AKENTEN APPIAH - MENKA UNIVERSITY OF SKILLS TRAINING AND ENTRERPRENEURIAL DEVELOPMENT

FACULTY OF SCIENCE EDUCATION

DEPARTMENT OF INTEGRATED SCIENCE EDUCATION

PERCEIVED MISCONCEPTION AND PERFORMANCE OF THE CONCEPT OF REDOX REACTIONS; A CASE STUDY OF SENIOR HIGH SCHOOLS IN THE OBUASI MUNICIPAL AND ADANSI NORTH DISTRICT OF THE ASHANTI REGION OF GHANA.

BY

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DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this dissertation is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Name: ……………………………………,

Candidate's Signature: …..……………………………..

Date: 3rd October, 2023.

SUPERVISOR'S DECLARATION

We hereby declare that the preparation and presentation of the dissertation were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

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ABSTRACT

The purpose of the study was to investigate Senior High School students' perceived misconception and performance of the concept of redox reactions. Specifically, the study investigated the perception of Senior High School form three Chemistry students on a) the concept of redox reaction, b) how teachers influence students' performance when they study redox reaction, c) students' misconceptions on how the concept of redox reactions, d) and students performance in class when they answered questions on redox reactions. The study employed a cross-sectional survey design. The sample used for the study consisted of year three chemistry students drawn from all the schools that offer elective science in Obuasi Municipality and Adansi North District of the Ashanti Region of Ghana. Purposive sampling was adopted for the study. The instruments used for data collection were questionnaire, achievement test and interview guide. Both descriptive and inferential statistics were used in analyzing the data in order to answer the research questions. The study revealed that poor performance of students in redox reaction is as a result of the inappropriate teaching approaches used by teachers when communicating the concept of redox reactions to students. Students also have problems appreciating the concept of reducing agent and identification of reactants as oxidizing or reducing agents. The study recommended that chemistry teachers should use redox reaction models in teaching redox reactions for easy conceptualization and understanding on the part of students.

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DEDICATION

This dissertation is dedicated to God Almighty, and to my family: Madam Stella Akwei, Mrs. Cecilia Erzuah, Emmanuella Erzuah, Godfred Erzuah, Gloria Erzuah, Blessing Erzuah, Esther Erzuah, Favour Erzuah. Also to my very good friend Mrs, Shirley Ofosuhene Asiedu Antwi.

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CHAPTER ONE

1.0 Introduction

This chapter deals with the introduction to the study. The background to the study, statement of the problem and purpose of the study are discussed in this chapter. The chapter also deals with the research questions that guide the study. Finally, the chapter closes with the limitations and organization of the rest of the dissertation.

1.1 Background of the study

Constructivists' views of learning in science suggest that students can only make sense of new situations in terms of their existing understanding, Prior knowledge is used by individuals to interpret observations and meaning is constructed by individuals in a process of adding to or modifying their existing ideas (Ludwig, 2019). The implications of such a view are that teachers need to find out students' ideas in order to take these into account in their teaching. Teachers then need to provide experiences which challenge their students' current understanding in order to help them restructure their ideas. McDermott (2019) posited that the most serious difficulty that has been identified in the study of redox reactions is the failure to integrate related concepts into a coherent framework. To be able to apply a concept in a variety of context, however, students must be able to define that concept as well as relate it to other concepts. They also need to differentiate that concept from related concepts. According to McDermott (2019), if the differentiation of concept does not occur, the students are likely to see the topic difficult to learn. According to McDermott (2019), certain conceptual difficulties are not overcome by traditional instruction. The persistent conceptual difficulties must be explicitly addressed by multiple challenges in different contexts. Students' difficulties in learning some concepts disappear during the normal course of instruction while others seem to be highly resistant to change.

Deep-seated difficulties, according to McDermott (2019), cannot be overcome through assertion by the instructor. Active learning is essential for a significant conceptual change to occur. A single encounter is rarely sufficient to overcome a serious difficulty. Students do not make the same mistakes under all circumstances, the context may be critical. Unless challenged with a variety of situations capable of evoking a given difficulty, students may simply memorize the answer for a particular case. To be able to integrate counter intuitive ideas into a coherent framework, they require time to apply the same concepts and reasoning in different contexts, to reflect upon these experiences and to generalize from them. The difficulty of learning topics is not peculiar to certain groups of students. Students who are better prepared often encounter the same difficulties as those who are not well prepared (McDermott, 2019).

From the study of McDermott (2019), the problem of difficult topics is as a result of students' difficulty in relating the concepts emanate from the sequence in which these topics were presented in textbooks. In addition, certain prerequisite concept is necessary for a student to develop understanding of certain concepts. If these do not exist, it would be difficult for the students to understand the new concepts. Teachers generally assume that the students have already mastered the prerequisite ideas. On the contrary, they may not have assimilated the pre-requisite ideas into their cognitive structure, which are necessary for a meaningful understanding of the new topic (Tekkaya, et al., 2023).

The reasons students gave ranged from teacher's inability to explain the topics well to students' understanding to teachers' lack of mastery over the topics being taught by the teacher. Teacher characteristics, according to Adediwura and Tayo (2019), are not the only factor that accounts for students' difficulty in learning a topic or even a subject. The characteristics of the student such as intelligence and student readiness as well as learning environment and family environment have an influence on whether a student perceives a topic to be difficult or not Appleton, 2019).

In the curriculum of chemistry at the Senior High School Level, certain concepts such as the mole concept, gas laws, mass-volume relationships, electrolysis, redox reactions, acid base reactions, rate of chemical reactions and others require adequate knowledge of basic mathematical concepts in order to cope with them, the factor which probably makes chemistry one of the most intellectually demanding subjects. However, studies by Kehinde (2019), Adesugba (2018) and the West African Examination Council (WAEC) Chief Examiner's Report (2018) showed that many secondary school students lacking the conceptual and understanding of chemistry is that, it is considered as a science which is not related with daily life but as only an academic science pursuit.

Redox reactions are part of the world around us, an important component of the processes that sustain life, so important that they have been called the driving force of the biosphere (2018). I believe that knowledge about redox reactions is important; not only for the chemistry and related disciplines but also for people in general, redox reactions are common chemical reactions in everyday life. Knowledge about this issue provides the means of understanding and participating in many debates, such as sustainable development. Four different redox models are commonly used in chemistry education today. These are the oxygen model, the hydrogen model, the electron model and the oxidation number model.

Table 1.1: Four Oxidation-Reduction Model

Model	Reduction	Oxidation
Oxygen model	Loss of O	Gain of O
Hydrogen model	Gain of H	Loss of H
Electron model	Gain of electrons	Loss of electrons
Oxidation number	Decrease in oxidation	Increase in oxidation
Model	Number	Number

The Ac1tivity Series of Metals (ASOM) arranges metals according to their ability to act as a reducing agent. The series also includes the non-metal hydrogen (H). Depending of the metal's reducing ability it can displace hydrogen gas from water, steam or acid (Silberberg, 2020).

Table 1.2: A Scientific Model of the Corrosion of Iron

a) $\mathbf{Fe_{(s)} \rightarrow Fe^{2+} + 2e^-}$

$O_{2(g)} \rightarrow O_{2(aq)}$ (Oxygen from air dissolves in the water)

$O_{2(aq)} + 2H_2O + 4e^- \rightarrow 4OH^-_{(aq)}$

b) $\mathbf{Fe^{3+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Fe(OH)_{2(s)}}$

c) $\mathbf{4Fe(OH)_{2(s)} + O_{2(g)} \rightarrow FeO(OH)_{(s)} + 2H_2O}$

The corrosion of copper is simple in comparison to rust formation. Copper will form oxide in the air in two steps according to reactions (a) and (b) in Table 1.3. Depending on pollutants in the air such as sulphur oxides, green verdigris is formed on copper surfaces (Hagg G. 2019).

Table 1.3: A Scientific Model of the Corrosion of Copper

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

$\frac{1}{2}O_{(g)}$ or $_{(aq)}$ $+ 2e^{-} \rightarrow O^{2}$

Total reaction: $2Cu_{(s)} + \frac{1}{2}O_{(g)} \rightarrow CuO_{(s)}$

b) $Cu_2O_{(s)} + \frac{1}{2}O_{2(g)} \rightarrow 2CuO_{(s)}$

Redox reactions are those chemical reactions in which both the oxidation and reduction processes take place simultaneously (Achimugu, 2021). These reactions involve the transfer of oxygen or hydrogen atoms, or electron from one unit of matter to another. The species which gives out electrons or hydrogen atom(s) is the reducing agent, and is oxidized in the process; while that which receives the electron or hydrogen atom is the oxidizing agent, and is reduced in the process. The species which gives out oxygen atom(s) is the oxidizing agent, and is reduced in the process; while that which receives the oxygen atoms is the reducing agent, and is oxidized in the process.

1.2 Statement of the Problem

According to De Jong, et al, (2018), teachers in science fraternity generally perceive redox as one of the difficult topics to teach. Research has shown that school students have difficulties in conceptualizing redox reactions (Schmidt, 2021). There are a number of explanations to the difficulties in conceptualizing redox reactions. (Schmidt, 2021) found that many students believed that oxygen always took part in all redox reactions and that oxygen was a pre-requisite for a redox reaction. (Schmidt, 2021), suggested further that this could be due to the syllable “ox” in “reDOX”.

