative charge.

Some students (10%) also think that the anode is always on the left and the cathode on the right. Also, 20% of the students interviewed said that the anode is where oxidation occur and the cathode is where reduction occurs. This is indicated in the following extract:

RESEACHER: How will you determine which electrode is the anode and which is the cathode?

DSI01: The left hand side is the anode and the right hand side is the cathode… the anode transfers electrons into the cathode by force so that the cathode is negative.

GSI05: the anode is where oxidation takes place…. therefore, losses electrons ….and the cathode is where reduction takes place ……...the cathode gains electrons.

GSI01: Zinc is the anode……...since it is oxidized…...and copper is the cathode since reduction occurs there.

One student (10%) said that Zn is anode because it losses electrons and Cu is cathode because it gains electrons. This is what he had to say:

DSI03: The zinc electrode is the anode because it losses electrons and the charge is negative… and the copper is the cathode because it gains electrons and the charge is positive.

4.4.3 Functions of the salt bridge

Four students (40%) correctly stated that the function of the salt bridge is to maintain electrical neutrality. This is what they had to say:

RESEACHER: What is happening in the solution? What does the salt bridge do?

GSI04: the salt bridge completes the internal circuit and maintains electrical neutrality.

DSI01: The solution will move from anode to cathode. The salt bridge maintains electrical neutralization.

GSI01: the salt bridge………it produces ions to maintain electrical neutrality.

GSI05: the salt bridge produces ions and ensures neutrality between the two solutions……ions are in the same solution.

The function of the salt bridge is not clear to many students. Two Students (20%) said that ions pass through the salt bridge to produce electricity. This is what they had to say:

RESEACHER: What is happening in the solution? What does the salt bridge do?

DSI05: The salt bridge is where the ions pass through to help to produce electricity.

GSI02: … the zinc ions oxidize the zinc metal to release electrons …….and the salt bridge when there is higher concentration of ions it……..the ions will flow through the salt bridge ……..so that it will become stable.

Students also have misconception that the salt bridge connects electrons from anode to cathode. And that the salt bridge transfers charges between the electrodes. This is supported by the following students' comments:

RESEACHER: What is happening in the solution? What does the salt bridge do?

DSI04: The salt bridge connects the electrons from cathode to anode.

DSI03: …The salt bridge is used for the transfer of charges to neutralize……

4.4.4 Direction of flow of ions/charges in electrochemical cell

Only one student out of the 10 interviewed (10%) was able to tell correctly that cations move from anode to cathode and anions from cathode to anode.

RESEACHER: In what direction do the charges/ions flow in this electrochemical cell to complete the circuit?

DSI05: It flows opposite…...cations from anode to cathode and anions flow from cathode to anode.

Five students out of the 10 (50%) were able to predict the direction of movement of charges/ions but could not tell which precise kind of ions, that is whether cations or anions. This is indicated in the following excerpt:

RESEACHER: In what direction do the charges/ions flow in this cell to complete the circuit?

DSI09: The charges flow from anode to cathode.

GSI01…charges flow from anode to cathode.

GSI03: the ions flow …anions flow from anode to cathode. Cations flow from cathode to anode. The anode is positive and the cathode is negative.

GSI04: cations flow from cathode to anode and anions flow from anode to cathode.

GSI05: charges flow from left to right……. anions flow from left to right and electrons move from right to left.

DSI04: The charges flow from left to right……Anions flow from left to right and cations from right to left.

DSI03: Charges flow from cathode to anode………...cations will flow to the anode and anions to the cathode.

Two students of the 10 said that charges flow from left to right. They could not tell to which electrode. This shows that students had no concrete understanding of the movement of ions in an electrochemical cell. This is supported by the following students' comments:

GSI05: charges flow from left to right……. anions flow from left to right and electrons move from right to left.

DSI04: The charges flow from left to right……Anions flow from left to right and cations from right to left.

4.4.5 Reactions occurring at the cells

Three students representing 30% were able to correctly tell the reactions taking place at each half-cell. In both galvanic and electrolytic cells oxidation occurs at the anode and reduction occurs at the cathode. The responses revealed that very few students have this understanding. Students also stated redox reaction without specifically stating the part of redox reaction.

RESEACHER: What reactions are taking place in each cell?

GSI01: …redox reactions…oxidation occurs at the anode and reduction at the cathode…. the anode is negative and the cathode is positive.

GSI02: zinc is oxidized at the anode. At the cathode copper is reduced. The reactions occurring are…...

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ (oxidation) and $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ (reduction). The anode is negative and the cathode is positive.

GSI04…oxidation at the anode and reduction at the cathode……. the anode is negative and the cathode is positive.

The remaining students representing 70% could not tell the kind of reactions taking place at each cell. They however cited various incorrect chemical reactions. Only 1 student of the remaining had no idea of the kind of chemical reaction taking place at each cell. This is indicated in the following dialogue:

RESEACHER: What reactions are taking place in each cell?

DSI01: …the first is a reaction…neutralization reaction.

DSI05: The reaction…chemical reaction e.g. zinc plus……

DSI09: Chemical reactions…zinc and copper.

DSI04: Zinc and copper reaction.

DSI03: Electrochemical reactions………..

GSI03: no idea

GSI05: …...chemical reactions……electrochemical reactions. The anode is negative and the cathode is positive.

Common student misconceptions were identified from analysis of the individual structured interviews. The misconceptions are summarized in Table 4.2.

Table 4.2: ***Misconceptions Identified from the Interview Data***

Misconceptions
Galvanic Cell
1. The left hand side is the anode and the right hand side is the cathode.
2. The current produced will pass through the salt bridge and the go to the voltmeter.
3. The current in electrochemical cell is produced by bringing two half-cells together.
4. Current is produced by the movement of charges through the salt bridge.
5. Current is produced by the transfer of charges from anode to cathode.
6. The salt bridge is used for the transfer of charges for neutralization.
7. The salt bridge maintains electrical neutralization.
8. The salt bridge connects the electrons from cathode to anode.
9. The salt bridge is where the ions pass through to help to produce electricity.
10. In electrochemical cell charges flow from cathode to anode
11. In electrochemical cell the anions flow from anode to cathode.
12. In electrochemical cell the charges flow from left to right.
13. Anions flow from left to right and cations from right to left.
14. The charges flow from anode to cathode.
15. Cations flow from cathode to anode and anions flow from anode to cathode.
Electrolytic Cell
16. In an electrolytic cell the left hand side is the anode and the right hand side is the cathode.
17. In an electrolytic cell the anode is negative electrode and the cathode is positive electrode.
18. The left hand side is anode because it is positive and the right hand side is cathode because it is negative.
19. In an electrolytic cell the negative terminal of the battery is the anode and the positive terminal is the cathode.
20. In electrolytic cell the metal which easily discharges electrons is the cathode.
21. In an electrolytic cell cations flow from anode to cathode and anions flow from cathode to anode.
22. In an electrolytic cell cations flow to the anode and anions flow to the cathode
23. In an electrolytic cell anions flow from anode to cathode.

4.4.6 Categories of misconceptions from the students test scores on ECCT

Students' scores in the ECCT were put into three categories according to score ranges. The categories are: sound understanding (SU) [21-28], partial understanding (PU) [10-20] and misconception (MC) [0-9]. Table 4.3 shows the categories of misconceptions held by students in the experimental and control group before the intervention.

Table 4.3: ***Categories of misconceptions held by students***

Test	Group	MC	PU	SU
Pre-test	EG	26 (50.9%)	25 (49.1%)	0
Pre-test	CG	33 (63.5%)	19 (36.5%)	0

The results show that for both experimental and control groups no student had sound understanding of the electrochemistry concepts tested. This suggests that students had difficulties in understanding the concepts in electrochemistry. In the pretest, 26 (50.9%) students of the experimental group had misconceptions and 25 (49.1%) students had partial understanding. Also, in the pre-test, 33 (63.5%) students of the control group had misconceptions and 19 (36.5%) students had partial understanding. In all, more students in the control group had misconceptions than in the experimental group.

4.4.7 Cognitive achievement of students in electrochemistry before the intervention

The cognitive achievement of students in electrochemistry was determined before the intervention by administering the ECCT as the pre-test. The aim of the pre-test was to determine students' misconceptions and prior knowledge in electrochemistry. It also presented the researcher with the baseline information which formed the basis for the comparison. Data was analysed using means, standard deviations and percentages. Table 4.4 shows the descriptive statistics of the pre-intervention achievement scores of the experimental and control groups.

Table 4.4***: Descriptive Statistics of Pre-Intervention Achievement Scores of Experimental and Control Groups.***

Test	Group	*N*	*M*	*SD*
Pre-test	Experimental	51	9.54	3.44
	Control	52	8.8	3.75

N= Sample size, M = Mean, SD = Standard deviation

The results showed that cognitive achievement mean score of the experimental group was higher ($M = 9.54$, $SD = 3.44$) than cognitive achievement mean score of the control group ($M = 8.80$, $SD = 3.75$) before the intervention. The mean difference between the experimental group and the control group was 0.74. This difference was insignificant which suggests that the two groups were similar in terms of their ability levels before the intervention. Cognitive achievement scores of the experimental group ranged from three to 17, whiles the cognitive achievement scores of the control group ranged from two to 18.

4.4.8 Percentage correct responses to pre-test items of ECCT

The percentage correct and incorrect responses of items to the ECCT were computed to determine the level of misconceptions held by students in electrochemistry. The percentage of incorrect response (%IC) indicated the level of misconceptions held by the students on each item. Table 4.5 shows the percentage of correct and incorrect responses of the experimental and control groups before the intervention.

Table 4.5: ***Percentage Correct and Incorrect Responses (ECCT) Of Experimental and Control Group before the Intervention.***

	Pre-test					
	Control group			Experimental group		
Item	*N*	%CR	%IC	*N*	%CR	%IC
1	52	51.9	48.1	51	60.8	39.2
2	52	15.4	84.6	51	9.80	90.2
3	52	23.1	76.9	51	21.6	78.4
4	52	23.1	76.9	51	27.5	72.5
5	52	32.7	67.3	51	43.1	56.9
6	52	17.3	82.7	51	5.90	94.1
7	52	42.3	57.7	51	11.8	88.2
8	52	50.0	50.0	51	43.1	56.9
9	52	15.4	84.6	51	3.90	96.1
10	52	63.5	36.5	51	41.2	58.8
11	52	13.5	86.5	51	7.80	92.2
12	52	34.6	65.4	51	43.1	56.9
13	52	46.2	53.8	51	66.7	33.3
14	52	40.4	59.6	51	23.5	76.5
15	52	57.7	42.3	51	17.6	82.4
16	52	28.8	71.2	51	29.4	70.6
17	52	61.5	38.5	51	49.0	51.0
18	52	15.4	84.6	51	33.3	66.7
19	52	71.2	28.8	51	62.7	37.3
20	52	40.4	59.6	51	45.1	54.9

CR = Correct Response, IC = Incorrect Response

In the control group, the percentage of correct responses in the pre-test ranged from 13.5% (item 11) to 71.2% (item 19). It was observed that the percentage of correct responses of items 2, 3, 4, 5, 6, 9, 11, 16 and 18 were 32.7% and below. Also, in the experimental group, the percentage of correct responses in the pre-test range from 3.9% (item 9) to 66.7% (item 13). It was observed for questions 9, 6, 11, 2, 3, 14, 7, 15, 16 and 18 of the pre-test by the experimental group that the percentages of correct responses were 33.3% and below. It was found out that these questions were related to placement of anode and cathode in electrochemical cell (items 2, 9) (9.8% and 3.9% respectively), functions of the salt bridge (item 7) [11.8%], oxidizing and reducing agents (item 11) [7.8%], using reactivity of metals to place anode and cathode (item 15) [17.6%], oxidation and reduction in terms of electron transfer (item 16) [29.4%], oxidation and reduction in terms of change in oxidation number (item 18) [33.3%], reactions occurring at the electrodes (item 3) [21.6%]. Students also have misconceptions regarding placement of anode and cathode (items 2 and 9). Many students had the misconception that the anode is always on the left and the anode on the right.

4.5 Summary of Pre-Intervention Findings

The results of the pre-intervention interview revealed that students have some difficulties (misconceptions) in identifying cathode and anode in galvanic cells, understanding the functions of the salt bridge, understanding charge at the cathode and anode, identifying cathode and anode in electrolytic cells and understanding current flow in galvanic and electrolytic cells.

The results showed that for both experimental and control groups no student had sound understanding of the electrochemistry concepts tested. This suggests that students had difficulties in understanding the concepts in electrochemistry. Item analysis using percentage of correct and incorrect responses of the ECCT items also revealed that students in both groups had some misconceptions in electrochemistry. The results showed that cognitive achievement mean score of the experimental group was higher (*M* = 9.54, *SD* = 3.44) than cognitive achievement mean score of the control group (*M* = 8.80, *SD* = 3.75). The mean difference between the experimental group and the control group cognitive achievement scores was 0.74. This difference was fairly small which suggests that the two groups were similar in terms of their ability levels before the intervention.

The pre-intervention results helped the researcher to identify students' misconceptions in electrochemistry which led the design of the conceptual change texts used as the intervention. Students' cognitive achievement scores also served as the baseline for comparison using inferential statistics in answering and testing the research questions and hypotheses. After the pre-intervention, the intervention was then implemented after which data was collected using the ECCT. The data was analysed to find out the effect of the intervention on students' cognitive achievement in electrochemistry.

4.6 Post-Intervention Results (data)

4.6.1 Cognitive achievement of students in electrochemistry after the intervention

The cognitive achievement of students in electrochemistry was determined after the intervention by administering the ECCT as a post-test to both groups. Data was analysed using means, standard deviations and percentages. Table 4.6 shows the descriptive statistics of students' cognitive achievement scores of the experimental and control groups after the intervention.

Table 4.6: ***Descriptive Statistics of Students' Cognitive Achievement Scores of the Experimental and Control Groups after the Intervention.***

Test	Group	*N*	*M*	*SD*
Post-test	Experimental	51	12.2	3.83
	Control	52	10.0	3.73

N= Sample size, M = Mean, SD = Standard deviation

The results showed that the cognitive achievement score of the experimental group was higher (*M* = 12.2, *SD* = 3.83) than the cognitive achievement score of the control group (*M* = 10.0, *SD* = 3.75). The experimental group's cognitive achievement scores ranged from 20 to four whiles the control group's cognitive achievement scores ranged from 18 to three.

4.6.2 Percentage of correct responses on post-test items of the ECCT

The proportions of correct responses and alternative conceptions were examined by performing item analysis of the ECCT items for both experimental and control groups after the intervention. Many students after the intervention failed to develop a scientifically acceptable understanding of the concepts in electrochemistry. Table 4.7 shows percentage of correct and incorrect responses of the ECCT of the experimental and control group after the intervention.

Table 4.7: ***Percentage Correct and incorrect Responses (ECCT) of Experimental and Control Group after the intervention***

	Post-test					
	Experimental Group			Control Group		
Item	N	%CR	%IC	N	%CR	%IC
1	51	70.6	29.4	52	57.7	42.3
2	51	29.4	70.6	52	13.5	86.5
3	51	15.7	84.3	52	23.1	76.9
4	51	29.4	70.6	52	26.9	73.1
5	51	54.9	45.1	52	51.9	48.1
6	51	13.7	86.3	52	19.2	80.8
7	51	31.4	68.6	52	28.9	71.1
8	51	64.7	35.3	52	53.8	46.2
9	51	25.5	74.5	52	13.5	86.5
10	51	49.0	51.0	52	55.8	44.2
11	51	7.8	92.2	52	17.3	82.7
12	51	35.3	64.7	52	23.1	76.9
13	51	39.2	60.8	52	51.9	48.1
14	51	41.2	58.8	52	46.2	53.8
15	51	43.1	56.9	52	46.2	53.8
16	51	29.4	70.6	52	34.6	65.4
17	51	47.1	52.9	52	59.6	40.4
18	51	33.3	66.7	52	19.2	80.8
19	51	74.5	25.5	52	80.8	19.2
20	51	43.1	56.9	52	51.9	48.1

CR = Correct Response, IC = Incorrect Response

The results showed that the percentage of correct responses to some questions were lower than other questions. In the experimental group, the percentage of correct responses ranged from 7.8% (item 11) to 70.6% (item 1), but in the control group, the percentage of correct responses ranged from 13.5% (items 2 and 9) to 80.0% (item 19). It was observed in questions 2,3,6,7,9,11,16, and 18 of the post-test of the experimental group that the percentage of correct responses were 31.4% and below. When these questions were examined in terms of their content areas, it was found that they were related to placement of anode and cathode in electrochemical cell (items 2, 9) [29.4 % and 25.5%], functions of the salt bridge (item 7) [31.4%], oxidizing and reducing agents (item 11) [7.8%], oxidation and reduction in terms of electron transfer (item 16) [29.4%], and oxidation and reduction in terms of change in oxidation number (item 18) [33.3%].