Sample question on redox reaction in the final chemistry theory paper 2 in WASSCE 2019 was worded as follows;

(b) (i) Balance the ionic equation of the reaction between potassium tetraoxomanaganate (II) and ethanedoic acid in acidic medium as follows:

$MnO^{-}_{4(aq)} + 18C_2O_4^{2-}{}_{(aq)} + H^{+}{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + CO_{2(q)} + H_2O_{(1)}$.

(ii) Name the oxidation and reducing agents

As indicated by the chief examiner's report comments on the above question noted that most candidates could not balance the ionic equation required and hence their inability to answer the question that followed. Furthermore, in Chemistry paper, there was a question on redox reaction as;

Question 4

a) Define in term of electron transfer
   i. Oxidizing agent
   ii. Reducing agent
b) Consider the following reaction equation: $H_2S + SO_2 \rightarrow S + H_2O$

(i) Identify the
   (a) Oxidizing agent;
   (b) Reducing agent

(ii) Write the half-reaction equation for the
   (a) Oxidation,
   (b) Reduction,

(iii) Write the overall balance equation for the reaction.

Summary of Chief Examiner's Report.

Candidates Weakness:

Candidates;

- candidates did not understand the demands of the questions;
- exhibited poor communication skills;
- lacked adequate knowledge of chemical concepts;
- wrote trivial names instead of formulae;
- could not write simple half reaction equation;
- could not recognize redox reactions;
- Could not write the correct formula of a compound.

In addition, assertion on this question indicated that most of the candidates could not distinguish between oxidation and oxidizing agent as well as reduction and reducing agent. Most of them, however, also defined oxidizing agent as a substance which adds oxygen, rather oxidizing agent is a substance which accepts electrons or electron acceptor and reducing agent is a substance which donates electron or electrons donor. Also, in chemistry paper 2B, students were required to determine the oxidation number of chromium in $K_2Cr_2O_7$, vanadium in V_2O_5 and also to explain why oxidation and reduction reactions are complementary. Assertion on this question indicated that, even though students were able to determine the oxidation numbers, some of them did not show the signs associated with them, i.e. either (+) or (-). Candidates were top note that oxidation number is a composite of a charge and numerical figure. From the earlier discussion so far, it is evidently clear that there are challenges with the identification of reactants as oxidizing agent and reducing agent, balance redox reactions, and identification of oxidation numbers of elements in redox reactions in Senior High Schools (SHSs).

These challenges will continue to contribute to the poor performance of chemistry students on the redox reactions aspect of the senior high school chemistry syllabus if not exposed and remedied. Once students continue to perform poorly on the redox reactions at the SHS level, they are likely not to pursue major courses in chemistry at the tertiary level. There is, therefore, the need to conduct a study to investigate into SHS students understanding of redox reaction since the concept of redox reaction is crucial in chemistry as a subject.

1.3 Purpose of the Study

The purpose of the study is to investigate the perceived misconception and performance of the concept of redox reactions of Senior High School chemistry students. The study was designed to explore SHS students' perception of Redox Reactions Concepts, investigate teachers' influence on SHS students' performance in Redox Reaction's Task, investigate SHS students' misconceptions in the concept of Redox Reactions, and also to find out the level of performance of SHS students on Redox Reactions.

Research Questions;

The following specific research questions were addressed by this study;

1. What are students' perceptions on the concept of redox reactions?
2. How do teachers' instructional activities influence students' performance when they study redox reactions?
3. What are the students' misconceptions of the concept of redox reactions?
4. How do the students perform in class when answering questions on redox reactions?

1.4 Significance of the Study

The findings from this study would help Chemistry or science teachers to appreciate difficulties students encounter in the learning of redox reaction and so modify their instructional activities to deal with misconceptions and conceptual challenges associated with the topic. The study would also help provide teachers, curriculum developers and other stakeholders in the area of chemistry with information that could help design appropriate instructional materials for teaching the concept of redox reactions.

Even though, the study would be confined to Senior High Schools in the Obuasi Municipality and Adansi North District of the Ashanti Region of Ghana, the findings will serve as indicators of what might be happening in other Senior High Schools in Ghana.

1.5 Delimitation

Only science students in SHS 3 were used for the study since they had studied chemistry for almost three years and were in a better position to share their views on the difficulties they encountered in understanding redox reactions. The study was delimited to schools that offered science as an elective programme. The study concentrated on answers that were given by science students in the achievement tests on Redox Reactions.

1.6 Limitations

Since quantitative and qualitative methodologies are based on different assumptions, it is possible that different techniques employed could produce different results. The findings of this study were limited to the final year SHS science students of Obuasi Municipality and Adansi North District of the Ashanti Region of Ghana. It is, however, the hope of the researcher that the findings of this research would stimulate the interest of other researchers to conduct similar researches on other chemistry topics that students find difficult to learn in order to seek solutions to the problem.

1.7 Definition of Key Terms:

Elective Science Students: These are students offering science in the Obuasi Municipality and Adansi North District. School Type: These are the public senior high schools in the

Obuasi Municipality and Adansi North District. Sex: Male (Boys) and Female (Girls) in the public senior high schools in Obuasi Municipality and Adansi North District.

1.8 Organization of the Test of the Study

The remaining chapters of the dissertation were organized as follows:

Chapter two discussed literature related to the study. Literature was reviewed under sub-headings such as students' perceptions of redox reactions, students' misconceptions of redox reactions, students' performance of redox reactions and balancing redox reactions. Chapter three described the methodology that was used in the study; that is the research design; research instrument, sample, procedure for data collection and the data analysis were discussed. In chapter four, the findings were presented and discussed in relation to the research objectives. Finally, chapter five gave the summary, conclusions, recommendations and areas for further research.

CHAPTER TWO

2.0 REVIEW OF RELATED LITERATURE

2.1 Overview

This chapter reviews literature that is related to the topic so as to help the researcher determine whether the topic is worth studying. It further provides an accurate and deep understanding into ways in which the researcher can limit the scope of the study to fulfill its purpose. The chapter is organized along the following headings: theoretical framework, areas of difficulty in chemistry, students' perceptions of redox reactions, students' misconceptions of redox reactions, students' performance in redox reactions, and senior high school redox reactions. Some related empirical studies were also reviewed in order to better illustrate the concept under study.

2.2 Theoretical Framework

The difficulty of balancing redox reactions has been treated many times, throughout the literature. A short literature checks shows that a primary source of papers in the last 20 years is the Journal of Chemical Education (JCE), (Glaister & Toth, 2021), although, information may be found in other works elsewhere. Then, on several occasions, Kolb (2019) has discussed various examples of oxidation reduction reactions as well as various methods to balance the corresponding reactions (the oxidation number method, the ion method, electron method, the algebraic method and the inspection method were clearly and unambiguously mentioned).

The sum of the oxidation numbers of the elements in any chemical species should be equal to the charge of that species.

i. The sum of the charges in oxidation number in a balanced equation should be zero.

2.3 General Areas of Difficulty in Chemistry

According to Sekyiwaa Boateng (2024), in looking at the several range of papers, which have addressed various facets of the learning difficulties related to chemistry, it is not easy to categorize the work into neat compartments. In the analysis presented here, the work has been divided into five main areas of concern, recognizing the fact that there are overlaps and potential omissions. Each is clearly discussed briefly (Putri & Latisma, 2022)

2.3.1 Chemistry curriculum content

The advent of revised school syllabuses in the 1960s and 1970s in many countries saw a move towards the presentation of school chemistry in a logical order, the logic usually being that of the experienced academic chemist, (Rury, & Hill 2013).

2.4 Language and communication during science lessons

Language has been shown to be another contributor to information overload (Johnstone, 2021). Language problems include foreign or confusing vocabulary, recognizable vocabulary which changes its import as it moves into chemistry, use of high - sounding language, and the use of double or triple negatives (Cassels, & Johnstone, 2021), (Brooks & Brooks, 2021). Language influences the thinking processes necessary to tackle any task.

2.4.1 Concept formation in chemistry

Chemistry learning requires much intellectual thought and discernment because the content is full up of many abstract concepts. Concepts such as particulate nature of matter, chemical bonding and dissolution are fundamental to learning chemistry (Deci, 2021; Nakhleh, 2019). Group work, dialogue and the exchange of ideas may all be very important in allowing misconceptions to be corrected effectively.

2.4.2 Motivation to learn science

There is no doubt that motivation to learn is a significant factor controlling the success of learning, and teachers face problems when their students do not have the motivation to seek to understand. Students' motivation to learn can be classified as either intrinsic (e.g. wanting to know for its own sake) or extrinsic (e.g. wanting to learn what is on an exam syllabus) (Entwistle, Thompson & Wilson, 2019).

There is also a third class, called a motivational learning, which covers the situation where students do things (like attending lectures) without any mindful belief that this will help them learn anything (Ward & Bodner, 2021).

2.5 Students' Perceptions of Redox Reactions

Perception, according to the Cambridge dictionary of philosophy defined perception as the extraction and use of information about one's environment and one's own body (Audi, 2019). Perception may be defined from physical, psychological and physiological perceptive. But for the purpose of this study, it shall be limited to its scope as postulated by Allport (2020), which is the way we judge or evaluate others.