Also, the percentage of correct responses of items 2,3,4,6,7,9,11,12,16 and 18 of the control group were 34.6% and below. These results showed that the percentage of correct responses of some items increased in the post-test after the treatment (items 1,2,4,5,6,7,8,9,10,14,15 and 19). This meant that the conceptual change text is effective in eliminating some misconceptions. Few items (11 and 16) did not increase after the intervention, which suggested that some misconceptions are difficult to change.

4.7 Testing of Hypothesis with Respect to Research Question 1

Research question 1:

What is the Effect of Conceptual Change Text Instruction on Student's Achievement in Electrochemistry?

H_0 1: There is no significant difference between post-test scores of the students taught with conceptual change texts and those taught with traditional instruction with respect to cognitive achievement in electrochemistry.

Independent samples t-test was performed to see if any significant difference exists between the experimental and control groups using pre-test and post-test scores. The significance value for Levene's Test was greater than .05 and therefore, equal variances were assumed. The results of the independent samples t-test is presented in Table 4.8.

Table 4.8: ***Mean, Standard deviation and Independent Samples t-test results on Experimental and Control Groups Pre and Post-Test Scores***

Test	Group	*N*	*M*	*SD*	*t*	*p*
Pre-Test	Experimental	51	9.54	3.44	1.04	.299*
	Control	52	8.80	3.75		
Post-Test	Experimental	51	12.2	3.83	2.99	.003**
	Control	52	10.0	3.73		

** Not significant, p > .05, ** Significant, p < .05*

The results showed that there was no significant difference between the means of experiment group and control group mean score before the intervention [t (101) = 1.04; p =.299]. This indicated that the students in the control and experimental groups were similar regarding their pre-test scores and prior knowledge on electrochemistry.

Also, the results of the independent-samples *t*-test showed that there was a significant difference in cognitive achievement scores of the experimental group and the control group after the intervention [t (101) = 2.99, p = .003, d = .582]. The effect size (Cohen's *d*) indicated a substantial effect, therefore, we reject the null hypothesis. This suggests that teaching with conceptual change texts caused a significantly better acquisition of scientific concepts than teaching with traditional instruction.

4.8 Research Question 2:

What is the Effect of Conceptual Change Text Instruction on Student's Attitude toward Electrochemistry?

4.9 Pre-Intervention (Data) Results

The purpose of research question two was to determine the effect of the use of conceptual change text instruction on students' attitude towards electrochemistry. The aim of the pre-test was to determine students' attitude towards electrochemistry before the intervention. It also presented the researcher with the baseline information which formed the basis for the comparison with the post-test results.

4.9.1 Attitude of students towards electrochemistry before the intervention

The attitude of students towards electrochemistry was determined administering the ATECS pre-test. Data was analysed using means and standard deviations. The attitude score of a student was obtained by summing up the student's responses for the items on the scale. The mean scores and standard deviations of students' responses to the ATECS items were also determined. On a five-point scale a mean score of 3 and above signifies a positive attitude on the item and a mean score below three means negative attitude on the item, a mean score of three indicates a neutral position. Table 4.9 shows the descriptive statistics of attitude scores of students before the intervention.

Table 4.9: ***Descriptive Statistics of Attitude Scores of Students before the Intervention.***

Test	Group	*N*	*M*	*SD*
Pre-test	Experimental	51	55.07	8.07
	Control	52	57.36	7.25

N= Sample size, M = Mean, SD = Standard deviation

The results showed that the mean attitude score of the control group was higher (*M* = 57.3, *SD* = 7.25) than the mean attitude score of the experimental group (*M* = 55.07, *SD* = 8.07). The attitude scores of the experimental group ranged from 27 to 67, whiles the attitude scores of the control group ranged from 41 to 70. The mean scores of both groups were above the neutral attitude score of 42. This suggests that generally students have positive attitude towards electrochemistry.

4.9.2 Descriptive statistics of pre-test items of the ATECS

Data from the pre-test items of the ATECS was analysed descriptively using means and standard deviations. Table 4.10 shows the descriptive statistics of the pre-test items in the ATECS of the experimental and control group.

Table 4.10: ***Descriptive Statistics of Items in the ATECS of the Experimental and Control Group Before the Intervention.***

Item	Statement	Pre-test: Experimental group *N*	*M*	*SD*	Pre-test: Control Group *N*	*M*	*SD*
1.	I like trying to solve new problems in Electrochemistry.	51	4.24	0.89	52	3.94	0.98
2.	Electrochemistry lessons are interesting.	51	4.47	0.9	52	3.88	1.11
3.	Electrochemistry is one of the most important topics for people to study.	51	4.20	1.1	52	4.6	0.75
4.	I consider myself a good chemistry student.	51	4.08	1.09	52	4	0.74
5.	I am willing to spend more time reading chemistry books.	51	3.49	1.3	52	4.63	0.79
6.	When I am working in the chemistry lab, I feel I am doing something important.	51	4.67	0.68	52	4.62	0.75
7.	Chemistry is one of my favorite subjects.	51	3.65	1.26	52	4.21	0.98
8.	*Chemistry tests make me afraid.	51	3.57	1.4	52	3.96	1.24
9.	In electrochemistry class I feel being in control of my learning.	51	3.82	1.01	52	3.27	1.16
10.	*My chemistry teacher makes me feel as if I am a dumb.	51	3.65	1.32	52	3.69	1.29
11.	*Electrochemistry makes me feel as though I am lost in the bush.	51	3.78	1.33	52	4.25	1.08
12.	If I had a chance, I would do a project in electrochemistry.	51	3.73	1.37	52	4.13	1.14
13.	I like to do electrochemistry experiments.	51	4.14	1.11	52	4.35	0.90
14.	People must understand electrochemistry because it affects their lives.	51	3.61	1.42	52	3.83	1.52
	Overall mean/SD		**3.95**	**1.15**		**4.09**	**1.03**

**Negative Items Being Reverse-Scored, So That a Higher Score Indicates Positive Attitudes toward Electrochemistry*

The results showed that the mean item score in the experimental group ranged from 3.61(item 14) to 4.47(item 2) with an overall mean score of 3.95. The least mean score of 3.61 (item 14) before the treatment implies that most students agreed that people must understand electrochemistry because it affects their lives. Also, the highest mean score of 4.47 (item 2) before the treatment suggests that students agree that electrochemistry lessons are interesting.

Also, in the control group, the item mean score before the treatment range from 3.27(item 9) to 4.63(item 5) with the overall mean score of 4.09. The least mean score of 3.27 (item 9) implies that students did agree that they are in control of their learning in electrochemistry class. In the same vein, the highest mean score was 4.63 (item 5) implies that students are willing to spend more time reading electrochemistry books. In both groups the mean scores of the items were above three, which suggests that the students in the experimental and control groups had positive attitude toward electrochemistry before the intervention.

4.10 Post-Intervention Results (data)

4.10.1 Attitude of students towards electrochemistry after the intervention

The attitude of students towards electrochemistry was determined by using the ATECS which was administered as the post-test after the intervention. Data was analysed using means and standard deviations. The attitude score of a student was obtained by summing up the students' responses for the items on the scale. The mean scores and standard deviations of student's responses to the ATECS items were determined. Table 4.11 shows the descriptive statistics of attitude scores of students after the intervention.

Table 4.11: ***Descriptive Statistics of Attitude Scores of Students after the Intervention***

Test	Group	*N*	*M*	*SD*
Post-test	Experimental	51	56.60	8.86
	Control	52	58.88	7.63

N= Sample size, M = Mean, SD = Standard deviation

The results showed that the mean attitude score of the control group was higher (*M* = 58.88, *SD* = 7.63) than the mean attitude score of the experimental group (*M* = 56.60, *SD* = 8.86). The attitude scores in the experimental group ranged from 28 to 69. The attitude scores in the control group ranged from 43 to 70. The mean scores in both groups were above the neutral attitude score of 42. This suggests that all the students have positive attitude towards electrochemistry.

4.10.2 Descriptive statistics of post-test items of the ATECS

Data from the post-test items of the ATECS was analysed descriptively using means and standard deviations. Table 4.12 shows the descriptive statistics of items of the ATECS of the experimental and control group after the intervention.

Table 4.12: ***Descriptive Statistics of Items of the ATECS of the Experimental and Control Group after the Intervention***

Item	Statement	Post-test					
		Experimental group			Control Group		
		N	*M*	*SD*	*N*	*M*	*SD*
1.	I like trying to solve new problems in Electrochemistry.	51	4.24	1.03	52	3.94	0.96
2.	Electrochemistry lessons are interesting.	51	4.45	0.92	52	3.96	1.01
3.	Electrochemistry is one of the most important topics for people to study.	51	4.20	0.87	52	4.35	0.99
4.	I consider myself a good chemistry student.	51	4.01	1.01	52	4.12	0.86
5.	I am willing to spend more time reading chemistry books.	51	3.76	1.11	52	4.62	0.53
6.	When I am working in the chemistry lab, I feel I am doing something important.	51	4.71	0.46	52	4.69	0.70
7.	Chemistry is one of my favorite subjects.	51	3.82	1.18	52	4.13	0.74
8.	*Chemistry tests make me afraid.	51	3.82	1.51	52	4.13	1.19
9.	In electrochemistry class I feel being in control of my learning.	51	3.59	1.06	52	3.54	1.09
10.	*My chemistry teacher makes me feel as if I am a dumb.	51	3.63	1.4	52	4.29	1.11
11.	*Electrochemistry makes me feel as though I am lost in the bush.	51	3.98	1.29	52	3.94	1.43
12.	If I had a chance, I would do a project in electrochemistry.	51	4.24	0.95	52	4.12	0.92
13.	I like to do electrochemistry experiments.	51	4.27	0.94	52	4.31	0.85
14.	People must understand electrochemistry because it affects their lives.	51	3.80	1.30	52	4.15	1.16
Overall mean/SD			**4.04**	**1.07**		**4.16**	**0.96**

**Negative Items Being Reverse-Scored, So That a Higher Score Indicates Positive Attitudes toward Electrochemistry*

The results showed that the mean item scores in the experimental group after the intervention ranged from 3.59 (item 9) to 4.71 (item 6) with the overall mean score of 4.04. The least mean score was 3.59 (item 9) and the highest mean score was 4.71 (item 6).

In the control group, the item mean scores also ranged from 3.54 (item 9) to 4.69 (item 6) with the overall mean score of 4.16. The least mean score of 3.54 (item 9) suggests that students did strongly agree that they are in control of their learning in electrochemistry class. Also, the highest mean score of 4.69 (item 6), implies that students feel that laboratory work is very important in the learning and understanding of electrochemistry. Students mean scores ranged from 1 to 5 with 3 as the neutral point. Mean scores below 3 indicates a negative attitude and mean scores above 3 indicates a positive attitude. In the experimental group, the mean scores for items 5, 7, 8, 9, 10, 11 and 14 were above 3 but less than 4. In the control group, the mean scores for items 1, 2, 9 and 11 were also above 3 but less than 4. The mean item scores in both groups were above 3 which suggest that students have positive attitudes towards electrochemistry.

4.11 Testing of Hypotheses with Respect to Research Question 2

Research question 2:

What is the Effect of Conceptual Change Text Instruction on Student's Attitude toward Electrochemistry?

H_0 2: There is no significant difference between post-test scores of the students taught using conceptual change texts and those taught using traditional instruction with respect to their attitude towards electrochemistry.

Research question two sought to find out the effect of conceptual change instruction on students' attitude toward electrochemistry. The data was collected through administering the attitude toward electrochemistry scale questionnaire (ATECS) after teaching using conceptual change texts, for the experimental group.

An Independent samples t-test was performed to see if there is any significant difference between the means of the experimental and control groups. Table 4.13 shows the results of the independent samples t-test.

Table 4.13: ***Independent Samples t-Test on Attitude Score of Post-Test of Experimental and Control Groups***

Test	Group	*N*	*M*	*SD*	*t*	*p*
Post-Test	Experimental	51	56.6	8.86	-1.03	.305*
	Control	52	58.2	7.63		

* Not significant, $p > .05$

The results showed that the mean attitude score of the control group was higher (M = 58.8, SD = 7.63) than the mean attitude score of the experimental group (M = 56.6, SD = 8.86) after the intervention.

The independent samples t-test results showed that there was no significant difference in the attitudes of students in the experimental group and control group [t (49) = -1.03, p = .305]. Therefore, we fail to reject the null hypothesis.

4.12 Research question 3:

What is the effect of conceptual change text oriented instruction compared with the conventional method of instruction on students' achievements in electrochemistry?

The question intends to find out the effectiveness of conceptual change text instruction compared with the traditional method of instruction. Data was obtained by administering Electrochemistry Concept Test (ECCT) to both groups after the interventions. The magnitude of the differences in the means of the post-test scores was computed using

Cohen's *d* index. Table 4.14 shows the mean difference and Cohen's *d* index between post-test scores of the experimental group and the control group.

Table 4.14*: Mean Difference between Experimental and Control Group Post-Test Scores*

Group	*N*	M	S*D*	Mean difference	Cohen's *d*
EG	51	12.2	3.83	2.20	.582
CG	52	10	3.73		

Cohen's *d* index was calculated for the post-test as a measure of effect size. Cohen (1992) interpreted the *d* index according to the following criteria: a *d* greater than .20 and less than .50 is considered a 'small' effect, a *d* greater than .50 but less than .80 is considered a ''medium'' effect, and a *d* greater than .80 is considered a 'large' effect.

The effect size of the mean difference between the groups for the post-test (Cohen's *d* = .582) indicated a medium effect. This indicated that there was a substantial difference between the means of the post-test scores of the two groups, which suggested that conceptual change texts have a significant effect on students' cognitive achievements in electrochemistry.

4.13 Research Hypotheses 4:

There is no significant difference in cognitive achievement of male and female students in electrochemistry.

Research hypotheses four required to test if there is any difference in cognitive achievement between male and female students. Data was acquired using Electrochemistry Concept Test (ECCT). Table 4.15 shows the descriptive statistics of achievements of males and females in electrochemistry after the intervention. Also, Tables 4.16 and 4.17 show the results of independent samples t-test on the achievement of males and females in the experimental group and the control group respectively.

Table 4.15*: Descriptive statistics of achievement of males and females*

Group	*Test*	*Sex*	*N*	*M*	*SD*
CG	Post test	Male	41	10.10	3.88
		Female	11	9.66	3.45
EG	Post test	Male	43	12.06	3.67
		Female	8	13.12	4.79

Table 4.16*: Independent Samples t-test on Achievement of Males and Females in Experimental Group*.

Group	Test		*N*	*M*	*SD*	*t*	*p*
EG	Post-Test	Male	43	12.06	3.67	-.711	.480*
		Female	8	13.12	4.79		

* not significant, $p > .05$

Table 4.17*: Independent Samples t-test on Achievement of Males and Females in Control Group*

Group	Test		*N*	*M*	*SD*	*t*	*p*
CG	Post-Test	Male	41	10.1	3.88	.406	.686*
		Female	11	9.66	3.45		

* not significant, $p > .05$

In the experimental group, the results showed that females obtained higher cognitive achievement scores (M = 13.12, SD = 4.79) than their male counterparts (M = 12.06, SD = 3.67). In the control group on the other hand, the results showed that males obtained higher cognitive achievement scores (M = 10.1, SD = 3.88) than their female counterparts (M = 9.66, SD = 3.45).

Independent samples t-test was performed on the post-test results to see if any significant difference exists between males and females in the experimental group.

The results showed that there was no significant difference in the post-test scores between males and females [t (50) = -.711; p = .480]. Therefore, we fail to reject the null hypothesis.

Also, there was no significant difference in the post-test scores of males and females of the control group [t (50) = .406; p = .686]. Therefore, we fail to reject the null hypothesis.

4.14 Research hypotheses 5:

There is no significant difference in Attitude of Male and Female Students toward Electrochemistry.

Research hypotheses five sought to find out if there is any difference in attitude of males and females students toward electrochemistry. Data was collected using the attitude toward electrochemistry scale questionnaire (ATECS). Table 4.18 shows the descriptive statistics of scores of males and females in electrochemistry. Also, Tables 4.19 and 4.20 shows the results of independent samples t-test on attitudes of males and females in the control group and experimental group respectively.

Table 4.18: ***Descriptive statistics of attitude scores of males and females***

Group	*Test*	*Sex*	*N*	*M*	*SD*
CG	Post test	Male	41	59.3	7.23
		Female	11	54.4	8.2
EG	Post test	Male	43	56.6	8.77
		Female	8	56.6	9.94

Table 4.19*: Independent Samples t-Test on Achievement of Males and Females in Control Group*

Group	Test		*N*	*M*	*SD*	*t*	*p*
CG	Post-Test	Male	41	59.3	7.23	1.92	.060*
		Female	11	54.4	8.20		

* Not significant, $p > .05$

Table 4.20*: Independent Samples t-test on Attitude of Males and Females in Experimental Group*

Group	Test		*N*	*M*	*SD*	*t*	*p*
EG	Post-Test	Male	43	56.6	8.77	-.006	.995*
		Female	8	56.6	9.94		

* *Not significant, $p > .05$*

In the control group, the results showed that males obtained higher attitude scores (M = 59.3, SD = 7.23) than their female counterparts (M = 54.4, SD = 8.2), but in the experimental group, the results showed that males obtained the same attitude scores (M = 56.6, SD = 8.77) as their female counterparts (M = 56.6, SD = 9.94).