Oxidation number is a number which is similar to the valency of an atom but oxidation number carries a sign with it. This sign expresses the charge on the corresponding species when it is formed from a neutral atom. For example, the oxidation number of chlorine in hydrochloric acid (HC1) is -1, in Chloric acid ($HC1O_3$) is +5 and in perchloric acid ($HCIO_4$) it is +7. There are various rules for finding oxidation number of an atom in a molecule. In finding the oxidation number of Cl in $HCIO_3$ as an example;

Oxidation number of H = +1

Oxidation number of Cl = Z (supposed)

Oxidation number of O = -2. Therefore, +1 + Z + 3 (-2) = 0 (since net charge on $HCIO_3$ =

0). Hence, +1 + Z + (-6) = 0. This means, Z = +5. So on a general note, oxidation generally involves any of the following changes: Loss of electrons, Loss of hydrogen atoms, Gain of oxygen, and Increase in oxidation state. Similarly, reduction is said to occur when any of the following changes occur: Gain of electrons, Gain of hydrogen atoms, Loss of oxygen atoms, and Decrease in oxidation state.

2.6 Students' Misconceptions of Redox Reactions

Research in science teaching has indicated misconception contribution on students learning outcome. Misconceptions are not a simple problem and cannot be taken for granted. Numerous studies have shown that misconceptions concerning many aspects of chemical phenomena are prevalent among students. Misconception can distract students' concepts construction processes in their cognitive structure.

It is, therefore, important for teachers to know their student's misconceptions so they can carry out remediation of misconception. However, as they interact with the teacher and learning materials, they ultimately construct, de-construct and modify their own understandings based on their new learning experience and cultural background.

Correspondence of oxidation and reduction always exists and as one speaks of reduction-oxidation reactions or redox reactions:

Fe atom --------► Fe^{2+} ion + $2e^-$ oxidation

2CI atoms + $2e^-$ -------► $2Cl^-$ ions reduction

Fe + Cl_2 --------► Fe^{2+} (Cl^-) 2 redox reaction

Again, extended definitions could be based on oxidation numbers of atoms in molecules.

2.7 Students' Performance in Redox Reactions

Redox (reduction-oxidation) chemistry is an important topic of general chemistry. The main aspects of redox chemistry are assigning oxidation numbers, identifying oxidizing and reducing agents and balancing redox equations. There are well-established sets of rules for assigning oxidation numbers and identifying redox agents and reactions. As for balancing a redox equation, specific stepwise procedures are listed in all general chemistry textbooks.

2.8 Oxidation-Reduction (Redox) Reactions Treated at the Senior High School Level in Ghana

A redox reaction is a chemical reaction in which oxidation and reduction occurs. **OR**

A redox reaction is a chemical reaction in which electron(s) is or are transferred from one species to another.

OR: A reaction in which there is a change in oxidation number of a species. Processes such as burning, rusting, electrolysis, photosynthesis, and internal respiration of animals and plants are examples of redox reactions.

Oxidation and reduction can be defined in terms of:

a) addition of oxygen, b) removal of hydrogen, c) electron transfer (loss and gain of electrons) d) change in oxidation number.

2.8.1 Oxidation and reduction in terms of oxygen and hydrogen

Oxidation: - It is a chemical change that involves complete or partial addition of oxygen to a substance.

E.g. Complete addition: $C_{(S)} + O_{2(g)} \rightarrow CO_{2(g)}$,

Partial addition: $C_{(S)} + {}^{1}/_{2}O_{2(g)} \rightarrow CO_{(g)}$,

OR: It is a complete or partial removal of hydrogen from a substance.

E.g. CH_3CH_2OH Cu, heat → $CH_3CHO + H_2$

Reduction: - It is a chemical change that involves complete or partial removal of oxygen from a substance e.g. $2NO_3^- \rightarrow 2NO_2^- + O_2$

OR: It is the complete or partial addition of hydrogen to a substance. E.g.

1. $CH_3CHO + H_2 \rightarrow CH_3CH_2OH$.

2. $CuO_{(S)} + H_{2(g)} \rightarrow Cu_{(S)} + H_2O_{(1)}$

In reaction 2, hydrogen has been oxidized to water. This is because oxygen has been added to it, while CuO has been reduced to Cu because oxygen has been removed from it.

3. $2Mg_{(S)} + O_{2(g)} \rightarrow 2MgO_{(S)}$

In the above reaction, Mg has been oxidized, while oxygen has been reduced.

4. $C_{(S)} + 2H_{2(g)} \rightarrow CH_{4(g)}$.

In this reaction, hydrogen has been oxidized, while carbon has been reduced. Take note of the following:

(a) In redox reactions, the substance, which is reduced is called oxidizing agent, while that oxidized is called reducing agent. In terms of oxygen and hydrogen:

(i) An oxidizing agent is a substance, which transfers oxygen to another substance or removes hydrogen from that substance.

(ii) A reducing agent is a substance, which transfers hydrogen to a substance, or removes oxygen from that substance.

In example 1, 2, 3 and 4, the oxidizing agents are respectively CH_3CHO, CuO, O_2 and carbon (C), while the reducing agents are Mg and H_2.

(b) An oxidizing agent cannot oxidize itself. Therefore, it always undergoes a reduction.

Similarly, a reducing agent cannot reduce itself and, therefore, it always undergoes an oxidation.

(c) Since oxygen and hydrogen are respectively electronegative and electropositive elements, oxidation and reduction can also, be defined as:

(i) Oxidation is the addition of an electronegative element to a substance or the removal of an electropositive element from a substance.

Examples of electronegative elements are non-metals such as F, O, CI, N, Br, S, etc.

(ii) Reduction is the addition of an electropositive element to a substance or the removal of an electronegative element from a substance.

Examples of electropositive elements are metals such as K, Na, Ca, Mg, Al, Zn, etc.

(i) $Na_{(s)} + 1/2Cl_{2(g)} \rightarrow NaCI_{(s)}$

(ii) $Mg_{(s)} + Br_{2(g)} \rightarrow MgBr_{2(s)}$

(iii) $Ca_{(S)} + S_{(s)} \rightarrow CaS_{(s)}$

(iii) $C_3H_{6(g)} + Cl_{2(g)} \rightarrow C_3H_6Cl_{2(g)}$

In reaction (i), (ii), (iii), and (iv), Na, Mg, Ca, and C_3H_6, are respectively the reducing agents, because each is oxidized; the corresponding oxidizing agents are CI_2, Br_2, S and Cl_2 because each is reduced.

2.8.2 Oxidation and reduction in terms of electron - transfer

Oxidation: - this is the complete or partial removal of electrons from an atom, molecule or ion.

OR: Oxidation is the process of electron loss.

(i) $Mg \longrightarrow Mg^{2+} + 2e^-$, or $Mg - 2e- \longrightarrow Mg^{2+}$

(ii) $Fe \longrightarrow Fe^{2+} + 2e-$,or $Fe - 2e- \longrightarrow Fe^{2+}$

(iii) $Fe^{2+} \longrightarrow Fe^{3+} + e-$, or $Fe^{2+} - e- \longrightarrow Fe^{3+}$

(iv) $H_2 \longrightarrow 2H^+ + 2e-$, or $H_2 - 2e- \longrightarrow 2H^+$

Reduction: - This is the complete or partial addition of electrons to an atom, molecule or ion.

OR: Reduction is the process of electron again.

(i) $^1/_2Cl_2$ + e- ⟶ Cl, or $^1/_2Cl$ ⟶ Cl - e-

(ii) S + 2e- ⟶ S^{2-} or Fe - 2e- ⟶ 2e- ⟶ Fe^{2+}

(iii) $2H^+ + 2e^- \longrightarrow H_2$, or $2H^+ \longrightarrow H_2 - 2e^-$

(iv) $Fe^{3+} + e^- \longrightarrow Fe^{2+}$ or $Fe^{3+} \longrightarrow Fe^{2+} - e^-$

In terms of electron transfer:

(i) An oxidizing agent (oxidant) is an atom, molecule or ion, which readily captures electrons, or oxidant is an electron acceptor.

(ii) A reducing agent (reduction) is an atom, molecule or ions, which readily release electrons, or reduction is an electron donor.

2.8.3 Oxidation and reduction in terms of a change in oxidation number

(i) Oxidation is a chemical reaction in which the oxidation number of an atom increases.

(ii) Reduction is a chemical reaction in which the oxidation number of an atom decreases,

e.g. (1) $FeCl_{2(S)} + {}^1/_2Cl_{2(g)} \rightarrow FeCl_{3(S)}$

(2) $2Fe_{(S)} +$ $3Br_{2(g)} \rightarrow FeBr_{3(s)}$

In reaction (1), the oxidation number of Fe increases from +2 in $FeCl_2$ to +3 in $FeCl_3$, while that of chlorine decreases from zero (0) in Cl_2 to - 1 in $FeCl_3$. Therefore, Fe in $FeCl_2$ has been oxidized while CI_2 has been reduced. In reaction 2, the oxidation number of Fe increases from zero (0) to +3 in $FeBr_3$, while that of Br_2 reduces from zero (0) to - 1 in $FeBr_3$. Therefore, Fe has been oxidized, while Br_2 has been reduced. From oxidation number point of view, oxidant and reductant are defined as: An oxidizing agent is a species containing an atom, which shows a decrease in oxidation number. A reducing agent is a species containing an atom, which shows an increase in oxidation number.

Oxidants: O_2, F_2, Cl_2, Br_2, I_2, metal ions, Conc. H_2SO_4, Conc./dil. HNO_3, HOCl, H_2O_2, IO_3, $K_2Cr_2O_{7(aq)}$ $KMnO_{4(aq)}$, higher oxides like PbO_2, SnO_2, etc.).

Reductants: H_2, C, CO, H_2S, $S_2O_3^{2}$; $C_2O_4^{2'}$, Fe^{2+} salts, metal atoms, H_2SO_3, $SnCl_2$, HI etc. It is important to note that a substance may be an oxidizing agent in one reaction and a reducing agent in another depending on the conditions- For example; H_2O_2 and SO_2 can behave as oxidants and reductant based on the reagent used.

(a)(i) As a reducing agent, SO_2 is oxidized from +4 to **+6** in each of the following reactions;

$$SO_2 + PbO_2 \longrightarrow PbSO_4$$

$$SO_2 + Na_2O_2 \longrightarrow Na_2SO_4$$

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

(ii) In the presence of a more powerful reducing agent, SO_2 acts as a strong oxidizing agent;

$$SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$$

$$SO_2 + 2Mg \longrightarrow 2MgO + S$$

(b)(i) H_2O_2 is a powerful oxidizing agent. It oxidizes iodide ion, and iron (11) salts in acidic medium as shown:

$$2l^- + H_2O_2 + 2H^+ \longrightarrow l_2 + 2H_2O$$

$$2Fe^{2+} + H_2O_2 + 2H^+ \longrightarrow 2Fe^{3+} + 2H_2O$$

Also in aqueous solution, H_2O_2 oxides sulphites (SO_3^{2}).

$$2PbS + 4H_2O_2 \longrightarrow PbSO_4 + 4H_2O$$

$So_2 \quad + \quad H_2O_2 \longrightarrow H_2SO_4$

(ii) H_2O_2 although an oxidizing agent, it acts as a reducing agent in the presence of a powerful oxidizing agent.

In acidic medium, it reduces permanganate ion (MnO_4-) to Mn^{2+}

$$2MnO_4^- + 5H_2O_2 + 6H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$$

Some oxidants and reductants change colour when they are reduced and oxidized respectively.

Oxidants:

1. MnO_4 (purple) $\longrightarrow$ Mn^{2+} (colourless or pink). This occurs in acidic medium

   MnO_4^- (purple) $\longrightarrow$ MnO_2 (brown). This occurs in basic medium

2. $Cr_2O_7^{2-}$ (yellow) $\longrightarrow$ Cr^{3+} (green). This occurs in acidic medium

3. I_2 (brown) $\longrightarrow$ $2I^-$ (colourless).

Reductants

1. $2I^-$ (colourless) $\longrightarrow$ I_2 (brown)

2. H_2S $\longrightarrow$ S (yellow)

Fe^{2+} (colourless in $KCNS_{(aq)}$) $\longrightarrow$ Fe^{3+}(red in $KCNS_{(aq)}$)

Disproportionation reaction

This is a redox in which one substance is simultaneously oxidized and reduced

$$3HNO_{2(aq)} \longrightarrow HNO_{3(aq)} + 2NO_{2(q)} + H_2O_{(1)}$$

In the reaction, the oxidation number of nitrogen increases from +3 in HNO_2 to +5 in HNO_3, but reduces to +2 in NO_2.

$Cl_{2(q)} + 2NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + NaClO_{(aq)} + H_2O_{(1)}$. Similarly, in this reaction, the oxidation number of Cl_2 increases from 0 to +1 in NaClO, but reduces to -1 in NaCl.

2.9 Importance of oxidation numbers

They are useful in:

i. Balancing redox reactions;
ii. Fixing ionic charges;
iii. Deciding whether or not a reaction is a redox.

2.10 Half reactions

A half reaction is a separate equation showing which substance gains or loses an electron in a redox reaction. A half reaction is a hypothetical reaction and cannot occur alone in solution. It is always accompanied by a second half reaction.

Oxidation half reaction (OHR):- An oxidation half-reaction is a separate equation showing the substance that becomes oxidized by losing one or more electrons.

Reduction half reaction (RHR): A reduction half-reaction is a separate equation showing the substance that becomes reduced by gaining one or more electrons. The sum of the oxidation half-reaction and reduction half- reaction gives the overall redox reaction.

Balancing redox reactions: There are two methods of balancing redox reactions. They are ion-electron method and oxidation number method. The former is the preferred method.

The ion-electron method: Redox reaction may occur in either acidic or basic medium.

1. **Balancing Redox Reaction in Acidic Medium**

Acid medium is recognized by the presence of H^+. For oxo-anions in acid medium, hydrogen and oxygen atoms are balanced by including $H^{+}_{(aq)}$ or $H_2O_{(l)}$ or both in the equation. Now using the redox reaction below as an example,

$$CrO_7^{2'} + Fe^{2+} + H^{+} \quad \rightarrow \quad Cr^{3+} + H_2O + Fe^{3+}$$

The following are the rules for balancing redox reactions:

a) Identify the oxidation and reduction processes, and write each separately.

Oxidation half- reaction: Reduction half-reaction:

$Fe^{2+} \rightarrow Fe^{3+}$ $Cr_2O_7^{2-} \rightarrow Cr^{3+}$

b) Balance the number of atoms.

Since in the reduction reaction there are two atoms of chromium on the left- hand side, 2 should be placed before Cr^{3+}. Also, the reaction occur in acidic medium, therefore, oxygen is balanced by introducing H_2O on the oxygen deficient side and H^{+} ion on the hydrogen deficient side of the reaction. $Cr_2O_7^{2'} + 14H^{+} \rightarrow 2Cr3^{+} + 7H_2O$

c) Balance the electric charges by adding electrons

In the reduction half-reaction, there are twelve (12) positive charges on the left and six **(6)** positive charges on the right. Therefore, to satisfy the charge balance rule, six electrons should be added to the left-hand side of the equation. Thus,

$$Cr_2O_7^{2-} + 14H^{+} + 6e \rightarrow 2Cr^{3+} + 7H_2O$$

In the oxidation half-reaction, there is a net positive charge on the right hand side. Therefore, to satisfy the charge balance rule one electron should be added to the right-hand side. Thus,

$$Fe^{2+} \rightarrow Fe^{3+} + e^{-}$$

d) Find the simplest mole ratio of electrons in the oxidation-reduction process.

e) Mole ratio; Oxidation: Reduction = 1:6

Multiplying oxidation equation by 6,

$6Fe^{2+} \rightarrow 6Fe^{3+} + 6e^-$

Multiplying reduction equation by 1,

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

f) Combine the two half reactions

$6Fe^{2+} \rightarrow 6Fe^{3+} + 6e^-$

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

$Cr_2O_7^{2'} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

2.11 Empirical Review on Students' Difficulties in Understanding Topics in Chemistry

Furthermore, Johnstone (2020) identified chemistry topics that students found difficult to learn by questioning students who had studied chemistry at the senior high school level. According to Johnstone (2020), as students arrived at the University of Glasgow and Strathclyde to begin their studies in chemistry, each student was given a list of all the topics in the chemistry curriculum and asked to categorize each of them into one of four groups. The four categories of responses that students were to select from were; I understood this easily, 1 had some difficulty but I now understand it, 1 have never been taught this. Johnstone (2020) plotted the frequency of the choice against the topic list for each of the two university samples. The result for the two universities gave almost perfect agreement to the issues. Johnstone (2020) repeated the study using 17-year-old pupils in secondary schools. The frequency pattern was found to be the same as that derived from the two universities. From Johnstone's (2020) study, the topics students found to be difficult include: volumetric analysis, Avogadro's number and the mole, heats of reaction, Hess's law and thermochemistry, redox reaction, equilibrium and organic chemistry.

According to Childs and Sheehan (2019), initially, the level of difficulty of a particular topic was determined by mean values as follows: mean ratings of less than 2.5 meant that students found that topic easy, and mean ratings between 2.5 and 5 meant that students found that topic difficult. Responses to each topic were then analyzed and the topics which got the highest number of difficult/very difficult responses were identified accordingly. The result of the study showed that forty-five topics scored a mean value above 2.5 from the leaving certificate responses. Overall, fifty-five topics out of sixty topics for 1st year university students scored a mean value above 2.5. Overall, fifty-seven topics out of sixty scored a mean value above 2.5. In general, the study by Childs and Sheehan (2019) showed that students at all levels find the majority of areas in chemistry difficult. What is interesting is that the perceived difficulty of a number of topics was a persistent feature from Junior Certificate level through to university level.

Topics that appeared in the investigations as being difficult, when results of section A and section B of the questionnaire for leaving certificate and 3rd level students were: volumetric analysis calculations, redox reaction and concentration of solutions. Comparing the results of this study involving Irish chemistry students with results of similar studies carried out in different part of the world, for example Johnstone (2020) in USA and Jimoh (2021) in Nigeria, it can be seen that despite curricular differences, students found similar topics in chemistry (redox reaction, the mole and Avogadro’s number, equilibrium and equilibrium calculations, volumetric and titration calculations and organic synthesis) difficult to learn.

2.12 Summary of Literature Review

Redox reactions are those chemical reactions in which both the oxidation and reduction processes take place simultaneously (Achimugu, 2019). The concept of redox reactions in chemistry is, however, generally one of the most difficult subjects for students, who often have trouble applying the given rules to specific problems. To master the subject, students need to work through a number of practice problems themselves. The more they practiced, the better they understood what they were doing. However, a key to their success is that they be given consistent feedback on their work. Redox reactions are studied at the SHS level not as a separate topic but as part of the SHS level chemistry programme.

Within subjects studied at schools, there are topics that students found difficult to learn and some topics that teachers find difficult to teach. In chemistry, studies have shown that redox reactions are difficult for students to learn.