Independent samples t-test was performed to establish if any significant difference existed between the attitudes of males and females in the experimental group. The results showed that there was no significant difference in attitude between the post-test scores of males and females [t (49) = -.006, p = .995]. Thus the null hypothesis cannot be rejected.

When the independent samples t-test was performed to establish if any significant difference existed between males and females in the control group, the results showed no significant difference between the post-test of males and females in the control group [*t* (50) = .925; *p* = .060]. Therefore, the null hypothesis cannot be rejected.

An analysis of covariance (ANCOVA) was used to assess whether students in the experimental group have higher cognitive achievements than students in the control group after controlling for differences in gender as covariate. Table 4.21 shows the results of the ANCOVA analysis.

Table 4.21: ***ANCOVA for Cognitive Achievement as a Function of group, using Sex as a Covariate***

Source	*df*	*MS*	*F*	*p*	*ηp2*
Sex	1	.257	.018	.894*	.000
Group	1	127	8.79	.004**	.081
Interaction	1	69.0	4.80	.010 **	.088
Error	100	14.4			

**Not significant at p > .05. **Significant, p < .05.*

The results revealed that predicted main effect of treatment was significant, *F* (1, 100) = 8.79, *p* = .004, ηp2 = .081. Predicted main effect of sex was not significant, *F* (1, 100) = 0.018, *p* = .894, ηp2 = .000. The interaction between group and sex was however significant, *F* (1, 100) = 4.80, *p* = .010, ηp2 = .088.

4.15 Common Misconceptions held by Students from the ECCT Items

Analysis of students' responses to items on the ECCT revealed some misconceptions held by students after the intervention.

Table 4.22 shows the percentage of common misconceptions held by students from the ECCT after treatment.

Table 4.22: ***Percentage of Common Misconceptions (%IC) held by Students in Control and Experimental Group on the ECCT after Treatment***

S/n	Misconception	Group			
		CG		EG	
		% IC	% CR	% IC	% CR
1	In an electrochemical cell oxidation occurs at the cathode and reduction at the anode	34.6	65.4	25.5	74.5
2	The cathode in an electrochemical cell always go on the left.	17.3	82.7	17.6	82.4
3	The cathode in an electrochemical cell always go on the right.	51.9	48.1	35.3	64.7
4	The cathode in an electrochemical cell always go with the reducing agent.	17.3	82.7	17.6	82.4
5	Nothing will happen at the surface of inert electrodes.	23.1	76.9	15.7	84.3
6	In an electrochemical cell anions move from anode to cathode	36.5	63.5	41.2	58.8
7	In an electrochemical cell anions move from anode to salt bridge	19.2	80.8	15.7	84.3
8	In an electrochemical cell anions move from salt bridge to cathode	17.3	82.7	13.7	86.3
9	The function of the salt bridge is to allow electron flow.	46.2	53.8	54.9	45.1
10	The function of the salt bridge is to allow proton flow.	3.80	96.2	5.90	94.1
11	The function of the salt bridge is to complete the circuit by providing electrons	21.2	78.8	7.80	92.2
12	In an electrolytic cell oxidation occur at the cathode and reduction occur at the anode.	46.2	53.8	33.3	66.7
13	The anode in an electrochemical cell always go on the left.	40.4	59.6	41.2	58.8
14	The anode in an electrochemical cell always go on the right.	26.9	73.1	13.7	86.3
15	The anode in an electrochemical cell always go with the oxidizing agent.	19.2	80.8	19.6	80.4
16	In an electrochemical cell electrons move from one electrode to the other through the salt bridge.	34.6	65.4	41.2	58.8
17	In an electrochemical cell electrons move throughout the entire system.	5.80	94.2	5.90	94.1
18	In an electrochemical cell the metals are connected through a salt bridge.	34.6	65.4	23.5	76.5

CR = Correct Response, IC = Incorrect Response

The results showed that there exists significant difference between the percentages of misconceptions of students in the experimental and control groups after treatment. This suggested that conceptual the change texts helped students to change their pre-existing conceptions or misconceptions for scientifically acceptable ones. The study also revealed that some misconceptions were held by a considerable number of students even after the instruction using conceptual change texts. The misconceptions numbered 1,3,6,9,12,13,16, and 18 were prevalent among the students in both groups. The most common misconception is that the function of the salt bridge is to allow electron flow (9), the anode in an electrochemical cell is always on the left (13), in an electrochemical cell electrons move from one electrode to the other through the salt bridge (16), in an electrochemical cell anions move from anode to cathode (6), the cathode in an electrochemical cell is always on the right (3), and in an electrochemical cell oxidation occurs at the cathode and reduction at the anode (1). Another common misconception held by students in both experimental groups and control groups is that, in an electrochemical cell the metals are connected through a salt bridge (18). The results also revealed that misconceptions 10, 11 and 17 are held by few students in both experimental and control groups. These misconceptions are: the function of the salt bridge is to allow proton flow (10), the function of the salt bridge is to complete the circuit by providing electrons (11), in an electrochemical cell electrons move throughout the entire system (17). Few students held misconceptions 1, 3, 5, 7, 8, 11, 12, 14, and 18 in the experimental group than in the control group. Also few students held misconceptions 2, 4, 6, 9, 10, 13, 15, and 17 in the control group than in the experimental group. Students still have some misconceptions even after the treatment. This confirms the assertion that some misconceptions are resistant to change. Bodner cited in Canpolat, Pınarbasi, Bayrakceken, and Geban (2006) confirmed that some misconceptions are resistant to instruction.

4.16 Drawing galvanic and electrolytic cells

Table 4.23 shows the percentage of correct labels of drawings of galvanic and electrolytic cells for experimental and control groups.

Table 4.23: ***Percentage of Correct Labels of galvanic and Electrolytic Cells in Both Groups***

	Post-Test			
	Electrochemical cell		Electrolytic cell	
Number of correct labels	EG (%)	CG (%)	EG (%)	CG (%)
No correct label	2	21.2	21.6	80.8
One correct label	13.7	13.5	17.6	5.8
Two correct labels	19.6	21.2	19.6	3.8
Three correct labels	54.9	42.3	33.3	7.7
Four correct labels	9.8	1.9	7.9	1.9

The results showed that students in both groups have problems in drawing and labelling both galvanic and electrolytic cells. As shown in Table 4.8, 2% of students in the experimental group and 21.2% of students in the control group had no correct (zero) label of the electrochemical cell. Only 9.8% of students in the experimental group and 1.9% of students in the control group had four correct labels or more for electrochemical cell. The majority of students in the experimental group (54.9%) and in the control group (42.3%) had three correct labels for galvanic cell. It could be seen that majority of the experimental group students (54.9%) had three correct labels for galvanic cell than the control group students (42.3%).

For the electrolytic cell, 21.6% of students in the experimental group and 80.8% of students in the control group had no correct label. Only 7.90% of students in the experimental group and 1.9% of students in the control group had four or more labels correct. Also, majority of the experimental group students (33.3%) had three correct labels for electrolytic cell than the control group students (7.70%).

In effect students had more difficulty in drawing and labeling the electrolytic cell than the galvanic cell. The results reflect the misconceptions students have about galvanic and electrolytic cells and the lack of concrete understanding of the concepts.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Overview

This chapter interprets and discusses the results of the study. The chapter also highlights the major findings of the study and makes inferences from them in line with findings from related studies in the literature.

5.2 Senior High School Students' Misconceptions in Electrochemistry

The study investigated the effect of conceptual change text on senior high school students' cognitive achievement and attitude towards electrochemistry. Students' misconceptions in electrochemistry were first identified using semi-structured interview and electrochemistry concept test (ECCT) as pre-test. Students attitude towards electrochemistry was also determine using the attitude towards electrochemistry scale (ATECS). Both the ECCT and the ATECS were administered to students before and after the treatment.

The results from the interview showed that students had many misconceptions in electrochemistry especially on galvanic cells and electrolytic cells. Some students (10%) think that the anode is always on the left and the cathode on the right. This confirms the findings of Sanger and Greenbowe (1997). They reported that students think the anode is always the electrode that appears on the left-hand side of a diagram and the cathode is always the electrode on the right. Students think that the identity of the anode and cathode depends on the physical placement of the half-cells. The source of the misconception is from the diagrams presented in the chemistry textbooks and teachers' diagrams during instruction.

Ozkaya, Uceb and Sahinb (2002) reported that this misconception was originally suggested by a student who observed that textbooks and the instructors always drew the anode half-cell on the left and the cathode half-cell on the right. Sanger and Greenbowe (1997) suggested that while it may seem logical for authors and instructors to consistently place the anode half-cell on the left-side according to the cell notation suggested by IUPAC and always to connect it to the (-) terminal of the voltmeter, this may mislead students into believing that these are viable methods to identify the anode and cathode in electrochemical cells. They suggested that these conventions might pose problems when students are asked to analyze electrochemical cell diagrams in examinations or build and draw cells in the laboratory.

Two students (20%) of the students interviewed said that the anode is where oxidation takes place and the cathode is where reduction occurs. One student said that Zn is the anode because it losses electrons and Cu is cathode because it gains electrons. Students also have misconceptions concerning the function of the salt bridge. For example, students report that the salt bridge connects electrons from anode to cathode and that the salt bridge transfers charges between the electrodes. Two students (20%) also said that ions passed through the salt bridge to produce electricity.

Only five students out of the 10 were able to predict the direction of movement of charges/ions but failed to tell which precise kind of ions involved that is whether cations or anions. Two students out of the 10 also said that charges flow from left to right.

Seven of the students (70%) out of the 10 could not tell the kind of reactions taking place in the set-ups. They however cited various incorrect chemical reactions (Table 5.1). One student said he had no idea of the kind of chemical reaction taking place at each electrode.

Table 5.1: Students Ideas of Reactions Occurring at the Electrodes

Reaction	Number of Students	Percent (%)
Electrochemical	2	20
Oxidation reduction	3	30
Neutralization	1	10
Zinc copper reaction	1	10
Chemical reaction	2	20
No idea	1	10

When students were asked how current is produced in an electrochemical cell, one student said that current is produced by the transfer of charges from anode to cathode. Three of the students (30%) said that current is produced through the electrodes. One student also said that current is produced when the two half cells are joint together.

In identifying the anode and cathode in electrolytic cells, two students (20%) said that the anode is the positive electrode and the cathode is the negative electrode. They could not give any reason for their explanation. Two students (20%) said the anode is on the left hand side and the cathode is on the right hand side. Hamza and Wickman, (2007) made a similar observation that students think that the anode is always on the left and the cathode on the right. When students where asked if they know what happens at the anode and the cathode electrodes, Hamza and Wickman found that learners had misconception about the electrode processes as depicted by one learner's response who said that 'the anode should be positive because it loses electrons'. The learners seem to think that the cathode is always on the right and the anode on the left.

One student said oxidation occurs at the anode and reduction occurs at the cathode.

A major student misconception that Sanger and Greenbowe (1997) identified pertains to electron flow through a cell. They found that many students believed that the electrons flow from ''anode to the cathode along the wire and are then released into the electrolyte at the cathode, traveling through the electrolyte solution''.

The findings of this study supports previous research reports. Ndovu (2014) reported that learners think that ions move through the salt bridge from one half-cell to the other half-cell and that ions move from the salt bridge into the half-cells to ensure that no built-up of charge takes place at the electrodes. Concerning the migration of electrons in electrochemical cells, students involved in this study displayed the commonly held belief that ions in the electrolyte accept electrons at one electrode and transport the electrons to the other electrode as has been documented in other studies (Garnett and Treagust 1992a, 1992b; Sanger and Greenbowe 1997a, 1997b; Schmidt, Marohn, and Harrison 2007). In a comparative study involving senior high-school students in Indonesia and Japan by Rahayu, Treagust, Chandrasegaran, Kita & Ibnu (2011) to assess their electrochemical concepts, it came out that students have problems about the type of ions in the salt bridge that moved to the cathode and the anode in a voltaic cell; 56.6% of the Indonesian students and 39.7% of the Japanese students believed that anions in the salt bridge moved to the cathode while cations moved to the anode.

Rahayu *et al* (2011) also found that 53.3% of the Indonesian students and 41.3% the Japanese students believed that electrons moved from one electrode to the other through the salt bridge. Similarly, 56.6% of the Indonesian students and 48.6% of the Japanese students believed that electrons moved from one half-cell to the other through the porous disc (in place of the salt bridge). These beliefs suggested that electrons are able to flow through aqueous solutions similar to findings in studies by Garnett and Treagust (1992a, 1992b) and Sanger and Greenbowe (1997a, 1997b).

In a review of studies involving high-school students' understanding about galvanic and electrolytic cells, Garnett, Garnett, and Hackling (1995) identified several alternative conceptions. Some of them include: the anode is positively charged because it loses electrons, the cathode is negatively charged because it gains electrons, the anode is negatively charged and has a surplus of electrons, and so it attracts cations, the cathode is positively charged and attracts anions, in electrolytic cells, oxidation occurs at the cathode and reduction at the anode; anions and cations move to the cathode and anode.

Garnett, Garnett, and Hackling said that a possible reason for the misconception may lie in the ambiguity of the language in their textbooks. Chemistry textbooks contain scientific terminology that may confuse the students and therefore, cause misconceptions to form. For example, Sanger (1996) after analyzing the illustrations in textbooks for evidence suggested that free electrons can travel in aqueous solutions, only two textbooks include a thoughtful discussion about the charge imbalance that occurs in the half-cells when the salt bridge is not present and both explained that cations and anions migrate to neutralize the charge build up. Unfortunately, statements suggesting that free electrons can exist in solution and that their migration accounts for the current flow in electrolyte solutions are prevalent in other textbooks.

Only one textbook adequately discussed the net charges of the electrodes in a galvanic cell. Electrodes in contact with electrolyte solutions reach an equilibrium which results in dissolved ions and a net negative charge on the electrode from the released electrons.

The extent of this dissociation and the charge imbalance between the metal electrode and the electrolyte solution differs from metal to metal and is responsible for the fact that half-cells composed of different metals have different potentials. This textbook also mentions that the net charge on the electrodes is exceedingly small.

Greenbowe and Sanger (1999) found that most students mistakenly identified the anode and cathode in galvanic cells according to the placement of the electrodes in diagrams in textbooks (the anode commonly depicted on the left and the cathode on the right. Again Sanger and Greenbowe (1999) attribute some of these misconceptions to over simplification of electrochemical cell by teachers. An example of a simplification would be repeatedly illustrating a voltaic cell with the anode on the left side, inferring that the relative location of the electrode determines the nature of the particular oxidation (or reduction) reaction that occurs there.

Sanger and Greenbowe (1997) found that students often describe the movement of electrons in electrochemical cells as: electrons flowing from the anode to the cathode along the wire, entering the solution from the cathode, traveling through the solution and the salt bridge, and emerging at the anode to complete the circuit.

5.3 Effect of Conceptual Change Text on Students' Cognitive Achievement in Electrochemistry

This study investigated the effectiveness of conceptual change text on senior high school students' cognitive achievements and attitudes towards electrochemistry. First, students' cognitive achievements in electrochemistry were measured using electrochemistry concept test (ECCT). Students' attitude was also measured before the treatment, using the attitude toward electrochemistry scale (ATECS). During treatment, students in the experimental group received conceptual change text instructions that took students' misconceptions into consideration and included explanations and demonstrations designed to maximize the plausibility of the concepts of electrochemistry. On the other hand, students in the control group received traditional instructions. The traditional instruction in this study was mainly lectures given by the researcher, use of textbooks, and clear explanation of important concepts to students. The difference between the two strategies was that the conceptual change approach clearly dealt with students' misconceptions, while the traditional approach did not.

The results of the independent-sample *t*-test showed that there was no significant difference between the experiment group and the control group in terms of cognitive achievement before the treatment (see Table 4.10). This showed that the students in the control and experimental groups were similar regarding pre-test scores and prior knowledge.

Independent samples *t*-test of the post-test scores on the other hand, showed that there was a significant difference between the experimental group and the control group in terms of cognitive achievement after the treatment (see Table 4.10). These results suggested that teaching with conceptual change texts caused a significantly better acquisition of scientific concepts than teaching using traditional instruction. These results were supported by Balci (2006) which indicated that conceptual change text instruction was more effective to get better understanding of scientific conceptions. There may be several reasons for the effectiveness of conceptual change text oriented instruction. Firstly, conceptual change texts were designed by considering students' misconceptions about electrochemistry concepts. These findings are consistent with that of Sendur and Toprak (2013) who found that conceptual change text was effective in enhancing the understanding of students in chemistry concepts. Uzuntiryaki and Geban (2005) explored the effect of conceptual change texts accompanied with concept mapping instruction on 8th grade students' understanding of solution concepts. The results revealed that conceptual change text accompanied with concept mapping instruction caused a significantly better acquisition of scientific conceptions about the solution concept.