Perception is the process of organizing and interpreting the raw data obtained through the senses. Knowledge and experience are extremely important for perception. This is because the human mind can only contemplate that which it has been exposed to.

Knowledge is the form of existence of the organism-environment system and new knowledge is created by perception when new parts of environment join to the system while changing the structure of the system. There are challenges associated with the learning of subjects. The challenges are mainly in the areas of perception of the difficulty of the topics in the subject, variables related to students characteristics, the discipline, and teacher characteristics.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Overview

The methodology involves the methods and procedures followed to obtain answers to the research questions. The purpose of this chapter is to provide a detailed description of the design, population, sample, instruments, procedure for data collection and data analysis.

3.2 Research Design

The study investigated students' performance in answering questions on redox reaction, the perceptions and misconceptions of SHS students on the concept of redox reaction and also the teachers' influence on the performance of students in redox reaction tasks. The research design that was used for the study was a cross-sectional survey.

The purpose of the survey design was to; a) explore SHS students' perception of Redox Reactions Concept, b) investigate teachers' influence on the performance of students in Redox Reaction Tasks, c) investigate SHS students' misconceptions in the concept of Redox Reactions, d) and also find out the performance of SHS students on redox reactions.

The design involved SHS 3 elective science students from six Senior High Secondary schools in the Obuasi Municipality and Adansi North District of the Ashanti Region of Ghana. The design has an advantage of producing good amount of responses from a whole range of people (Best & Khan, 2019). It is also good for descriptive analyses and for generating hypotheses, relatively quick and easy to conduct and able to measure prevalence for all factors under investigation. Furthermore, it is the most used design for large scale study.

The weaknesses of the cross-sectional survey design, however, include the following:

i. Difficult to determine whether the outcome followed exposure in time or exposure resulted from the outcome.

ii. Not suitable for studying rare diseases with a short duration.

iii. Unable to measure incidence.

iv. Associations identified may be difficult to interpret.

Survey includes studies that use questionnaires or standard interviews for data collection with the intent of generalizing from a sample to a population (Babbie, 2020). Since the study was concerned with the students’ perception, misconception and the difficulties in understanding Redox Reaction Concepts, firstly, SHS 3 elective science students drawn from six senior high schools offering science as an elective in the Obuasi Municipality and Adansi North District of the Ashanti Region of Ghana were tasked to respond to statements in the questionnaires. Secondary, standardized achievement tests on the Redox Reaction Concept were administered separately to SHS 3 elective science students drawn from the said six schools. This was done to investigate the difficulties the students encountered when they answered questions on redox reactions.

3.3 Population

The target population for this study comprised all students offering elective chemistry for the 2022/2023 academic year in the Obuasi Municipality and Adansi North District of the Ashanti Region; while the accessible population comprised all SHS 3 students offering elective chemistry for the 2022/2023 academic year in the Obuasi Municipality and Adansi North District of the Ashanti Region. These students who might have studied chemistry for almost three years and could, therefore, make meaningful contribution to the study. The schools were six in number.

As at the beginning of the 2018/2019 academic year, there were 1580 students studying chemistry as an elective subject in the two municipalities (GES, 2019; Republic of Ghana, 2019)

3.4 Sample and Sam1pling Procedure

The sample size for the study was 208. This sample was selected based on the recommendation of Macmillan (1996) who stated that in a cross section survey a sample size of five to ten percent of the accessible population is appropriate. The purposive sampling procedure was used to select schools such as schools A, B, C, D, E, and F.

All in Obuasi Municipal and Adansi North District because these wxere the only schools teaching chemistry as an elective science subject in the two municipalities.

All science chemistry students of the selected schools were purposely selected to form part of the sample (See Table 4). As presented in Table 4, A, B, C, D, E, F. Table presents the sample distribution of the respondents.

Table 3.1: Sampled Students from Obuasi Municipality and Adansi North District

Name of School	Frequency (No.)	Percentage (%)
School A	53	25.5
School B	42	20
School C	36	17.3
School D	26	12.5
School E	25	12
School F	26	12.5
Total	208	100

Further description of the sample is depicted in Table 3.2. The sample consisted of 208 SHS 3 students in Obuasi Municipality and Adansi North District. Student's background by sex and age is presented in Table 3.2.

Table 3.2: Student's Background by Sex and Age

	Frequency (No.)	Percent (%)
Background information		
Sex		
Male	141	67.8
Female	67	32.2
Age		
15 years	2	1.0
17 years	25	12.0
18 years	85	40.9
19 years	56	26.9
20 years	40	19.2

(N=208)

Table 3.2 shows 141 (67.8%) of males and 67 (32.2%) of females participated in the study. More males participated in the study than females; this may mean that male population in the study area dominate that of female with regard to the study of science programme at the SHS level in Ghana. According to, Table 3.2, 85 (40.9%) SHS students were aged 18 years whiles 56 (26.9%) SHS students were aged 19 years. Forty (19.2%) SHS students were aged 20 years. From the data above it could be seen that all students were teenagers and reflect the age range of students at the SHS level in Ghana.

3.5 Data Collection Instruments

Three research instruments were used for data collection. The instruments were questionnaire, achievement test and interview.

3.6 Redox reactions questionnaires for students

Questionnaire was selected because it is effective in securing information from respondents (Macmillan, 1996). The questionnaire could be of anonymity. According to Wallen and Fraenkel, (2018), designing one's instrument is time consuming, and do not recommend for those without a considerable amount of time, energy and money to invest in the endeavor.

The Redox Reactions Questionnaires for Students had two sections. Section A solicited from respondent their background characteristics, whiles section B focused on the students' perception of the redox reactions. The format for the questionnaire on the students' perception on the redox reaction concept was a Likert-scale type items. The advantage of using the Likert-scale type items is that it enables a single instrument to cover a wide range of subjects and also because respondents do not write out their own ideas, it is easy to complete (DeMatteo, Festinger & Marczyk, 2022).

3.7 Achievements test

Two sets of test were administered to the students to assess their performance and misconception on redox reactions concept. Students were required to identify with reasons the oxidizing agents (oxidants) and the reducing agents (reductants), balance redox reactions in acidic and basic mediums. They were also tasked to determine the oxidation number of the underlined species of compounds.

In developing this instrument, the items were constructed by adapting some items from the May/June 2012-2021 chemistry paper one of the West African Senior Secondary Certificate Examination.

The instrument was, therefore, pilot-tested using a sample of 40 elective science students drawn from New Edubiase Senior High School in Ashanti Region.

3.8 Redox reaction focus group interview schedule

The Redox Reaction Focus Group Interview *Schedule was developed as* a follow-up to items in Redox Reactions Questionnaire for Students. The Focus Group Interview was employed in order to solicit from students what might be their teachers' influence on their performance when they study redox reaction so as to gain insight into why they have difficulties in understanding redox reactions.

3.9 Validity and reliability of the instruments

The validity is concerned with the extent to which an instrument measures what it is intended to measure (Ebel & Fresbie, 2021). The items were carefully examined to determine if the items will be able to elicit data on the issues raised in order to measure the intended content area (face validity) and whether they covered the whole content area (content validity). The comments and suggestions from the experts informed the modification of items in the questionnaire. Moreover, the factors that contribute to low validity such as ambiguities in language, and unclear directions were eliminated.

The reliability of a measuring instrument is the degree to which that instrument consistently measures whatever it measures (Leedy, 2019; Gay, 2018). The redox reactions questionnaire for students (RRQS) was pilot-tested in New Edubiase Senior High School (a school that was not used in the main study) that had treated redox reaction. The RRQS was pilot-tested using 40 elective science students. The responses provided by them were analyzed to test.

3.10 Data Analysis

The data was analyzed using the research questions as guide. This was then organized and coded with various numbers assigned to each distinctive variable such as age, sex among others for students. In addressing research question one, the options strongly agree, agree, undecided, disagree and strongly disagree in students' perceptions of the redox reactions of Redox Reaction Questionnaire for Students were coded 5, 4, 3, 2, and 1 respectively for all positive statements. The order of the weighting was reversed for negative statements. The analysis of the data involved the use of multiple statistical procedures such as frequencies, percentages and mean scores.

Research question two is on the teachers' influence on the students' performance in redox reaction tasks. This research question was answered using the data from Redox Reaction Focus Group Interview Schedule. Data from the interview were analyzed thematically.

In answering research question three about students' misconceptions in the concept of redox reactions, three essay questions from the achievement test were used to elicit data from the respondents. This research question was answered as by using content analysis technique. To begin the analysis, the responses of the students were broken into sentences. In doing the analysis, students' responses on each item was read and categorized of responses were developed. Codes were then ascribed to the sentences in line with categories and the frequency with which the codes occurred was counted.

The higher the score obtained by a respondent, the lesser the misconception of redox reactions. Conversely, the lower the score obtained by a student the higher the misconception of redox reactions. Also, in addressing research question four about the performance of students, descriptive statistics such as mean, standard deviation, frequencies and percentages were used in analyzing the data based on the research achievements test constructed.

The independent samples t-test analysis was employed to further examine the difference in performance of school A and school B students on answering questions on redox reactions. This statistical tool was deemed appropriate since it was used to determine whether a significant difference existed between the two schools being compared.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

This chapter provides the analysis of responses and discussion of the findings from the study. Presentation under this chapter covers analysis of demographic data of the respondents and results of the main data. The analysis and discussion focused on investigating senior high schools' students' difficulties in understanding redox reaction. In investigating senior high schools' students' performance of the concept of redox reaction, the study focused on exploring SHS 3 students' perception of Redox Reaction Concept, investigating teachers' influence on performance of SHS 3 students when they study redox reaction, investigating SHS 3 students' misconceptions in the concept of Redox Reactions and also to find out the performance of SHS 3 students on Redox Reactions.

4.2 Research Question One: What are the SHS 3 students' perceptions of the concept of redox reactions?

Research question one examined students' perception of Redox Reaction Concept. For easy analysis, two response categories, Strongly Agree (SA) and Agree (A) were collapsed into a single response category of Agree (A) while the two opposite response categories, disagree (D) and Strongly Disagree (DA) were also collapsed into a single response category of Disagree (D), the neutral response category, Undecided (UN) was however retained. Their perception of the concept of redox reaction is presented in Table 9.

Table 4.1: Students Perception of Redox Reactions Concept

Statements	A		UN		D	
	No	**%**	**No.**	**%**	**No.**	**%**
1. Teacher rushed through the Redox Reaction Concept	64	30.8	25	12.0	119	57.2
2. Teacher devoted much of his time	155	74.5	17	8.2	36	17.3
3. I do not like the way chemistry teacher taught redox reactions	55	26.4	20	9.6	133	63.9
4. Did not understand the Redox Concept contents	81	38.9	23	11.1	104	50.0
5. Redox reactions concept is boring	72	34.6	30	14.4	106	51.0
6. Redox reactions concept is very difficult	66	31.7	15	7.2	127	61.1
7. Redox reaction concept is difficult to learn	71	34.1	22	10.6	115	55.3
8. Requires the leaning of too many unrelated						

facts	85	40.9	35	16.8	88	42.3
9. It makes me nervous	60	28.8	29	13.9	119	57.2
10. Concept is easy to understand	94	45.2	22	10.6	92	44.2
11. Redox reaction is abstract	101	48.6	36	17.3	71	34.1
12. It takes a lot of time to read and understand redox reaction	112	53.8	15	7.2	81	38.9
13. Chemistry teacher did not allow us to ask questions	38	18.3	18	8.7	152	73.1
14. Chemistry teacher told us redox reactions concept is difficult	54	21.6	17	8.2	146	70.2
15. Learning redox reactions concept is time-consuming	77	37.0	17	8.2	114	54.8
16. I do not understand redox reaction because of the way I was taught	71	34.1	25	12.0	112	53.8
17. I found redox reactions concept interesting	88	42.3	25	12.0	95	45.7

18. Chemistry teacher did not mind whether or not the class understood the redox reactions	70	33.7	22	10.6	116	55.8
19. Redox reactions concept questions are difficult to answer	74	35.6	27	13.0	107	51.4
20. Redox reactions questions demand a lot of recall of facts	83	39.9	31	14.9	94	45.2
21. Redox reactions concept should not be studied at the SHS level	68	32.7	25	12.0	115	55.3
22. Did not answer redox reactions questions in class test and exams	58	27.9	23	11.1	127	61.1

From Table 4.1, 119 (57.2%) students perceived that their chemistry teachers do not rush when teaching the concept of redox reaction. This was affirmed by 155 (74.5%) students indicating that chemistry teachers devote much time when teaching redox reaction concept. Because of this, 133 (63.9%) students indicated that they liked the way their chemistry teachers taught redox reaction concept.

Because chemistry teachers had enough time in teaching redox reaction concept, 104 (50.0%) students were able to have better understanding. Also, this made the redox reaction lesson very interesting which was indicated by 106 (51.0%) of the students.

Furthermore, 152 (73.1%) students indicated that their chemistry teachers allowed them to ask questions to clear any difficulty they had, understanding the concept of redox reaction. This helps students to feel part of the lesson being taught and also creates a very good atmosphere for teaching and learning since it draws teachers' attention to aspects of the redox reactions' concepts that students don't understand.

On the issue of redox reactions' concepts interesting to learn, 95 (45.7%) students perceived that it is not interesting to study redox reaction concept whiles 88 (42.3%) students perceived that redox reactions' concepts are interesting to learn. However, 146 (70.2%) students were of the view that their chemistry teacher was their source of motivation in learning the concept of redox reactions. The teacher is seen as the immediate role model to students in the classroom. Students see their teachers as their role models and, therefore, the teacher is the first and immediate person to motivate students in making learning of difficult and abstract concept very easy an interesting based on teacher's approach and motivation.

Because of the significant roles that are played by chemistry teachers in teaching redox reactions, 112 (53.8%) students perceived that they did understand the concept of redox reaction because of the way their chemistry teachers taught redox reaction. Chemistry teachers were perceived to show much interest on whether students have understood the concept of redox reaction. This was affirmed by 116 (55.8%) students disagreeing that their chemistry teachers didn't mind whether or not they have understood the redox reaction concepts with the ideology of one needs not score all questions to be graded the best. The findings on whether redox reaction concept is the most difficult compared with other chemistry concepts revealed that 127 (61.1%) of the students disagreed with this assertion.

One hundred and fifteen (115) representing 55.3 percent of the respondents indicated that the redox reactions concepts were very easy to learn. However, 85 (40.9%) of the students indicated that the learning of redox reactions concepts required the learning of unrelated facts. To this, 35 (16.8%) of the students were undecided whiles 88 (42.3%) of the students disagreed to redox reactions concepts requiring learning of unrelated facts.

On the issue of redox reaction concept been abstract, 101 (48.6%) students perceived the concept of redox reactions as abstract. However, 71 (34.1%) of the students perceived the concept of redox reactions as not abstract. Because of this, 112 (53.8%) of the students perceived the learning of redox reactions take much of their time. However, 119 (57.2%) students perceived that due to the abstract nature of the redox reaction concepts a lot of their time is taken in learning, it does make them nervous when answering questions on them. When it came to the issue of the concept of redox reaction easy to understand, students had divided perception on this. This was indicated by 94 (45.2%) of the students agreed to the concept being easy to understand whiles 92 (44.2%) of the students disagreed to the concept being easy to understand because the concepts of redox reactions have been perceived by appreciable number of students to be abstract.

Lastly, 107 (51.4%) of the students perceived redox reaction questions as not difficult to answer. To this, 94 (45.2%) of the students perceived that the difficulty nature of the concept is attributed to less recall of facts that redox reactions questions demand. These 127 students, representing (61.1%) indicated that they would answer redox reaction questions in class test and exams. In all, 115 (55.3%) of the students perceived that it is appropriate to study redox reaction concept at the SHS level.

The answer to the first research question is that Redox Reaction is not as difficult as being perceived by some students of chemistry.

The findings further show that the abstract nature of the redox reactions concepts and the lot of time it takes in learning them makes students nervous when studying redox reactions. However, students noted that it was appropriate to study redox reaction concept at the SHS level.

4.3 Research Question Two: How do teachers' instructional activities influence students' performance when they study redox reactions?

A focus group interview was conducted using twelve (12) students; two students from each of the six schools. The twelve (12) students were made up of class prefects and various assistants from each school. The focus group interview was conducted immediately after the redox reaction questionnaire for students and redox reaction achievement test have been administered. With permission from the various assistant heads of academic, the interviews were conducted in various classrooms. The focus group was a follow-up to the questionnaire and the achievement test. The focus group interview lasted between ten (10) and fifteen (15) minutes.

All the twelve students responded positively to the interview. Their comments were received on the period for teaching redox reactions, difficult contents to understand, contents their teachers found difficult to teach and the challenges of the teaching and learning of redox reaction at the senior high school level. The students said that they were taught redox reactions concept. However, many of them said, the concept of redox reactions are mostly treated in the first term of SHS 3, thus, just before writing WASSCE chemistry paper. Meanwhile, redox reaction according to the WAEC chemistry teaching syllabus should be taught in SHS 2. According to most of the students interviewed, the time they were taught redox reaction concept affected their performance in redox reactions in examinations.

According to most of the students, even though, the chemistry teachers did not start teaching the concept of redox reactions when they were actually supposed to, they did not give redox reaction concept contents as reading assignments.

However, some of them said, their chemistry teachers skipped some of the redox reactions' contents. The contents they normally skipped were redox titration and balancing of redox reactions. According to the students, the chemistry teachers knew questions are usually not set on especially redox titrations in the WASSCE and they usually skip it. The teachers might have studied the trend of questions in past WASSCE chemistry paper 1 and noticed that questions were not likely to be set on it or questions had already been set on it in the previous examination. The students said, they learned the skipped contents on their own or they asked their colleagues who understood the contents to teach them.

4.4 Research Question Three: What are SHS 3 students' misconceptions of the concept of redox reactions?

Research question three examines student's misconceptions of the concept of redox reactions. The misconception on the concept of redox reactions test consisted of items 6, 7 and 9 of the nine essay items in the redox reactions achievement test. Item 6 was meant to reveal misconceptions in oxidation and reduction in redox reaction. Item 7 was also meant to revealed students' misconceptions in reducing agents in redox reactions while item 9 revealed misconceptions in determination of redox reactions. These items largely helped in revealing misconceptions of students with regard to redox reactions.

4.5 Misconceptions on species being oxidized and those being reduced as in

a. $Cr_2O_7^{2-} + CH_3CHO + H^+ \longrightarrow Cr^{3+} + CH_3CHO + H_2O$

b. $NO_3^- + Fe^{2+} + H^+ \longrightarrow NO_2 + Fe^{3+} + H_2O$.