5.4 Effect of the use of Conceptual Change Text on Students Attitude towards Electrochemistry

The attitude towards electrochemistry scale (ATECS) was used to investigate the effect of treatment on students' attitude towards chemistry. It was administered to both groups before the treatment and the results showed that the experimental group and the control groups were not significantly different with respect to attitudes towards electrochemistry. The same test was again administered after the treatment and when the post attitude results were examined it was found that there was no significant effect of treatment on students' attitude towards electrochemistry chemistry.

This suggests that conceptual change text instruction has no significant effect on students' attitude towards electrochemistry. Similar results were reported by Unlu (2000) and Çakır *et al*. (2002), who found that conceptual change approach was effective in increasing achievement in the experimental group, but not effective in increasing students' attitude towards science significantly. In this study it was also found that conceptual change text instruction was more effective than the traditional instruction in increasing cognitive achievement, but did not increase students' attitude towards chemistry. One reason may be the duration of the treatment which was only four weeks, so this period may be too short to change the students' attitudes towards chemistry. Koballa, Fishbein and Ajzen cited in Balci (2006) maintained that long duration of new teaching strategies is needed to change students' attitude towards science. He explained that limited time for the application of new teaching strategy to only one unit may be short to change students' attitudes towards chemistry. According to Johnstone cited in Salta and Tzougraki (2004), the application of chemistry concepts and symbols depend on the students' abilities to transfer from macroscopic level to symbolic level, from symbolic level to microscopic level, and vice versa. According to Salta and Tzougraki (2004), the content of chemistry curriculum, the chemistry lessons time, the methods of teaching chemistry, and the lack of laboratory experiments might be some of the reasons that form such attitudes. In this study the method of teaching chemistry might have resulted in the findings. Schibeci and Riley cited in Salta & Tzougraki (2004) indicated that students' attitudes toward science are strongly influenced by what the teacher is doing in the classroom. They found that a positive attitude toward science was related to the laboratory program. They observed that students' attitudes towards chemistry were greatly influenced by the method of teaching chemistry and the nature of the chemistry curriculum\, and so teachers need to adopt conceptual change approaches in teaching chemistry so as to improve students' achievements and attitudes towards the subject.

5.5 Conceptual Change Text Oriented Instruction Compared with the Traditional Method of Instruction

The effect size of the mean difference between the experimental and the control group after the intervention (d = 58.2%) indicated a medium effect. This means there was a substantial difference between the means of the experimental group and the control group after the intervention. This suggests that conceptual change text instruction have a significant effect in eliminating misconceptions than the traditional instruction. The findings are consistent with that of other researchers, such as Gunay (2005) who investigated the effectiveness of conceptual change text oriented instruction accompanied with analogies over traditionally designed chemistry instruction on 10th grade students' misconceptions, with regard to their understanding of atom and molecule concepts and attitudes towards chemistry as a school subject. The result of that study showed that the conceptual change text oriented instruction accompanied with analogies provided better conceptual understanding of atoms and molecules and gave more opportunities to eliminate the misconceptions about the atom and molecule concepts than the traditional instruction in chemistry. Geban and Bayir (2000) also conducted a research to investigate the effectiveness of conceptual change texts instruction over the traditionally designed chemistry instruction on students' understanding of chemical change. The result of that study also showed that students in conceptual change text instruction group had a significantly higher score with respect to achievement than the students in the traditionally designed instruction group. Again, when Uzuntiryaki and Geban (2005) explored the effect of conceptual change texts accompanied with concept mapping instruction on 8th grade students' understanding of solution concepts, they realized that conceptual change text accompanied with concept mapping instruction caused a significantly better acquisition of scientific conceptions about the solution concept.

In a similar study, Cakir, Uzunkiyati and Geban (2002) compared the effects of concept mapping and conceptual change texts instruction over the traditional instruction on tenth grade students' understanding of acid and base concepts. Their results showed that concept mapping instruction and the conceptual change texts instruction caused a significantly better acquisition of scientific conceptions related to acids and bases than the traditional instruction. Other works that give credence to this present study are those of Gunay (2005), who found that refutational text was more effective than regular or traditional text for conceptual change, and concluded that these texts are, at least, more effective to support conditions suggested by Posner, Strike, Hewson and Gertszog (1982)as well as Canpolat, Pinarbasi, Bayrakceken, and Geban (2006) who investigated the effect of a conceptual change approach over traditional instruction on students' understanding of chemical equilibrium concepts, and realized that the students in experimental group performed better than those in the control group.

5.6 Achievement of Males and Females in Electrochemistry

Independent samples t-test showed that there was no significant difference in the post-test scores of males and females in the experimental group in terms of cognitive achievement as well as in the post-test scores of males and females in the control group (Tables 4.15 and 4.16).

This outcome was not consistent with the findings of some studies which reported that male students usually outperformed female students in mathematics and science. For example, Abu- Hola (2005) found that the achievement of boys in earth science, biology, chemistry and physics was significantly better than the achievement of the girls, which was supported by others such as; Beller and Gafni (2000); Neuschmidt, Barth, and Hastedt, (2008); Korporshoek, Kuyper, van der Werf, and Bosker, (2011). Their conclusions were that many students perceive science as a masculine subject and so believed that males have a more scientific intellect than females.

5.7 Attitude of Males and Females toward Electrochemistry

With regards to attitudes, the independent samples t-test shows that there was no significant difference in the post-test scores of males and females in both the experimental group and the control group in terms of their attitude towards electrochemistry (Tables 4.18 and 4.19).

These results agreed with those of Cheung (2011) who also found no statistically significant difference between males and females, regarding attitudes toward chemistry lessons. The results of this study however did not agree with the findings of some other studies, such as Cheung (2009) which revealed that girls had a more favorable attitude towards studying chemistry than did boys, Salta, & Tzougraki (2004) which showed that girls had more positive attitudes towards chemistry compared with boys. They posit that it is possible that these attitudes of girls are due to "social norms" or in other words to social stereotypes. This belief by many that chemistry is difficult reflects stereotypes like "boys are born to be scientists or chemists." As shown in most books, films, television, and newspaper articles which highlight male science figures. Thus, gender-equity should be a goal of science education.

CHAPTER SIX

6.0 SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 Overview

In this chapter, a summary of the research and the major findings of the research study, conclusion and recommendations are presented. Also, implications for teaching chemistry and suggestions for further research are presented.

6.2 Summary of the Study

The main purpose of this study was to determine the effect of conceptual change texts on students' cognitive achievements and attitudes towards electrochemistry. Students' prior understanding of electrochemistry was measured using electrochemistry concept test (ECCT). Students' attitude were also measured as pre-test before the treatment using the attitude toward electrochemistry scale (ATECS). During treatment, the experimental group received conceptual change text instruction that took students' misconceptions into account and included explanations and demonstrations designed to increase the understanding of the concepts of electrochemistry. These texts were prepared according to the Posner *et al.'s* conceptual change model. Students in the control group received traditional instruction. The results revealed that conceptual change texts resulted in a significantly better acquisition of scientific concepts and cognitive achievement of students in electrochemistry than the traditional teaching approach. The conceptual change texts instruction was more effective in the elimination of misconceptions, for most of the questions in the test. Students in the experimental group performed better than those of the control group. This can be explained by the fact that students in the experimental group were involved in activities that helped to bring out their misconceptions in electrochemistry. In the conceptual change texts, emphasis was given to students' misconceptions. In the control group, the teacher could not consider students' pre-existing knowledge but only communicates knowledge to students by means of lecturing.

6.3 Main Findings of the Study

1. Many students before treatment, had no scientifically acceptable understanding of the concepts in electrochemistry. Many of these misconceptions were related to placement of anode and cathode electrodes in electrochemical cells (9.8% and 3.9% respectively), functions of the salt bridge (11.8%), oxidizing and reducing agents (7.8%), using reactivity of metals to identify the anode and the cathode (17.6%), oxidation and reduction in terms of electron transfer (29.4%), oxidation and reduction in terms of change in oxidation number (33.3%), and reactions occurring at the electrodes.

   Conceptual change texts have a significant effect on students' cognitive achievement in electrochemistry. There was a significant difference in cognitive achievement scores of the experimental group and the control group [t (101) = 2.99, p = .003, d = .582]. The effect size of d = .582 indicated a substantial effect. There was no significant difference in the post-test scores between males and females in terms of cognitive achievement in electrochemistry of the experimental group [*t* (50) = -.711; *p* = .480], as well as that of the control group [*t* (50) = .406; *p* = .686].

2. Students in both groups had positive attitude towards electrochemistry. After the treatment, there was also, no significant difference in the attitude of students in the experimental group and the control group [*t* (49) = -1.03, *p* = .305]. There was no significant difference in attitudes between the post-test scores of males and females in the experimental group [*t* (49) = -.006, *p* = .995], as well as in the control group [*t* (50) = .1.925; *p* = .060]. There was significant interaction between main group and sex as a covariate *F* (1, 100) = 4.80, *p* = .010, ηp2 = .088.
3. There was a substantial difference between the means of the post-test scores of the two groups, the effect size of the mean differences between the groups for the post-test (Cohen's *d* = .582) indicated a medium effect.

6.3 Conclusions

Based on the findings of the study, the following conclusions were drawn:

The use of conceptual change text instruction resulted in a better acquisition of electrochemistry concepts and improved students' cognitive achievement in electrochemistry than the traditional method of instruction.

Conceptual change texts however did not change students' attitude towards electrochemistry, but had a significant effect on students' cognitive achievements in electrochemistry than the traditional method of instruction.

There was no significant difference in cognitive achievements of males and females in electrochemistry, as well as no significant difference in attitudes of males and females towards electrochemistry, thus for conceptual change to occur, teachers should always plan well and in advance in order to create the right conditions for the changes to take place.

6.4 Implications for Teaching Chemistry

1. Students may have some misconceptions about electrochemistry concepts and chemistry teachers should be informed about the misconceptions and their sources before instruction.
2. Traditional chemistry instruction is not enough to eliminate students' misconceptions. The teacher should consider the students' misconceptions and pre-existing knowledge when planning the instruction.
3. Some conceptual change texts oriented instruction provides better conceptual understanding of electrochemistry concepts, chemistry teachers should be aware of how to develop and apply conceptual change texts in the classroom.

6.5 Recommendation

Based on the findings of the study, the following recommendations were made:

1. Conceptual change texts oriented instruction should be used to teach other chemistry concepts.
2. During instruction, demonstrations and group works should be combined with conceptual change texts in order to activate students' pre-conceptions.
3. Chemistry teachers should promote active involvement of students through the use of conceptual change texts and other student-centered strategies.
4. Chemistry teachers should consider students' misconceptions and their effect on the acquisition of scientific knowledge.

6.6 Suggestions for Further Studies

The following suggestions were recommended for further research:

1. A study can be carried out on the use of conceptual change texts for different chemistry topics.
2. This study can be conducted with a larger sample size so as to generalize the results for the larger population.
3. The study can also be replicated in other schools to confirm or otherwise the results of this study.

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Appendix A
Electrochemistry Concept Test (ECCT)

Pre-Test/Post-Test

Part 1: Multiple Choice Questions

NAME: ______________________________________ **Male** ☐ ☐
Female

SCHOOL: ______________________________________ **Age:** _______ **Serial:** _______

PART 1: MULTIPLE CHOICE QUESTIONS

Answer All Questions **Circle Your Choice**

1. In electrochemical cells, oxidation occurs at the _______and reduction occurs at _______ the
   A. Cathode/anode
   B. Anode/cathode
   C. Cathode/cathode
   D. Anode/anode
2. The cathode in an electrochemical cell is always go:
   A. On the left
   B. On the right
   C. With reducing agent
   D. With the oxidizing agent
3. What will occur at the surface of inert electrodes?
   A. Nothing
   B. Reduction
   C. Oxidation
   D. Either oxidation or reduction

4. To maintain electrical neutrality in a galvanic cell, anions move from:
   A. Anode to cathode
   B. Cathode to anode
   C. Anode to salt bridge
   D. Salt bridge to cathode
5. To make an electrolytic cell work, it needs a _________
   A. Salt bridge
   B. Electron

C. Power source
D. Nothing, it is spontaneous

6. In an electrochemical cell involving zinc metal in zinc sulphate solution and copper metal in copper sulphate solution, which of the following occurs at the surface of the cathode?
   A. Zinc atoms are reduced to form zinc ions.
   B. Zinc ions are oxidized to form zinc atoms.
   C. Copper atoms are reduced to form copper ions.
   D. Copper ions are reduced to form copper atoms.
7. The function of the salt bridge is to;
   A. Allow electron flow
   B. Allow proton flow
   C. Complete the circuit by providing electrons
   D. Complete the circuit by providing ions
8. In electrolytic cells, oxidation occurs at the _______ and reduction occurs at the _______
   A. Cathode/anode
   B. Anode/cathode
   C. Anode/anode
   D. Cathode/cathode
9. In an electrochemical cell the anode always goes;
   A. On the left
   B. On the right
   C. With the reducing reaction
   D. With the oxidizing reaction
10. How do electrons move through the electrochemical cell?
    A. Throughout the entire system.
    B. From one electrode to the other through the wire.
    C. From one electrode to the other through the salt bridge
    D. They are not moving

11. Consider the reaction: $Zn(s) + Cu^{2+} (aq) \rightarrow Zn^{2+} (aq) + Cu(s)$ which of the following represents the oxidizing agent in the above reaction?
    A. Zn
    B. Zn^{2+}
    C. Cu
    D. Cu^{2+}
12. Which statement is correct?
    A. Oxidation involves loss of electron and a decrease in oxidation state.
    B. Oxidation involves Gain of electrons and an increase in oxidation state.
    C. Reduction involves loss of electrons and an increase in oxidation state.
    D. Reduction involves gain of electrons and a decrease in oxidation state.

13. Which of the following characteristics are specific to an electrolytic cell?
    I. The chemical reaction is spontaneous.
    II. The reaction requires energy from an electrical source.
    III. The anode is the positive electrode of the cell.
    A. Only I
    B. Only II
    C. I and II
    D. II and III
14. Which of the values given below is the overall cell voltage of reaction occurring?
    $Fe^{2+}_{(aq)} + 2e^- \rightleftharpoons Fe_{(s)}$ -0.44V
    $Cu^{2+}_{(aq)} + 2e^- \rightleftharpoons Cu_{(s)}$ +0.34V
    A. -0.78V
    B. +0.78V
    C. +0.10V
    D. -0.10V
15. In electrochemical cells:
    A. one metal has to be more reactive than the other
    B. a power source is necessary
    C. the metals are connected through a salt bridge
    D. water becomes an electron donor
16. In a particular redox reaction, the oxidation number of phosphorus changed from -3 to 0. From this it may be concluded that phosphorus:
    A. Lost 3 electrons and was reduced.
    B. Lost 3 electrons and was oxidized.
    C. Gained 3 electrons and was reduced.
    D. Gained 3 electrons and was oxidized.

17. In which of the following unbalanced reactions does chromium undergo oxidation?
    A. $Cr^{3+} \longrightarrow Cr$
    B. $Cr^{3+} \longrightarrow Cr^{2+}$
    C. $Cr^{3+} \longrightarrow Cr_2O_7^{2-}$
    D. $CrO_4^{2-} \longrightarrow Cr_2O_7^{2-}$
18. Which of the following is an equation representing a redox reaction?
    A. $2NO_{2(g)} \longrightarrow N_2O_{4(g)}$
    B. $Mg_{(s)} + Cl_{2(g)} \longrightarrow MgCl_{2(s)}$
    C. $Ag^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)}$
    D. $NH_{3(aq)} + H^+_{(aq)} \longrightarrow NH_4^+{}_{(aq)}$
19. What is the next step in balancing the half reaction $Cr_2O_7^{2-} \longrightarrow 2Cr^{3+}$?
    A. Add 7 H_2O to the left.
    B. Add $7H_2O$ to the right

C. Add 5 electrons to the left
D. Add 5 electrons to the right

20. What is the next step in balancing the reaction $SO_3^{2-}(aq) + H_2O(l) \longrightarrow SO_4^{2-}(aq) + 2H^+ (aq)$?
A. Add 2 electrons to the left
B. Add two electrons to the right
C. Add 4 electrons to the left
D. Add four electrons to the right

PART 2

ANSWER ALL QUESTIONS

1. Draw a zinc/copper electrochemical cell. Label all the necessary parts including the solution in the beakers, the anode and cathode, the salt bridge, reactions at the electrodes, the metal electrodes and the signs at the electrodes.

2. Draw an electrolytic cell showing the electrolysis of sodium chloride. Label all the necessary parts including the electrolyte, cathode and anode, reactions at the electrodes, signs at the electrodes, the power source, and the carbon electrodes.