The achievement test on this aspect of redox reaction sought to find out from students the identification of species being oxidized and those being reduced in a redox reaction and their reasons for their answers. In the aspect concerning the identification of species being oxidized and those being reduced in a redox reaction, three categories of misconceptions emerged.

These were: correct answers with wrong explanations category as shown in Table 7, wrong answer with wrong explanation category as shown in Table 8 and correct and wrong answer with no explanation category as shown in Table 9.

(a) $Cr_2\,O_7^{2-} + CH_3CHO + H^+ \longrightarrow Cr^{3+} + CH_3COOH + H_2O$

(b) $NO_3^- + Fe^{2+} + H^+ \longrightarrow NO_2 + Fe^{3+} + H_2O$ (Correct Answer with Wrong Explanation)

Table 4.2: Students' Misconceptions on Species being Oxidized and Those Being Reduced as in the Case of:

Students' Response	No.	%
1) CH_3CHO is oxidized because its oxidation state changes from 0 to -1	8	3.8
2) Fe^{2+} is oxidized because an electron is gained and $N0_3^-$ is reduced because an electron is loss	18	8.7
3) Fe^{2+} is oxidized because the oxidation state increases from +2 to +4.	12	5.8
4) CrO_7^{2-} is reduced because of the oxidation state of Cr has decreased from +6 to +5 and CH_3CHO is oxidized because the oxidation state of C has increased from 0 to 1	4	1.9
5) NO_3^- is reduced because N is decreased from +5 to -5		

	oxidation state and Fe^{2+} is oxidized from +2 to +5 oxidation state.	11	5.3
6)	CH_3CHO is oxidized to CH_3COOH since oxidation number of CH_3CHO is more than that of CH_3COOH	9	4.3
7)	CH_3CHO is being oxidized because hydrogen has been added to a specie	3	1.4
8)	Fe^{2+} has been oxidized because it has changed its oxidation number from 0 to 3	5	2.4
9)	CrO_7^{2-} has been reduced because it has lost oxygen to become Cr^{3+}	5	2.4
10)	CH_3CHO is oxidized because it is deficient of one oxygen atom	10	4.8

(N=208)

As shown in Table 4.2, 8 (3.8%) students thought that the oxidation number of CH_3CHO decreases from 0 to -1. Eighteen (8.7%) students thought that F^{2+} was oxidized because an electron was gained and NO_3^- was reduced because an electron was lost. Twelve (5.8%) students felt that Fe^{2+} was oxidized because the oxidation state increased from +2 to +4. Four (1.9%) were of the view that since CrO_7^{2-} was reduced, Cr was decreased from +6 to+5, and also, CH_3CHO was oxidized because the oxidation state of C increased from 0 to 1. Eleven (5.3%) students stated that NO_3^- is reduced because N is decreased from +5 to -5 oxidation state and Fe^{2+} is oxidized from +2 to +5 oxidation state. Again, 9(4.3%) students gave the wrong reason that CH_3CHO is oxidized to CH_3COOH since oxidation number of CH_3CHO is more than that of CH_3COOH. Also, 3(1.4%) students thought that CH_3CHO is being oxidized because hydrogen has been added to specie. Moreover, 9(4.3 %) students said that Fe^{2+} has been oxidized because it has changed its oxidation number from 0 to 3.

Furthermore, 5 (2.4%) students were of the reason that CrO_7^{2-} has been reduced since it has loss oxygen to become Cr^{3+} Finally, 10 (4.8%) students felt that CH_3CHO is oxidized because it is deficient of one oxygen atom. It appears from the explanations given by students that they do not appreciate the concept of oxidation numbers to tell whether or not that specie is being oxidized or reduced (De Jong et al. 2019).

Table 4.3 shows students' misconceptions in the wrong answer with wrong explanation category. As shown in Table 4.3, most of the students (4.8%) that got the answer wrong attributed the cause of their answers to the gain and loss of oxygen atoms. It appears that some of the students failed to appreciate the fact that the presence of H^+ is denoting the medium in which the redox reaction is occurring, and for that matter acidic medium.

a. $Cr_2O_7^{2-}$ $^+CH_3CHO + H^+ \longrightarrow Cr^{3+} + CH_3COOH + H_2O$

b. $NO_3^- + Fe^{2+} + H^+ \longrightarrow NO_2 + Fe^{3+} + H_2O$

(Wrong Answer with Wrong Explanation)

Table 4.3: Students' Misconceptions on Species Being Oxidized and Those Being Reduced as in the Case of

Students' responses	**No.**	**%**
1. H^+ is reduced because it has gained oxygen	10	4.8
2. $Cr_2O_7^2$ is oxidized from +6 to +3 because there is a decrease in oxidation number	4	1.9
3. NO_3^- in (b) is oxidized because it has lost one oxygen to form No_2.	8	3.8
4. $Cr_2O_7^2$ is being oxidized because at the reactant side the oxidation state is -2 but at the product side the oxidation	9	4.3

	state is +3.		
5.	NO_2 is being reduced because it has gained one oxygen atom to become NO_3^-.	11	5.3
6.	$Cr_2O_7^{2-}$ is oxidized because oxygen has been removed to make it Cr^{3+}.	4	1.9
7.	H^+ has been oxidized because oxygen has been added to it to form H_2O	12	5.8
8.	$Cr_2O_7^{2-}$ is the reducing agent in the equation because there is a decrease in oxidation number from +6 to +3. Also, CH_3CHO is the oxidizing agent because there is an increase in oxidation number	2	1
9.	$Cr_2O_7^{2-}$ is oxidized to Cr^{3+} since the number of electrons for Cr in $Cr_2O_7^{2-}$ was 7 and has reduced to Cr^{3+}	2	1

(N=208)

Four (1.9%) students said CrO_7^{2-} is being oxidized, and attributed their reason to the fact that there is a decrease in oxidation number from + 6 to + 3. These students probably do not know that when there is a decrease in the oxidation number of specie, it becomes reduced. Eight (4%) students thought that NO_3' in (b) was oxidized because it has lost one oxygen to form NO_2, NO_3' in (b) was rather reduced because the oxidation number of nitrogen in NO_3' has decreased from +5 to + 4 in NO_2.

Also, the loss of oxygen is not about specie being reduced but about specie being oxidized.

(a) $Cr_2O_7^{2-}$ $^+CH_3CHO + H^+ \longrightarrow Cr^{3+} + CH_3COOH + H_2O$

(b) $NO_3^- + Fe^{2+} + H^+ \longrightarrow NO_2 + Fe^{3+} + H_2O$

(Correct and Wrong Answers without Explanation)

Table 4.4: Students' Misconceptions on Species being Oxidized and those being Reduced as in the Case of

Students' responses	No.	%
Correct answers		
1. $Cr_2O_7^{2-}$ is reduced to Cr^{3+}.	3	1.4
2. CH_3CHO is oxidized to CH_3COOH.	1	0
3. Fe^{2+} is oxidized to Fe^{3+}.	2	1
4. NO_3^- is reduced to NO_2.	5	2.4
Wrong answers		
5. $Cr_2O_7^{2-}$ is oxidized to Cr^{3+}.	2	1
6. CH_3CHO is reduced to CH_3COOH.	4	1.9
7. Fe^{2+} is reduced to Fe^{3+}.	1	0
8. NO_3^- is oxidized to NO_2.	2	1

(N =208)

As indicated in Table 4.4, nine students (4%) felt that since the oxidation state of $Cr_2O_7^{2-}$ at the reactant side was -2 but at the product (Cr^{3+}) side was +3, it was being oxidized. In the first place, $Cr_2O_7^{2-}$ is rather reduced to Cr^{3+} for the very reason that the oxidation number of Cr in $Cr_2O_7^{2-}$ has decreased from +6 to +3 in Cr. Eleven (5.3%) students argued that NO_2 is being reduced because it has gained one oxygen atom to become NO_3^-. It is rather NO_3^- which is being reduced to NO_2. This is because the oxidation number of nitrogen in NO_3^- has decreased from +5 to +4 in NO_2.

Meanwhile, gaining of oxygen is oxidation but not reduction as championed by such students. Four (1.9%) students who thought $Cr_2O_7^{2-}$ is being oxidized gave a reason that oxygen has been removed to make it Cr^{3+}. $Cr_2O_7^{2-}$ is rather reduced to Cr^{3+} because the oxidation number of Cr in $Cr_20_7^{2-}$ has decreased from + 6 to + 3 in Cr. Also 2 (1%) students misunderstood the substance being reduced as a reducing agent and also, the substance being oxidized as an oxidizing agent.

Table 4.4 shows the number of students who had correct and wrong answers but could not explain their answers. Although, some of the students had the items correct it was not because they understood the concept but because they guessed or their choice was based on intuition. This misconception may be linked to students' difficulty in determining species involved in a redox reaction which are being reduced and being oxidized (Ekpo & Udo, 2020).

4.6 Misconceptions on the identification of a reducing agent

The achievement test on this aspect of redox reaction sought to find out from students the determination of a reducing agent in a redox reaction and their reasons for their answers. The misconceptions identified fall under two categories. These are: correct answer with wrong explanation category as shown in Table 4.5, and wrong answer with wrong explanation category as shown in Table 4.4.