Appendix B
Attitude toward Electrochemistry (ATECS)-modified

This work is purely for academic purpose. Confidentiality is assured.

Please indicate the extent to which you agree or disagree with each of the following statements by circling your choice. The responses are: ***Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D) and Strongly Disagree (SD)***

NAME: ______________________________ SCHOOL: ______________

CLASS: ______________________________ SERIAL NUMBER: ________

SEX: Male ☐ Female ☐

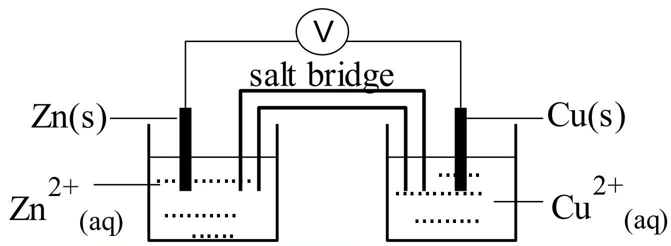
S/N	ITEMS	RESPONSES				
1	I like trying to solve new problems in Electrochemistry.	SA	A	U	D	SD
2	Electrochemistry lessons are interesting.	SA	A	U	D	SD
3	Electrochemistry is one of the most important topics for people to study.	SA	A	U	D	SD
4	I consider myself a good chemistry student.	SA	A	U	D	SD
5	I am willing to spend more time reading chemistry books.	SA	A	U	D	SD
6	When I am working in the chemistry lab, I feel I am doing something important.	SA	A	U	D	SD
7	Chemistry is one of my favorite subjects.	SA	A	U	D	SD
8	Chemistry tests makes me afraid.	SA	A	U	D	SD
9	In electrochemistry class I feel being in control of my learning.	SA	A	U	D	SD
10	My chemistry teacher makes me feel as if I am a dumb.	SA	A	U	D	SD
11	Electrochemistry makes me feel as though I am lost in the bush.	SA	A	U	D	SD
12	If I had a chance, I would do a project in electrochemistry.	SA	A	U	D	SD
13	I like to do electrochemistry experiments.	SA	A	U	D	SD
14	People must understand electrochemistry because it affects their lives.	SA	A	U	D	SD

Appendix C:
Semi-Structured Interview

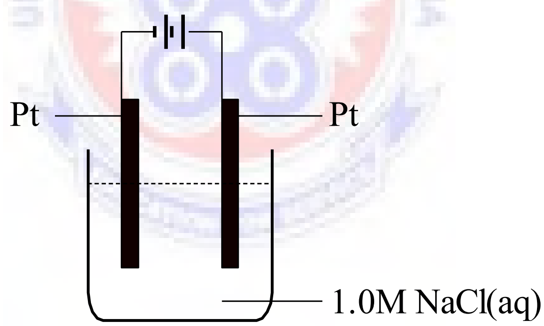
(Protocol Adapted and Modified from Sangar and Greenbowe, 1995)

Name: ____________________**Class:** _______ **Age:**________ **Code:** ______

Interviewer: ____________________ **Date:**__________ **Sex:** ______



1. What is the purpose of each piece of apparatus shown above?
2. How will you determine which electrode is the anode and which is the cathode?
3. How is current produced in this cell?
4. What is happening in the solution? What does the salt bridge do?
5. In what direction do the charges/ions flow in this cell to complete the circuit?
6. What reactions are taking place in each cell?



1. How does this cell differ from the electrochemical cell shown above?
2. How will you determine which electrode is the cathode and which is the anode?
3. In which direction do the charges flow to complete the circuit?
4. Which reactions are taking place at each electrode?

Appendix D

Attitude toward Electrochemistry (ATECS) - Original

This work is purely for academic purpose. Confidentiality is assured.

Please indicate the extent to which you agree or disagree with each of the following statements by circling your choice. The responses are: ***Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D) and Strongly Disagree (SD)***

NAME: ______________________________ SCHOOL: ______________

CLASS: ______________________________ SERIAL NUMBER: ________

SEX: Male ☐ Female ☐

1	I like electrochemistry more than any other chemistry topic.	SA	A	U	D	SD
2	Electrochemistry lessons are interesting	SA	A	U	D	SD
3	Electrochemistry is one of my favorite chemistry topics	SA	A	U	D	SD
4	I like to do electrochemistry experiments	SA	A	U	D	SD
5	When I am working in the chemistry lab I feel I am doing something important.	SA	A	U	D	SD
6	Doing electrochemistry experiments is fun	SA	A	U	D	SD
7	Electrochemistry is useful for solving everyday problems	SA	A	U	D	SD
8	People must understand electro chemistry because it affects their lives.	SA	A	U	D	SD
9	Electrochemistry is one of the most important topics for people to study.	SA	A	U	D	SD
10	I am willing to spend more time reading electrochemistry textbooks.	SA	A	U	D	SD
11	I like trying to solve new problems in electrochemistry.	SA	A	U	D	SD
12	If I had a chance I will do a project in electrochemistry.	SA	A	U	D	SD
13	Chemistry makes me feel as though I am lost in the bush.	SA	A	U	D	SD
14	Chemistry tests makes me afraid.	SA	A	U	D	SD
15	I will not do well in chemistry in my final exams.	SA	A	U	D	SD
16	I consider myself a good chemistry student.	SA	A	U	D	SD
17	I think I am not capable of becoming a doctor or a scientist in future	SA	A	U	D	SD
18	I chemistry class I feel being in control of my learning.	SA	A	U	D	SD
19	My chemistry teacher makes me feel as if I am a dumb.	SA	A	U	D	SD
20	I enjoy talking to my chemistry teacher after class.	SA	A	U	D	SD

Appendix E

Item-Total Statistics of original 20 items

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
ATECS1	80.6800	128.727	.027	.766	.869
ATECS2	80.8400	115.973	.506	.964	.858
ATECS3	80.7200	117.877	.547	.929	.857
ATECS4	80.7200	112.627	.537	.937	.857
ATECS5	80.2000	119.500	.661	.972	.857
ATECS6	81.4800	122.593	.148	.820	.876
ATECS7	81.1200	126.110	.101	.809	.872
ATECS8	81.1600	111.640	.573	.889	.855
ATECS9	80.4800	114.760	.694	.903	.853
ATECS10	81.2800	109.793	.612	.955	.853
ATECS11	80.6400	121.490	.471	.833	.861
ATECS12	80.4000	119.583	.593	.913	.858
ATECS13	81.0800	107.993	.656	.824	.851
ATECS14	81.0800	103.327	.795	.984	.844
ATECS15	80.0400	129.040	.037	.922	.868
ATECS16	80.2800	120.293	.520	.967	.859
ATECS17	80.1600	126.890	.140	.906	.868
ATECS18	80.8800	111.610	.638	.957	.852
ATECS19	80.5600	108.757	.659	.891	.851
ATECS20	81.2000	120.833	.229	.712	.871

Appendix F
Item-Total Statistics of the 14 items

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
ATECS2	55.5200	96.343	.587	.894	.900
ATECS3	55.4000	98.833	.603	.857	.900
ATECS4	55.4000	93.083	.615	.864	.899
ATECS5	54.8800	100.443	.730	.915	.898
ATECS8	55.8400	93.723	.585	.831	.900
ATECS9	55.1600	96.640	.710	.852	.896
ATECS10	55.9600	93.790	.552	.888	.902
ATECS11	55.3200	102.310	.530	.765	.903
ATECS12	55.0800	100.077	.688	.823	.899
ATECS13	55.7600	91.940	.605	.698	.900
ATECS14	55.7600	87.273	.760	.943	.892
ATECS16	54.9600	101.790	.536	.806	.902
ATECS18	55.5600	93.673	.653	.867	.897
ATECS19	55.2400	91.357	.660	.826	.897

Appendix G
Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.822	48.726	48.726	6.822	48.726	48.726	3.118	22.271	22.271
2	1.777	12.692	61.418	1.777	12.692	61.418	2.980	21.285	43.556
3	1.386	9.899	71.317	1.386	9.899	71.317	2.782	19.874	63.430
4	1.007	7.191	78.508	1.007	7.191	78.508	2.111	15.079	78.508
5	.795	5.679	84.188						
6	.688	4.913	89.101						
7	.440	3.140	92.241						
8	.355	2.537	94.777						
9	.256	1.826	96.603						
10	.215	1.539	98.142						
11	.118	.846	98.988						
12	.065	.466	99.453						
13	.055	.389	99.843						
14	.022	.157	100.000						

Extraction Method: Principal Component Analysis.

Appendix H
Conceptual Change Texts (CCT)

Table 1: List of conceptual change texts (CCT)

TEXT	TOPIC
CCT1	Introduction to Electrochemistry
CCT2	Oxidation and Reduction Reactions
CCT3	Electrochemical Cells
CCT4	Standard Electrode Potentials
CCT5	Electrolytic Cells
CCT6	Balancing Redox Reactions

TEXT 1: Introduction to Electrochemistry

What is electrochemistry?

Electrochemistry is the branch of chemistry that deals with the chemical changes produced by electricity and the production of electricity by chemical changes. **Electrochemistry deals with the interconversion of chemical and electrical energy.**

Why study electrochemistry?

Discuss with your friend some of the applications of electrochemistry. Mention some of the applications of electrochemistry.

Electrochemistry is an important topic. It has many applications and some of them include:

1. Production of metals like Na, Mg. Ca and Al.

2. Electroplating.
3. Purification of metals.
4. Batteries and cells used in various gadgets.

Discus some devices that use batteries. Can you imagine how live would be without batteries?

Devices that use the principles of electrochemistry/batteries include the following. Can you identify them?

Fig. 1: Devices that use the principles of electrochemistry.

TEXT 2: Oxidation and Reduction

- Electrons are always transferred from one atom or molecule to another in an electrochemical reaction.
- There are three different types of electrochemical reactions based on the changes in oxidation state that occur in them.

Some students incorrectly think that…….
That there is only one definition for oxidation. That is the addition of oxygen to a species.

That there is only one definition for reduction. That is the removal of oxygen from a species.

This is called a misconception and is incorrect.

1. Oxidation is the **addition** of oxygen to a species
2. Reduction is the **removal** of oxygen from a species
3. Oxidation is the **removal** of hydrogen from a species.
4. Reduction is the **addition** of hydrogen to a species.

For example:

Oxidation-reduction in terms of oxygen

$2Zn_{(s)} + O_{2(g)} \rightarrow 2ZnO_{(s)}$

$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$

$ZnO_{(s)} + C_{(s)} \rightarrow Zn_{(l)} + CO_{(g)}$

Oxidation and reduction can also be defined in terms of electrons transfer and in terms of oxidation state.

Oxidation and reduction can **also be defined** in terms of electron transfer.

- Oxidation is the **loss** of electrons (**OIL**).
- Oxidation is an **increase** in oxidation state.
- Reduction is the **gain** of electrons (**RIG**).
- Reduction is **decrease** in oxidation state.

What is oxidation and reduction reactions?

Example 1

In the formation of sodium chloride, NaCl,

$2Na + Cl_2 \longrightarrow 2NaCl$

- Na loses two electrons to form $2Na^+$. Therefore, we say that Na is oxidized.
- $2Na \longrightarrow 2Na^+ + 2e^-$
- The Cl_2 gains two electrons to form $2Cl^-$. Therefore, we say that Cl is reduced.
- $Cl_2 + 2e^- \longrightarrow 2Cl^-$
- The overall reaction is: $2Na + Cl_2 \longrightarrow 2NaCl$

Discuss oxidation and reduction reactions

Definition of oxidation

Oxidation is any chemical reaction in which a substance combined with oxygen.

Example 1

- When oxygen gas is passed over heated copper, the copper combines with the oxygen to form copper (II) oxide. In other words, the copper is oxidized.

  $2Cu_{(s)} + O_{2(g)} \longrightarrow 2CuO_{(s)}$

- What does oxidation mean in terms of electron transfer in the equation below?

  $2Cu_{(s)} \longrightarrow 2Cu^{2+}{}_{(s)} + 4e^{-}$

- The copper metal has lost electrons, and in doing so, it has formed copper (II) ions.

Example 2

- When magnesium burns in oxygen, the magnesium combines with the oxygen to form magnesium oxide. In other words, the magnesium is oxidized.

  $2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$

- What does the oxidation of magnesium mean in terms of electron transfer as shown below?

  $2Mg_{(s)} \longrightarrow 2Mg^{2+}{}_{(s)} + 4e^{-}$

- The magnesium metal has lost electrons, and in doing so, it has formed magnesium ions. All reactions concerning the gain of oxygen involve a loss of electrons. Oxidation can therefore be extended to include any reaction which involves a loss of electrons.

Example 3

- Magnesium reacts with dilute hydrochloric acid to form magnesium chloride and hydrogen gas.

  $Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(s)} + H_{2(g)}$

- The magnesium is losses electrons to form magnesium ions.

  $Mg_{(s)} \longrightarrow Mg^{2+}{}_{(aq)} + 2e^{-}$

- The magnesium is said to be oxidized.

Definition of reduction

Reduction is any chemical reaction in which oxygen is removed from a substance.

Example 1

- When hydrogen gas is passed over heated copper (II) oxide, the hydrogen removes the oxygen to form water. In other words, the copper (II) oxide is reduced.

  $CuO_{(s)} + H_{2(g)} \longrightarrow Cu_{(s)} + H_2O_{(l)}$

- What does the reduction of copper (II) ion mean in terms of electron transfer?

  $Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$

- The copper (II) ion has gained electrons and in doing so has been reduced to copper metal.

Example 2

- Iron (III) oxide reacts with carbon monoxide gas to form iron metal and carbon dioxide gas.

  $Fe_2O_{3\,(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(s)} + 3CO_{2(g)}$

- The iron (III) ions are gaining electrons to form iron metal.

  $2Fe^{3+} + 6e^- \longrightarrow 2Fe_{(s)}$ the iron (III) ion is being reduced.

Consider the reaction:

$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$

i. Which species is oxidized?
ii. Which species is reduced?

- The oxidation state of Zn has increased from **0 to +2**. We say that zinc is oxidized.
- The oxidation state of Cu has decreased from **+2 to 0**. We say that copper is reduced.
- **Oxidation number:** is the assigned charge on an atom.
- **Oxidizing agent**: is the species that is reduced and thus causes oxidation.

- **Reducing agent**: is the species that is oxidized and thus causes reduction.

In the reaction below:

$MnO_4^-{}_{(aq)} + Fe^{2+}{}_{(aq)} + H^+{}_{(aq)} \longrightarrow Mn^{2+}{}_{(aq)} + Fe^{3+}{}_{(aq)} + H_2O_{(l)}$

- Assign **oxidation numbers** to the species in the reaction.
- Is there any **change** in the oxidation numbers?
- Identify the species that is **oxidized** and the species that is **reduced**.

....

....

....

TEXT 3: Electrochemical Cells

What is a galvanic cell?

Galvanic cell is a device which converts spontaneous chemical energy into electrical energy in a redox reaction.

- In an electrochemical cell, the half-cell where oxidation takes place is known as the **oxidation half-cell** and the half-cell where reduction takes place is known **as** the **reduction half-cell.**
- Oxidation takes place at the anode**.**
- The anode is negatively charged.
- Reduction takes place at the cathode**.**
- The cathode is positively charged.

- During this process transfer of electrons takes place from anode to cathode while electric current flows in the opposite direction.

Cell Notations

A shorthand (line) notation is often used to represent the voltaic cell diagram.

$Zn_{(s)}$ | Zn^{2+} || Cu^{2+} | $Cu_{(s)}$

The single vertical line (|) represents a phase boundary between the metal and the ion in solution.

The double vertical line (||) represents the salt bridge. By convention, the anode half-cell is written first, to the left of the double lines, and the cathode half-cell is written second, to the right of the double lines.

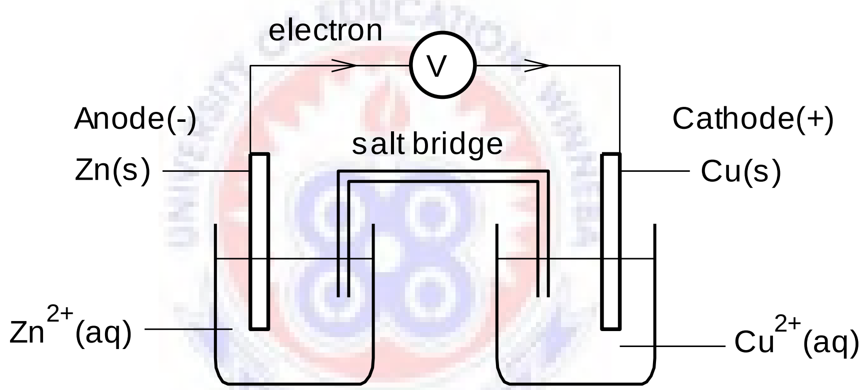


Fig. 2: Labeled diagram of a galvanic cell

This voltaic cell/Galvanic cell consists of:

- An oxidation half-cell.
- Oxidation takes place at the anode: Zn(s)→ Zn^{2+} (aq) + $2e^{-}$
- A reduction half-cell.
- Reduction takes place at the cathode: Cu^{2+} (aq) + 2e- → Cu(s)
- A salt bridge (used to complete the electrical circuit).
- Cations move towards the cathode.
- Anions move towards the anode.
- The two solid metals are the **electrodes** (cathode and anode).

Some students incorrectly think that:

1. The **anode** like **anions** is negative and the **cathode** like **cations** is always positive. **This is a misconception and is wrong**.
2. The **anode** is **positively** charged because it has lost electrons and the cathode is negatively charged because it has gained electrons. **This is wrong!**
3. In all types of cells: Cathode is ***always*** the (–) pole and anode ***always*** the (+) pole.
4. The anode is always the half-cell drawn on the ***left*** side in an electrochemical cell diagram. And the cathode is always the half-cell on the right.

Correct!

The metal at the anode (Zn) is more reactive and **loses electrons** and the ions of the metal are released into solution. The electron lost is a **product** and therefore the anode **attains a negative** charge.

At the cathode, the metal ion (Cu^{2+}) **gains** the electron from the anode. The electron is consumed as a reactant. Therefore, the cathode attains a **positive charge.**

- At the anode electrons are lost.
- The electrons become products.
- Thus the anode is negative.
- At the cathode electrons are gained.
- Electrons are consumed therefore the cathjode electrode is positive.

Some students incorrectly **think** that:

1. **Electrons enter** the solution from the cathode, **travel through** the solutions and the **salt bridge**, and emerge at the anode to complete the circuit. **This is wrong!**

2. Anions in the **salt bridge** and the electrolyte **transfer** electrons from the cathode to the anode. **This is wrong!**

- Electrons travel from the anode to the cathode through the **external circuit** (the wire).
- Electrons **do not** travel through the solution (electrolyte) and the salt bridge.
- Only ions (cations and anions) travel through the solution and the salt bridge.
- Salt bridge does not transfer electrons.

What is the function of the salt bridge?

Some students incorrectly think that:

1. Electrons travel from the anode enters the cathode and then travel through the electrolyte into the salt bridge and back to the anode. **This is wrong**!
2. The function of the salt bridge is to complete the circuit. **This is also wrong!**

- Anions and cations move through a porous barrier or salt bridge.
- To maintain electrical **neutrality** but **does not** allow the two solutions to mix.
- Cations move into the cathodic compartment to neutralize the excess negatively charged ions.
- Anions move into the anodic compartment to neutralize the excess positively charged ions (Zn^{2+}) ions formed by oxidation.

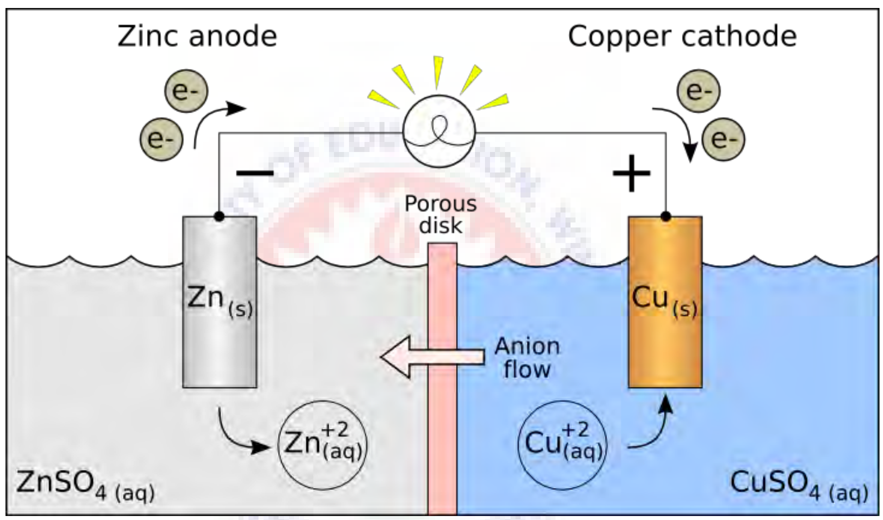


Fig. 3: A Zn-Cu galvanic cell showing the movement of ions and electrons

TEXT 4: Standard Electrode Potentials

The Standard Hydrogen Electrode (S.H.E)

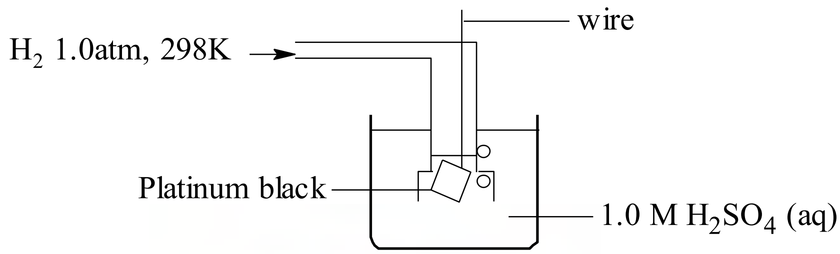


Fig. 4: Standard Hydrogen Electrode (S.H.E)

The SHE consists of hydrogen gas bubbling over a platinum electrode immersed in a solution of hydrochloric acid at standard conditions.

What are the conditions of the standard hydrogen electrode? Discuss.

- The hydrogen gas must be at a pressure of 1.0 a.t.m.
- The acid concentration must be 1.0 moldm^{-3}.
- The temperature should be 25^{0}C (298K).

The potential of a single electrode cannot be measured. The standard reference potential is the hydrogen electrode. The standard hydrogen electrode has been arbitrary set at zero volts (0.000V).

The reaction taking place is: $2H^+_{(aq)} + 2e^- \leftrightharpoons H_2$ $\quad E^0 = 0.000V$

Therefore, the potential of a cell constructed by combining the hydrogen electrode with a second electrode gives the potential of the second electrode. The half-cell potential measured relative to the standard hydrogen electrode is called **standard electrode potential** (E^0) of that half-cell.

Standard Electrode Potential

The standard electrode (reduction) potential, E^Θ of a standard half-cell is the potential of that half-cell relative to the standard hydrogen halve-cell under standard conditions.

For example, when a standard zinc half-cell is connected to the standard hydrogen half call, the e.m.f produced is -0.76 volts. That is to say the standard electrode potential of zinc is -0.76V.

Table 2: Standard electrode potential (E^0) values of some elements

REDUCTION HALF- REACTION	E^0 /V
$Li^+_{(aq)} + e^- \longrightarrow Li_{(s)}$	-3.03
$K^+_{(aq)} + e^- \longrightarrow K_{(s)}$	-2.92
$Ba^{2+}_{(aq)} + 2e^- \longrightarrow Ba_{(s)}$	-2.9
$Ca^{2+}_{(aq)} + 2e^- \longrightarrow Ca_{(s)}$	-2.87
$Na^+_{(aq)} + e^- \longrightarrow Na_{(s)}$	-2.71
$Mg^{2+}_{(aq)} + 2e^- \longrightarrow Mg_{(s)}$	-2.37
$Al3^+_{(aq)} + 3e^- \longrightarrow Al_{(s)}$	-1.66
$Zn^{2+}_{(aq)} + 2e^- \longrightarrow Zn_{(s)}$	-0.76
$Fe^{2+}_{(aq)} + 2e^- \longrightarrow Fe_{(s)}$	-0.44
$Ni^{2+}_{(aq)} + 2e^- \longrightarrow Ni_{(s)}$	-0.23
$Sn^{2+}_{(aq)} + 2e^- \longrightarrow Sn_{(s)}$	-0.14
$Pb^{2+}_{(aq)} + 2e^- \longrightarrow Pb_{(s)}$	-0.13
$2H^+_{(aq)} + 2e^- \longrightarrow H2_{(g)}$	0
$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$	0.34
$Ag^+_{(aq)} + e^- \longrightarrow Ag_{(s)}$	0.8
$Au^{3+}_{(aq)} + 3e^- \longrightarrow Au_{(s)}$	1.5

Increasing reactivity ↑

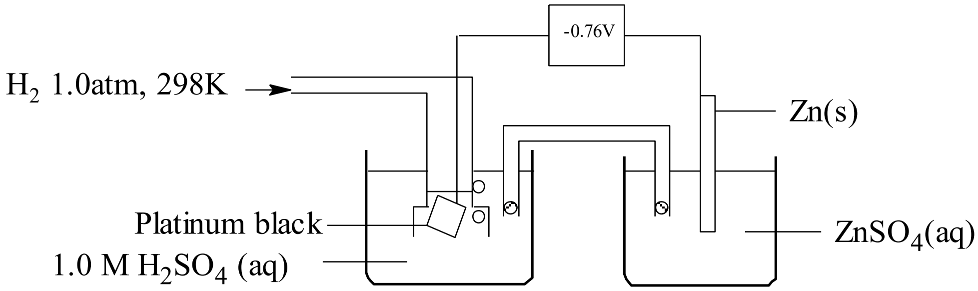


Fig. 5: SHE connected to a Zinc half-cell at STP

The e.m.f of a cell can be calculated from the standard reduction potentials; using the expression;

$E^0 = E^0$ (cathode)-E^0 (anode)

The standard electrode potential of the cell above is given by:

- $E^0 = E^0 (Zn^{2+}/Zn) - E^0 (2H^+/H_2)$
- E^0 = -0.76V-0.00V = **-0.76V**

Question:

Explain the statement that the standard electrode potential of Copper is +0.34V?

Answer:

- The statement means that when a copper half-cell is connected to the hydrogen half-cell under standard conditions, the e.m.f produced is +0.34V.

For example, calculate the emf of the following reactions: Use the values in the table of standard electrode potential values above.

1. $Ni_{(s)} + Cu^{2+}{}_{(aq)} \longrightarrow Ni^{2+}{}_{(aq)} + Cu_{(s)}$
2. $Zn_{(s)} + Cu^{2+}{}_{(aq)} \longrightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)}$

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Some students incorrectly think that……

1. The designation of the hydrogen half-cell's voltage as zero volts is **not *arbitrary*** but is somehow based on the chemistry of the H_2 and H^+.
2. A S.H.E half-cell is ***not necessary*** to measure the potential of a given half-cell reaction.

- The potential of a single electrode cannot be measured. The standard reference potential is the hydrogen electrode. The standard electrode of the hydrogen electrode has been arbitrary set at zero volts (0.000V).

- The standard electrode (reduction) potential, $E^{\ominus}$ of a standard half-cell is the potential of that half-cell relative to the hydrogen half-cell under standard conditions.
- For example, when a zinc half-cell is connected to the hydrogen half call under standard conditions, the e.m.f produced is -0.76 volts. That is to say the standard electrode potential of zinc is -0.76V.

- The magnitude of the electrode potential measures the tendency of the reduction half-reaction to occur as the equation is written.
- The reactions at the top of the table have the least tendency for reduction (or the greater tendency for oxidation). The reactions at the bottom have the greater tendency for reduction (least tendency for oxidation).
- The more negative the value of the standard electrode potential, the greater is the tendency for a metal to give up its electrons (oxidation), and the stronger is the reducing power.
- Conversely, the more positive the value, the greater the tendency for the metal to accept electrons (reduction) and the stronger the oxidizing power.

What are the uses of standard electrode potential values?

1. To calculate the emf of a cell
2. To determine the spontaneity of redox reactions

- For any electrochemical process,
  Emf = E^0 (reduction)-E^0 (oxidation).
- A positive E^0 value indicates a spontaneous process (the reaction can process on its own without energy being supplied).
- A negative E^0 value indicates a non-spontaneous process (the reaction cannot proceed on its own without energy being supplied to it).

For example

Consider the displacement of silver ion by nickel:

$Ni_{(s)} + 2Ag^{+}{}_{(aq)} \longrightarrow Ni^{2+}{}_{(aq)} + 2Ag_{(s)}$

$E^0 = E^0\ (Ag^+/Ag)\text{-}E^0\ (Ni^{2+}/Ni)$

$E^0 = (0.80\ V)\text{-}(-0.28\ V)$

$E^0 = 1.08\ V$. This indicates that the reaction is spontaneous.

Calculate the potential of the cell: $Ni(s) + Fe^{2+}(aq) \longrightarrow Ni^{2+}(aq) + Fe(s)$.

$Ni^{2+}(aq) + 2e^- \longrightarrow Ni\ (s)$ $\qquad E° = -\ 0.26\ V$
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$ $\qquad E° = -\ 0.45\ V$

$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$ $\qquad E° = +\ 0.26\ V$

$Fe^{2+}\ (aq) + 2e^- \longrightarrow Fe\ (s)$ $\qquad E° = -\ 0.45\ V$

$Fe^{2+}(aq) + Ni(s) \longrightarrow Fe(s) + Ni^{2+}\ (aq)$ $\qquad E°_{\ (CELL)} = \mathbf{-\ 0.19\ V}$

Therefore the reaction is not spontaneous since the overall $E^0{}_{(CELL)}$ value is negative.

Calculate the potential of the cell: $3Ag^{+}{}_{(aq)} + Al_{(s)} \longrightarrow 3Ag_{(s)} + Al^{3+}{}_{(aq)}$

$Ag^{+}{}_{(aq)} + e^{-} \longrightarrow Ag_{(s)}$ $E° = +0.80$ V

$Al^{3+}{}_{(aq)} + 3e^{-} \longrightarrow Al_{(s)}$ $E° = -1.66$ V

$Ag^{+}{}_{(aq)} + e^{-} \longrightarrow Ag_{(s)}$ $E° = +0.80$ V

$Al_{(s)} \longrightarrow Al^{3+}{}_{(aq)} + 3e^{-}$ $E° = +1.66$ V

$3Ag^{+}{}_{(aq)} + Al_{(s)} \longrightarrow 3Ag_{(s)} + Al^{3+}{}_{(aq)}$ $E°_{(CELL)} = +$ **2.46 V**

The reaction is spontaneous since the overall E^{0} value is positive.

Some students incorrectly think that:

1. Cell potentials are derived by *adding* individual reduction potentials.

- Standard potentials are in the reduction form. Therefore, the more negative potential should be reversed before the addition.
- When a half-cell reaction is reversed, the sign of the potential is also reversed.

Problems

1. Consider a galvanic cell based on the reaction $Al^{3+}_{(aq)} + Mg_{(s)} \longrightarrow Al_{(s)} + Mg^{2+}_{(aq)}$. Give the balanced cell reaction and calculate the E° for the cell.
2. Calculate the cell voltage for the following reaction. Draw a diagram of the galvanic cell for the reaction and label it completely. $Fe^{3+}_{(aq)} + Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + Fe^{2+}_{(aq)}$

TEXT 5: Electrolytic cell

What is an electrolysis cell?

- Electrolysis is the process in which electrical energy is used to cause a non-spontaneous reaction to occur. The use of electricity to bring about chemical reaction.
- A labeled diagram of an electrolytic cell is provided below. Study it carefully.

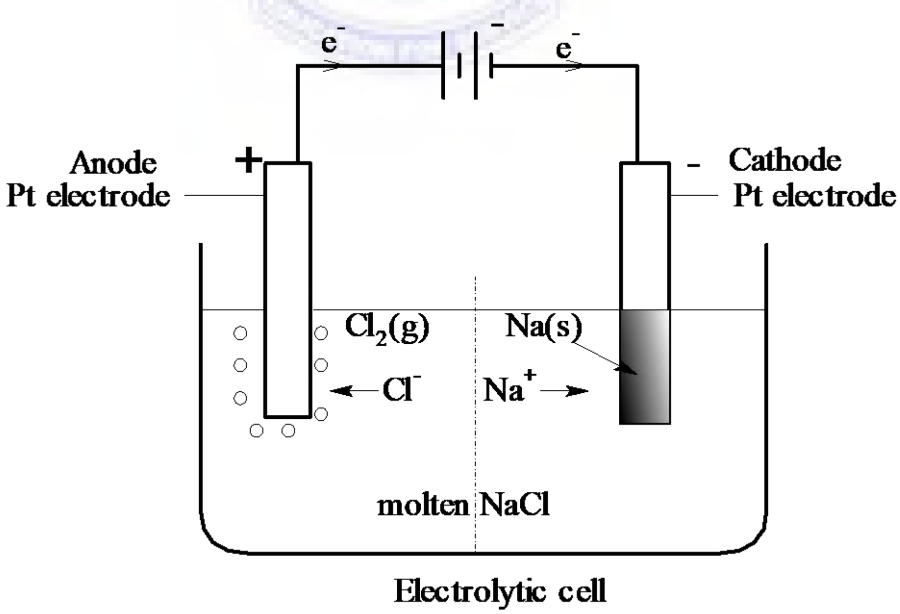


Fig. 6: An electrolytic cell

- Note the similarities between an electrolytic cell to a galvanic cell.
- One of the differences in the set-up of the apparatus is that in an electrolytic cell, a source of electricity is required to push the usually non-spontaneous reaction to occur,
- Whereas in a galvanic cell, the cell generates electricity through a spontaneous chemical reaction.
- Another difference is that in an electrolytic cell, both reactions occur in the same container, whereas separate containers are needed for each electrode in a galvanic cell.
- The following items should be included in a diagram of an electrolytic cell: a container, an electrolyte solution (acid, base, or salt), the two electrodes, an external electron "pump" (battery),
- The positive electrode of the battery connected to the anode, and the negative electrode of the battery connected to the cathode. Half-cell reactions and the net reaction are still necessary.

Some students incorrectly think that:

- Oxidation and reduction at the anode and cathode are reversed in voltaic and electrolytic cells. In voltaic cells, oxidation occurs at the anode and reduction at the cathode, while in electrolytic cells oxidation occurs at the cathode and reduction at the anode. ***This is wrong!***

- In both galvanic cell and electrolytic cell oxidation always occur at the anode and reduction occurs at the cathode.
- The electrode that is connected to the positive side of the battery is the anode and the electrode that is connected to the negative side of the battery is the cathode.

TEXT 6: Balancing Redox Reactions

What is oxidation state?

Oxidations state is a real or hypothetical charge given to an atom in a compound based on given rules. For example, the oxidation state of Na^{+} is +1 (real charge). The oxidation state of Cr in $Cr_2O_7^{2-}$ is +6 which a hypothetical charge.

Rules for Assigning Oxidation State

1. The oxidation state of an element in its elemental state is zero (0). Example, Cu(s) has an oxidation state of 0, as does Fe(s).
2. The oxidation number of an atom in a monoatomic ion is equal to the charge on that ion. E.g. the oxidation state of Fe^{2+} is +2.
3. The oxidation state of hydrogen is +1 in all compounds except in metallic hydrides where it is -1. E.g NaH, CaH_2, $NaBH_4$, $LiAlH_4$
4. The oxidation number of oxygen is -2 in all compounds except in peroxides where it is -1. Example, in H_2O oxygen is -2. In H_2SO_4 each oxygen is -2. The oxidation number of oxygen in H_2O_2 is -1.
5. The oxidation state of all group I elements in a compound is +1. E.g Li, Na, K in compounds have oxidation states of +1.
6. The oxidation number of all group II elements in a compound is +2
7. The sum of the oxidation numbers of all the atoms in a neutral compound must equal zero.
8. The sum of the oxidation numbers of all of the atoms in a polyatomic ion must equal the ionic charge on that ion.

Question

- Calculate the oxidation state of the underlined elements in the following compounds.

  $K\underline{Mn}O_4$, $K_2\underline{Cr_2}O_7$, $\underline{Mn}O_2$, $\underline{S}O_4^{2-}$, $Na_2\underline{C}O_3$

Answers

$K\underline{Mn}O_4$

- The oxidation state of K is +1
- The oxidation state of Mn is say x to work for
- The oxidation state of O is -2
- The sum of the oxidation states must be equal to zero since it is a neutral compound.

$+1 + x + 4(-2) = 0$
$+1 + x - 8 = 0$
$x = 8 - 1 = +7$

- Try the remaining questions.
- Expected answers: Cr in $K_2\underline{Cr_2}O_7$ = **+6**, Mn in $\underline{Mn}O_2$ = **+4**, S in $\underline{S}O_4^{2-}$ = **+6**, C in $Na_2\underline{C}O_3$ = **+4**

Balancing Redox reactions: half-cell equation method

Half-cell equation method: a process for balancing redox reactions by using half-cell reactions that are balanced separately. Then after balancing the charges and elements, the half-cell reactions are combined to yield a fully balanced overall equation.

Rules for Ion- electron Method in Acidic Solution:

1. Write the equation in the ionic form.
2. Separate the equation into 2 half reactions (oxidation half and reduction half)
3. Balance all atoms besides H and O,
4. Balance O by adding water (H_2O),
5. Balance hydrogen by adding H^+,

6. Balance the net charge by adding electrons (e^-) in each half-cell reaction,
7. Balance the electrons among the half reactions (by multiplying with a factor),
8. Add the half reactions and cancel out the electrons)
9. Cancel out anything that is the same on both sides.

Balance the following equation for a reaction that occurs in acidic solution:

$MnO_4^-(aq) + Fe^{2+}(aq) + H^+(aq) \longrightarrow Mn^{2+}(aq) + Fe^{3+}(aq) + H_2O(l)$

Step 1: the reaction is already in the ionic form.

$MnO_4^-(aq) + Fe^{2+}(aq) + H^+(aq) \longrightarrow Mn^{2+}(aq) + Fe^{3+}(aq) + H_2O(l)$

Step 2: Separate the reaction into half reactions

1. $Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq)$ (oxidation half)
2. $MnO_4^-(aq) \longrightarrow Mn^{2+}(aq)$ (reduction half)

Step 3: all atoms except O and H are balanced.

Steps 4 and 5: Balancing oxygen and hydrogen:

1. $Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq)$ (oxidation half) has no oxygen and hydrogen.
   $MnO_4^-(aq) + 8H^+(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$ (reduction half). 4 oxygen atoms are deficient on the right hand side so we add $4H_2O$ and $8H^+$ to the left hand side
2.

Step 6: Balancing charges:

$Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq)$ (oxidation half)
The net charges are +2 on the left and +3 on the right. Therefore, we add one electron (e^-) to the left.

1. $Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq) + e^-$ (oxidation half)

$MnO_4^-(aq) + 8H^+(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$ (reduction half)

The net charges are +7 on the left hand side and +2 on the right hand side. Therefore, we add $5e^-$ to the left side.

2. MnO_4^- (aq) + $8H^+$ (aq) + $5e^-$ ⟶ Mn^{2+} (aq) + $4H_2O$ (l) (reduction half)

Step 7: Making the electrons equal:

To make the electrons in both half reactions equal we multiply the equations by a factor. We multiply the oxidation half equation by 5 and the reduction half equation by 1.

1. $5Fe^{2+}$ (aq) ⟶ $5Fe^{3+}$(aq) + $5e^-$ (oxidation half)
2. MnO_4^- (aq) + $8H^+$ (aq) + $5e^-$ ⟶ Mn^{2+} (aq) + $4H_2O$ (l) (reduction half)

Step 8: Adding the two half reactions and cancel out the electrons.

1. $5Fe^{2+}$ (aq) ⟶ $5Fe^{3+}$ (aq) + ~~$5e^-$~~ (oxidation half)
2. MnO_4^- (aq) + $8H^+$ (aq) + ~~$5e^-$~~ ⟶ Mn^{2+} (aq) + $4H_2O$ (l) (reduction half)

   MnO_4^- (aq) + $5Fe^{2+}$ (aq) + $8H^+$ (aq) ⟶ Mn^{2+} (aq) + $5Fe^{3+}$ (aq) + $4H_2O$ (l)(overall)

Appendix I
Transcription of Interview

Set-up 1(Electrochemical Cell)

RESEACHER: What is the purpose of each piece of apparatus shown above? (Electrochemical cell)

DSI03: The wire is used to connect the voltmeter through the zinc and copper to produce electricity.

The voltmeter it helps to produce the light.

The salt bridge helps to transfer the charges ……. Which ensures electrical neutralization.

The two containers …. That is the place that holds the substance ……. That is the copper and the zinc.

DSI01: The wire will connect to each other to produce light……light and current.

The voltmeter will regulate the power of the current.

The salt bridge…it maintains neutralization (neutrality).

The containers contain electrons…… the anode is called oxidation and the cathode is called reduction.

The electrodes…… electrons move from anode to cathode.

DSI04: The wire is used to connect the electrons together.

The voltmeter ……. It helps the wire to generate electricity.

Salt bridge…. It is where the electrons pass through into the cell.

The containers are used to determine the electric galvanic.

The electrodes………. No idea.

DSI05: The wire connects the cathode and the anode for electrons and current to flow.

The salt bridge it is where the electrons move……. Cations move from anode to cathode and anions move from cathode to anode.

The voltmeter……. it helps the anode and cathode to connect for current to flow….to produce electricity or light.

The electrodes produce electrons

The containers contain the ions.

DSI09: The wire joints the anions and cations together.

The salt bridge it shows the positive charge of the electrons.

The voltmeter is where the current is …and when plucked light will come.

The electrodes are a metal which accepts cathode and anode.

The container is where the solution is prepared showing the cathode and anode.

GSI01: the salt bridge facilitates the transfer of ions between the electrodes to maintain electrical neutrality in the system.

The wire serves as a medium through which electrons passes.

Voltmeter…it measures the voltage.

Electrodes ……… they take part in the reaction……oxidation/reduction.

GSI02: salt bridge ….it maintains electrical neutrality.

Wire……. it connects the electrodes to ensure flow of electrons.

Electrodes……the zinc undergoes oxidation and serves as anode and the copper undergoes reduction and serves as cathode.

Container contains the solutions……. copper ions and zinc ions.

GSI03: salt bridge………..it serves as a bridge for the transfer of electrons from on electrode to the other.

Wire …it is used for the transfer of charges from one substance to the other.

Voltmeter…it is used to measure the amount of charges.

Electrodes….no idea.

Containers……… It is used to hold the solutions in the set up.

GSI04: salt bridge… it completes the internal circuit and therefore maintains electrical neutrality.

Wire….it carries electrons from anode to cathode.

Voltmeter……. to determine the electromotive force of the cell.

Electrodes……. that is where electrons enter and leaves the cell……. the leave the anode and enter the cathode.

Container……. they hold the solutions …that is the zinc ions and copper ions.

GSI05: salt bridge ……it ensures neutrality between the two solutions….by producing ions.

Wire……. current passes through the wire.

Electrodes……… They are metal strips dipped in their own solutions……it serves as a medium of transferring electrons.

Voltmeter…… it reads the e.m.f…………that is the electromotive force.

Containers……… they contain the various solutions.

RESEACHER: How will you determine which electrode is the anode and which is the cathode?

DSI03: The zinc electrode is the anode because it losses electrons and the charge is negative… and the copper is the cathode because it gains electrons and the charge is positive.

DSI01: The left hand side is the anode and the right hand side is the cathode… the anode transfers electrons into the cathode by force so that the cathode is negative.

DSI04: The zinc is the anode…. because it is the negative electrode… and the copper is the cathode because it is the positive electrode.

DSI05: You look at the charge… the anode is always negative and the cathode is positive.

DSI09: Looking at the diagram……. Zinc is anode and copper is cathode……. The zinc is positive acceptor and the copper is negative acceptor.

GSI01: Zinc is the anode………. since it is oxidized……. and copper is the cathode since reduction occurs there.

GSI02: …you consider the reactivity of the metals…… zinc is above copper in the activity series…… the one that is above the other is the anode……it means it has a higher concentration of electrons……electrons flow from the anode to the cathode. Copper is the cathode …… that is it accepts electrons.

GSI03: the zinc is the anode……… because it has a positive charge. The copper is the cathode because it has a negative charge.

GSI04: you consider the two elements……… their positions in the electrochemical series……. the one on top will loss electrons and becomes the anode……and the one below accepts electrons and becomes the anode…….and the one below accepts electrons and becomes the cathode.

GSI05: the anode is where oxidation takes place…… therefore losses electrons ….and the cathode is where reduction takes place ………. the cathode gains electrons.

RESEACHER: How is current produced in this cell?

DSI03: It is produced through the zinc and copper. The current will pass through the salt bridge and the go to the voltmeter.

DSI01: The current is produced by bringing two cells together…… positive and negative.

DSI04: Current is produced by passing through the anode and cathode.

DSI05: Electrons move opposite to each other to produce the electricity…by electrochemical cell.

DSI09: The current is produced by joining zinc and copper together by using the wire.

DSI06: It produces current by the moving of charges to and fro through the salt bridge.

GSI01: the zinc losses electrons which passes through the wire……. to serve as the current.

GSI02: current is produced when the electrons move from the anode to the cathode …… but the current flows from the cathode to the anode.

GSI03…the transfer of charges from anode to cathode.

GSI04: current is produced through the exchange of ions between the two solutions and the transfer of electrons from anode to cathode.

GSI05: electrons flow from the first beaker into the second one ………. and intends current flow from the second to the first. …that is from anode to cathode and the current from cathode to anode.

RESEACHER: What is happening in the solution? What does the salt bridge do?

DSI03: The salt bridge is used for the transfer of charges to neutralize.

DSI01: The solution will move from anode to cathode. The salt bridge maintains electrical neutralization.

DSI04: The salt bridge connects the electrons from cathode to anode.

DSI05: The salt bridge is where the ions pass through to help to produce electricity.

DSI09: The salt bridge shows the different solutions in the diagram.

GSI01: the salt bridge………it produces ions to maintain electrical neutrality.

GSI02: … the zinc ions oxidize the zinc metal to release electrons …….and the salt bridge when there is higher concentration of ions it………. the ions will flow through the salt bridge ………. so that it will become stable. The copper ions are reduced to copper metal.

GSI03: no idea.

GSI04: the salt bridge completes the internal circuit and maintains electrical neutrality.

GSI05: the salt bridge produces ions and ensures neutrality between the two solutions……ions are in the same solution.

RESEACHER: In what direction do the charges/ions flow in this cell to complete the circuit?

DSI03: Charges flow from cathode to anode………… cations will flow to the anode and anions to the cathode.

DSI01: The anions flow from anode to cathode. The cations flow from… electrons are being forced to enter.

DSI04: The charges flow from left to right. Anions flow from left to right and cations from right to left.

DSI05: It flows opposite……..... cations from anode to cathode and anions flow from cathode to anode.

DSI09: The charges flow from anode to cathode.

GSI01…from anode to cathode.

GSI02: anions flow to the cations.

GSI03: the ions flow (anions) flow from anode to cathode. Cations flow from cathode to anode. The anode is positive and the cathode is negative.

GSI04: cations flow from cathode to anode and anions flow from anode to cathode.

GSI05: charges flow from left to right……. anions flow from left to right and electrons move from right to left.

RESEACHER: What reactions are taking place in each cell?

DSI03: Electrochemical reactions…………

DSI01: …the first is a reaction…neutralization reaction.

DSI04: Zinc and copper reaction.

DSI05: The reaction…chemical reaction e.g. zinc plus……

DSI09: Chemical reactions…zinc and copper.

GSI01: …redox reactions…oxidation occurs at the anode and reduction at the cathode……. the anode is negative and the cathode is positive.

GSI02: zinc is oxidized at the anode. At the cathode copper is reduced. The reactions occurring are…….... $Zn (s) \rightarrow Zn^{2+} (aq) + 2e^{-}$ (oxidation) and $Cu^{2+} (aq) + 2e^{-} \rightarrow Cu(s)$ (reduction). The anode is negative and the cathode is positive.

GSI03: no idea

GSI04…oxidation at the anode and reduction at the cathode……… the anode is negative and the cathode is positive.

GSI05: …….... chemical reactions……electrochemical reactions. The anode is negative and the cathode is positive.

Set-up 2 (Electrolytic Cell)

RESEACHER: How does this cell differ from the electrochemical cell shown above?

DSI03: The electrolytic cell is different because it has no salt bridge… and it forces electrons to enter. The cathode is negative and the anode is positive…but in the first one (electrochemical cell) the anode is negative and the cathode is positive.

DSI01: The first one has salt bridge and the second one has no salt bridge…. The first one has voltage and the second one has no voltage. In the first one the anode is negative and cathode is positive…in the second one the anode is positive and the cathode is negative.

DSI04: The first one has two containers and the second one has one container…the second one contain a battery and the first one has no battery…. The battery generates electricity. The first one has salt bridge……….. The second one has no salt bridge. In the first one the anode is negative and the cathode is positive……… in the second one the anode is positive and the cathode is negative. The first one electrons flow from anode to cathode. In the second one electrons flow cathode to anode. ….. There is release of electrons in the first one and the cathode accepts electrons.

DSI05: The first cell serves two containers containing the ions. In the second one electrons are forced to enter the cathode.

DSI09: This is an electrolytic cell and the other is an electrochemical cell. In electrochemical cell the anode does not force to cathode (electrons)……… whiles with electrolytic cells electrons force to the cathode. The anode is positive and the cathode is negative.

GSI01: the first one has no source of electricity. The second one has source of electricity.

GSI02: the electrolytic cell…….. it has an electric source. The electrochemical cell has none. In the electrolytic cell the two electrodes are in one container.

GSI03: there are two containers in the first one …...And one container in the second set-up.

GSI04…no salt bridge. The two electrodes are in the same container.

GSI05: in the electrolytic cell ……electric current is used…is converted to chemical energy. Current is used to cause chemical reaction……the platinum is inert therefore no oxidation or reduction…. the battery produces the electric current for breakdown.

RESEACHER: How will you determine the electrode which is the cathode and which is the anode?

DSI03: no idea

DSI01: Use the charges…...the anode is positive and the cathode is negative.

DSI04: The left hand side is the anode and the right hand side is the cathode.

DSI05: You use the charges…the anode is negative and the cathode is positive.

DSI09: The left hand side is anode because it is positive …. the right hand side is positive and the left hand side is negative.

GSI01: the negative terminal of the battery is the anode and the positive terminal is the cathode.

GSI02: …you look at the atom which easily discharges electrons is the cathode…...you use the reactivity series.

GSI03: the positive electrode is the anode……and the negative electrode is the cathode.

GSI04: by considering the direction of flow of charge.

GSI05: oxidation takes place at the anode …. reduction occurs at the cathode.

RESEACHER: In which direction do the charges flow to complete the circuit?

DSI03: The charges flow throughout the solution… within the solution.

DSI01: Cations flow from anode to cathode and anions flow from cathode to anode.

DSI04: Cations flow to cathode to anode and anions from anode to cathode.

DSI05: By the electrodes… that is they flow towards the electrodes.

DSI09: it is from anode to cathode (anions)…. Cations flow from cathode to anode.

GSI01…from anode to cathode.

GSI02: cations flow to the anode……...anions flow to the cathode…...the cathode is negatively charged and the anode is positively charged.

GSI03: ……from cathode to anode.

GSI04: anions flow from anode to cathode.

GSI05: from anode to cathode.

RESEACHER: Which reactions are taking place at each electrode?

DSI03: electrolysis reaction

DSI01: Neutralization reactions.

DSI04: Electrochemical reactions …...Or electrolytic reactions.

DSI05: … electronic reactions.

DSI09: Electrochemical reactions.

GSI01: oxidation occurs at the anode….and reduction at the cathode.

GSI02: …...oxidation reaction at the anode and reduction reaction at the cathode.

GSI03: electrolysis

GSI04: at the anode is oxidation reaction….and at the cathode is reduction reaction.

GSI05: …electrolytic reaction.

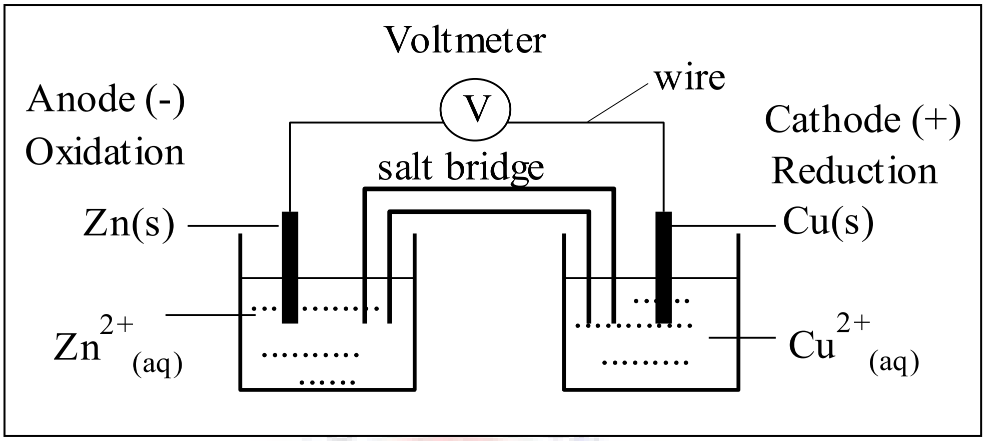
Appendix J
Suggested Answers to the ECCT

PART 1

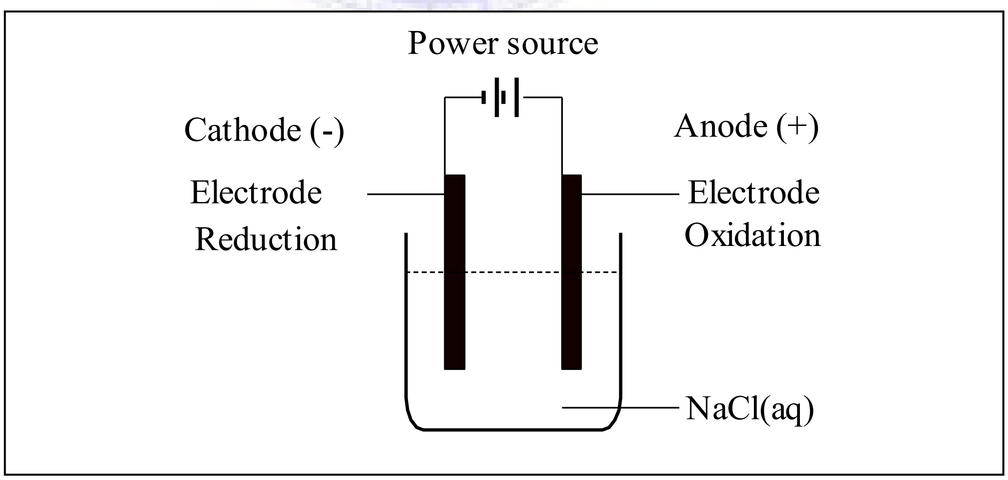
Item	Correct Option
1	B
2	D
3	D
4	B
5	C
6	D
7	D
8	B
9	C
10	B
11	D
12	D
13	D
14	B
15	A
16	A
17	C
18	B
19	B
20	B

PART 2

1. Draw a zinc/copper electrochemical cell. Label all the necessary parts including the solution in the beakers, the anode and cathode, the salt bridge, reactions at the electrodes, the metal electrodes and the signs at the electrodes.



2. Draw an electrolytic cell showing the electrolysis of sodium chloride. Label all the necessary parts including the electrolyte, cathode and anode, reactions at the electrodes, signs at the electrodes, the power source, and the carbon electrodes.



Appendix K

Letter of Introduction

UNIVERSITY OF EDUCATION, WINNEBA

FACULTY OF SCIENCE EDUCATION

DEPARTMENT OF SCIENCE EDUCATION

P.O BOX 25, WINNEBA-TEL. NO. 0202041079

December 7, 2015.

Dear Sir,

TO WHOM IT MAY CONCERN
INTRODUCTORY LETTER

The bearer of this letter, Philip Dorsah with index Number **8140130007** is a Student offering Master of Philosophy in Science Education in the Department of Science Education in the above University.

He is conducting a research on '*'Effect of Conceptual Change Texts on Senior High School Students Cognitive Achievement and Attitude toward Electrochemistry''*.

Your school has been selected as part of his sampling area.

I hope you would assist him to do a good thesis write-up.

Thank you.

VICTOR ANTWI, PHD.
Head of Department

Appendix L

Sample Responses of Students from the ECCT

8

UNIVERSITY OF EDUCATION, WINNEBA

FACULTY OF SCIENCE EDUCATION

M.PHIL SCIENCE EDUCATION

EFFECT OF CONCEPTUAL CHANGE TEXTSONSENIOR HIGH SCHOOL STUDENTS' COGNITIVE ACHIEVEMENT AND ATTITUDE TOWARD ELECTROCHEMISTRY

ELECTROCHEMISTRY CONCEPT TEST (ECCT)

PRE-TEST

PART 1: MULTIPLE CHOICE QUESTIONS

NAME: AIZOBA MARTIN **Male** ☐ **Female** ☐

SCHOOL: GHANASCO **Age:** 17 **Serial:** 43

PART 1: MULTIPLE CHOICE QUESTIONS

Answer All Questions **Circle Your Choice**

1. In electrochemical cells , oxidation occurs at the ______ and reduction occurs at the______
   A. Cathode/anode
   B. Anode/cathode
   C. Cathode/cathode
   D. Anode/anode
2. The cathode in an electrochemical cell is always go:
   A. On the left
   B. On the right
   C. With reducing agent
   D. With the oxidizing agent
3. What will occur at the surface of inert electrodes?
   A. Nothing
   B. Reduction

C. Oxidation
D. Either oxidation or reduction

4. To maintain electrical neutrality in a galvanic cell, anions move from:
   A. Anode to cathode
   B. Cathode to anode
   C. Anode to salt bridge
   D. Salt bridge to cathode
5. To make an electrolytic cell work, it needs a ________
   A. Salt bridge
   B. Electron
   C. Power source
   D. Nothing, it is spontaneous
6. In an electrochemical cell involving zinc metal in zinc sulphate solution and copper metal in copper sulphate solution, which of the following occurs at the surface of the cathode?
   A. Zinc atoms are reduced to form zinc ions.
   B. Zinc ions are oxidized to form zinc atoms.
   C. Copper atoms are reduced to form copper ions.
   D. Copper ions are reduced to form copper atoms.
7. The function of the salt bridge is to:
   A. Allow electron flow
   B. Allow proton flow
   C. Complete the circuit by providing electrons
   D. Complete the circuit by providing ions
8. In electrolytic cells, oxidation occurs at the ________ and reduction occurs at the ________
   A. Cathode/anode
   B. Anode/cathode
   C. Anode/anode
   D. Cathode/cathode
9. In an electrochemical cell the anode always goes:
   A. On the left
   B. On the right
   C. With the reducing reaction
   D. With the oxidizing reaction
10. How do electrons move through the electrochemical cell?
   A. Throughout the entire system.
   B. From one electrode to the other through the wire.
   C. From one electrode to the other through the salt bridge
   D. They are not moving

11. Consider the reaction: $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ which of the following represents the oxidizing agent in the above reaction?
    A. Zn
    B. Zn^{2+}
    C. Cu
    D. Cu^{2+}
12. Which statement is correct?
    A. Oxidation involves loss of electron and a decrease in oxidation state.
    B. Oxidation involves Gain of electrons and an increase in oxidation state.
    C. Reduction involves loss of electrons and an increase in oxidation state.
    D. Reduction involves gain of electrons and a decrease in oxidation state.
13. Which of the following characteristics are specific to an electrolytic cell?
    I. The chemical reaction is spontaneous.
    II. The reaction requires energy from an electrical source.
    III. The anode is the positive electrode of the cell.
    A. Only I
    B. Only II
    C. I and II
    D. II and III
14. Which of the values given below is the overall cell voltage of reactionoccurring:
    $Fe^{2+}_{(aq)} + 2e \rightleftharpoons Fe_{(s)} -0.44V$
    $Cu^{2+}_{(aq)} + 2e \rightleftharpoons Cu_{(s)} -0.34$
    A. -0.78V
    B. +0.78V
    C. +0.10V
    D. -0.10V
15. In electrochemical cells:
    A. one metal has to be more reactive than the other
    B. a power source is necessary
    C. the metals are connected through a salt bridge
    D. water becomes an electron donor
16. In a particular redox reaction, the oxidation number of phosphorus changed from -3 to 0. From this it may be concluded that phosphorus:
    A. Lost 3 electrons and was reduced.
    B. Lost 3 electrons and was oxidized.
    C. Gained 3 electrons and was reduced.
    D. Gained 3 electrons and was oxidized.

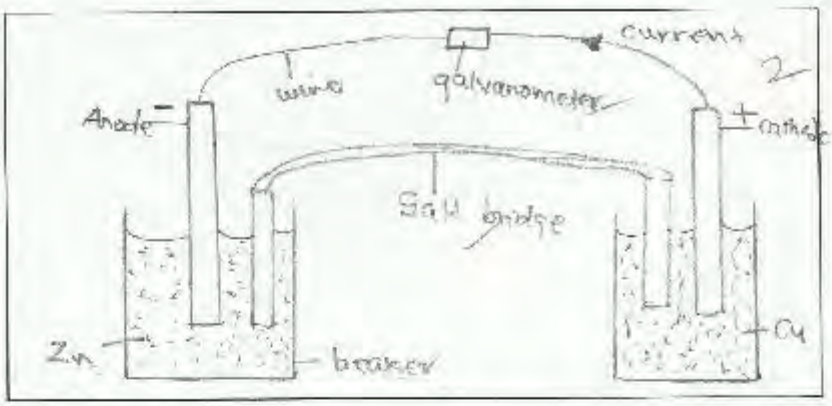
17. In which of the following unbalanced reactions does chromium undergo oxidation?
    A. $Cr^{3+} \rightarrow Cr$
    B. $Cr^{3+} \rightarrow Cr^{2+}$
    C. $Cr^{3+} \rightarrow Cr_2O_7^{2-}$
    D. $CrO_4^{2-} \rightarrow Cr_2O_7^{2-}$
18. Which of the following is an equation representing a redox reaction?
    A. $2NO_{2(g)} \rightarrow N_2O_{4(g)}$
    B. $Mg_{(s)} + Cl_{2(g)} \rightarrow MgCl_{2(s)}$
    C. $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$
    D. $NH_{3(aq)} + H^{+}_{(aq)} \rightarrow NH_4^{+}{}_{(aq)}$
19. What is the next step in balancing the half reaction $Cr_2O_7^{2-} \rightarrow 2Cr^{3+}$?
    A. Add 7 H_2O to the left.
    B. Add $7H_2O$ to the right
    C. Add 5 electrons to the left
    D. Add 5 electrons to the right
20. What is the next step in balancing the reaction $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^{+}$?
    A. Add 2 electrons to the left
    B. Add two electrons to the right
    C. Add 4 electrons to the left
    D. Add four electrons to the right

2

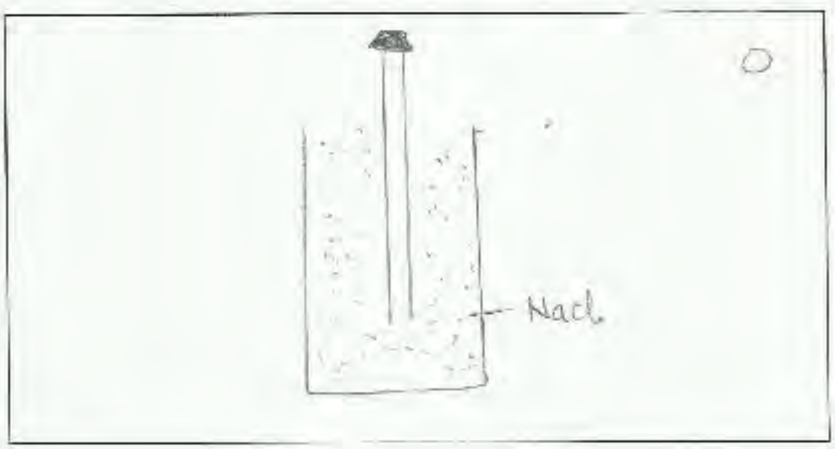
PART 2

ANSWER ALL QUESTIONS

1. Draw a zinc/copper electrochemical cell. Label all the necessary parts including the solution in the beakers, the anode and cathode, the salt bridge, reactions at the electrodes, the metal electrodes and the signs at the electrodes.



2. Draw an electrolytic cell showing the electrolysis of sodium chloride. Label all the necessary parts including the electrolyte, cathode and anode, reactions at the electrodes, signs at the electrodes, the power source, and the carbon electrodes.



UNIVERSITY OF EDUCATION, WINNEBA

FACULTY OF SCIENCE EDUCATION

12

M.PHIL SCIENCE EDUCATION

EFFECT OF CONCEPTUAL CHANGE TEXTSONSENIOR HIGH SCHOOL STUDENTS' COGNITIVE ACHIEVEMENT AND ATTITUDE TOWARD ELECTROCHEMISTRY

ELECTROCHEMISTRY CONCEPT TEST (ECCT)

PRE-TEST

PART 1: MULTIPLE CHOICE QUESTIONS

NAME: ISSAHAKU SALAMATU Male ☐ Female ☑

SCHOOL: DASS Age: 16 Serial: 51

PART 1: MULTIPLE CHOICE QUESTIONS

Answer All Questions **Circle Your Choice**

1. In electrochemical cells , oxidation occurs at the ______ and reduction occurs at the______
   A. Cathode/anode
   (B.) Anode/cathode
   C. Cathode/cathode
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2. The cathode in an electrochemical cell is always go:
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PART 2

ANSWER ALL QUESTIONS

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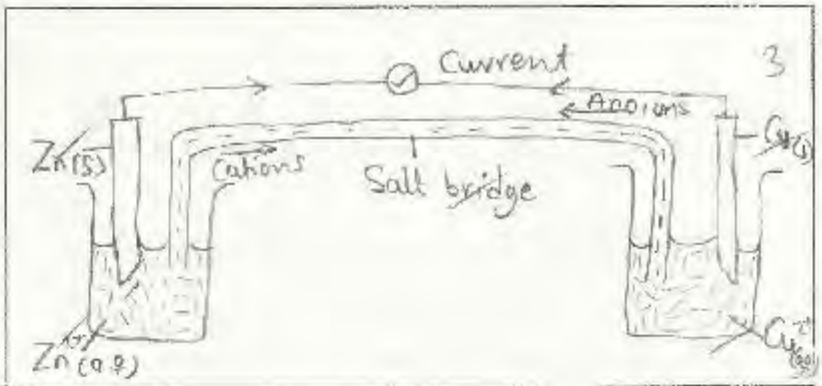
(6)



2. Draw an electrolytic cell showing the electrolysis of sodium chloride. Label all the necessary parts including the electrolyte, cathode and anode, reactions at the electrodes, signs at the electrodes, the power source, and the carbon electrodes.