$2A1_{(s)} + Fe_2O_{3(s)} + H_2SO_3 \longrightarrow A1_2O_{3(S)} + 2\ Fe_{(s)}$ (Correct

Answer with Wrong Explanation)

Table 4.5: Students' Misconceptions about Reducing Agent in a Redox Reaction such as

Students' responses	**No.**	**%**
1. Al is a reducing agent because its oxidation state has increased from +1 to +3	20	9.6
2. Al is a reducing agent because it has reduced from 2 moles of electrons to 1 mole of electron.	15	7.2
3. Al is the reducing agent because it has gained electrons	30	14.4
4. Al has reduced in the reaction and so it is the reducing agent	38	18.3

(N = 208)

As shown in Table 4.5, 20 (9.6%) students gave the reason that A1 is a reducing agent because its oxidation state has increased from + 1 to +3. They failed to appreciate the fact that, the oxidation state of any element in its elemental state is 0 but not +1. Fifteen (7.2%) students thought that when there is a reduction of the moles (stoichiometric coefficients) of one species to another, there is then a reducing agent. Thirty (14.4%) students argued that A1 is a reducing agent because it has gained electrons. They are supposed to be mindful of the fact that gaining of electrons is a reduction process and for that matter an oxidizing agent.

Also, 38 (18.3%) of the students were of the view that A1 was the reducing agent because it had been reduced in the reaction. But a substance/specie that reduces is not a reducing agent but then, an oxidizing agent. It appears from the explanations given by students that they do not appreciate the concept of reducing agent. They therefore, have problems identifying reactants as oxidizing or reducing agents (De Jong et al., 2019).

2A1 (s) + $Fe_2O_{3(S)}$ + H_2SO_3 --- > $AI_2O_{3(s)}$ + $2Fe_{(2)}$ > (Wrong Answer with

Wrong Explanation) Table 4.6: Students' Misconceptions about Reducing Agents in Redox Reactions such as

Students' response	**No.**	**%**
1. Fe_2O_3 is the reducing agent because it is oxidized to Fe.	10	4.8
2. Fe_2O_3 is the reducing agent because Fe in the reaction has gained electrons	8	3.8
3. Fe_2O_3 is the reducing agent because it has reduced from +3 to 0 oxidation state	9	4.3
4. Fe_2O_3 is the reducing agent because oxygen has been removed from it to form Fe.	15	7.2
5. Al_2O_3 is the reducing agent since it has removed oxygen from Fe_2O_3	4	1.9

6. Fe_2O_3 is the reducing agent because the oxygen atoms have reduced from 3 in Fe_2O_3 to 0 in Fe	7	3.4
7. Al_2O_3 is the reducing agent because it is the one that is being oxidized in the reaction	3	1.4
8. Fe_2O_3 is the reducing agent because it has been oxidized to form Fe	8	3.8

(N=208)

Table 4.7 shows students' misconceptions in the wrong answer with wrong explanation category. As shown in Table 4.6, most of the students who had the answer wrong gave the reason that removal of oxygen from specie is the reducing agent. Such students did not understand that removal of oxygen atoms is a process of reduction and for that matter an oxidizing agent.

Ten (4.8%) students said Fe_2O_3 is the reducing agent (reductant) since it is oxidizing to Fe. In the reaction Fe_2O_3 rather reduces to Fe and becomes an oxidizing agent. Eight (3.8%) students reckoned that Fe_2O_3 is the reducing agent because Fe in the reaction has gained electrons. Gaining of electrons is reduction and for that matter an oxidizing agent but not a reducing agent (Toth, 2021).

Nine (4.3%) students said Fe_2O_3 is the reducing agent because it has reduced from +3 to 0 oxidation state. The students failed to appreciate that when there is a decrease in oxidation state, the substance or specie is said to have been reduced. The substance or specie that reduces is rather an oxidizing agent.

Three (1.4%) students were of the view that AI_2O_3 is the reducing agent because it is the one that is being oxidized in the reaction. But looking at the above reaction it is Al that is being oxidized. Again, 8 (3.8%) of the students wrote that Fe_2O_3 is the reducing agent because it has been oxidized to form Fe. But looking at the reaction, Fe_2O_3 rather reduces to Fe and hence, an oxidizing agent.

4.7 Misconceptions on the determination of a redox reaction

The achievement test on this aspect of redox reaction sought to find out from students the identification of a redox reaction and their reason for their answer. The misconceptions identified fell under two categories. These are correct answer with wrong explanation category as shown in Table 4.6, and wrong answer with wrong explanation category as shown in Table 4.7.

$$6\,Fe^{2+}_{(aq)} + 8HNO_{3(aq)} \text{ ---------------}\blacktriangleright 6Fe_{(aq)} + 6NO_{3(aq)} + 4H_2O + 2NO_{(g)}$$

$$HCl_{(aq)} + NaOH_{(aq)} \text{ -------------------------}\blacktriangleright NaCl_{(aq)} + H_2O_{(1)}$$

***Table 4.7*: Students' Misconceptions about a Reaction being Considered as a Redox Reaction as in the Case of**

Students' responses	**No.**	**%**
1. "a" is considered as a redox reaction because some of the elements or atoms have cations and anions	8	3.8
2. "a" is a redox reaction because it involves the balancing of ions and electrons	5	2.4
3. "a" is regarded as a redox reaction because of oxidants and reductants in the	10	4.8

	given equation		
4.	“a” is a redox reaction because $6Fe^{2+}$ is oxidized by gaining electrons and $8HNO_3$ is reduced by losing electrons	7	3.4
5.	“a” is a redox reaction because it has well balanced atoms	3	1.4
6.	“a” is a redox reaction because there has been an addition of oxygen to the reaction	25	12.0
7.	“a” is a redox reaction because it is a neutralization reaction	6	2.9
8.	“a” is regarded as a redox reaction because both side are balanced with the use of either H_2O or H^+	4	1.9
9.	Reaction “a” is a redox reaction because Fe^{2+} is oxidized from the state of +2 to +3 in Fe^{3+}	9	4.3
10.	Reaction “a” is regarded as a redox reaction because both the reactants and products have oxidation numbers	7	3.5
11.	“a” is a redox reaction because there is a loss of electrons	6	2.9
12.	“a” is regarded as a redox reaction because there is only reduction reaction	4	1.9
13.	“a” is a redox reaction because oxidation number of Fe increased from +12 to +18	4	1.9

As shown in Table 4.7, 8 (3.8%) students wrote that reaction "a" is considered as a redox reaction because some of the elements or atoms have cations and anions. It is not always true that reaction that has cations and anions are redox reactions. Five (2.4%) students felt that since the electrons and ions involved in the reaction are balanced, reaction "a" becomes a redox reaction. Any reaction could involve electrons and ions; which might necessarily not be a redox reaction. Ten (4.8%) students argued that reaction "a" is a redox reaction because of the oxidant and reductant in the given equation. The presence of oxidant and reductant does not necessarily make a reaction a redox reaction. Seven (3.4%) students suggested that reaction "a" is a redox reaction because $6Fe^{2+}$ is oxidized by gaining electrons and $8HNO_3$ is reduced by losing electrons.

Such students could not appreciate the fact that the species which give out electrons or hydrogen atom(s) is the reducing agent, and is oxidized in the process while that which receives the electron or hydrogen atom is the oxidizing agent, and is reduced in the process (Achimugu, 2019). Three (1.4%) students wrote that reaction "a" is a redox reaction because it has well balanced atoms. Well balanced atoms do not make a reaction a redox reaction.

Twenty-five (12.0%) students decided that since there has been an addition of oxygen to the reaction, "a" becomes a redox reaction. An addition of oxygen to a reaction could be any reaction like acid-base reactions. It must be noted, however, that oxygen is not necessary for all redox reactions (Schmidt, 2021). Six (2.9%) students said that reaction "a" is considered as a redox reaction because it is a neutralization reaction. Simple combination, combustion, hydrogenation, and displacement reactions are redox reactions, but most neutralization and precipitation reactions are not redox reactions.

Four (1.9%) students thought that because both sides of reaction "a" are balanced with the use of either H_2O or H^+, it was a redox reaction. The use of H_2O or H^+ indicates the medium in which the reaction is occurring and for that matter acid medium.

For oxo -anions in acid medium, hydrogen and oxygen atoms are balanced by including $H^{+}_{(aq)}$ or $H_2O_{(l)}$ or both in the equation. Nine (4.3%) students said that reaction “a” is a redox reaction because Fe^{2+} is oxidized from the state of +2 to +3 in Fe^{3+}. When there is an increase of an oxidation number from one species to another, we have an oxidation half-reaction or process. This does not only make a reaction a redox reaction. Redox reactions are those chemical reactions in which both the oxidation and reduction processes take place simultaneously (Achimugu, 2019).

Seven (3.4%) students thought that reaction “a” is regarded as a redox reaction because both the reactants and products have oxidation numbers. The students did not know that the presence of mere oxidation numbers does not make a reaction a redox reaction. Six (2.9%) students misconceived that reaction “a” is a redox reaction because there is a loss of electrons. When there is a loss of electrons, we have an oxidation process (Tóth, 2021). But for a redox reaction to take place, there must be both oxidation and reduction processes taking place simultaneously (Achimugu, 2019).

Four (1.9%) students suggested that reaction “a” is a redox reaction because there is only a reduction reaction. Only a reduction half-reaction could not be a redox reaction, but reduction half-reaction and oxidation half-reaction must take place at the same time to give a redox reaction. Also, four (1.9%) students misconceived that reaction “a” is a redox reaction because oxidation number of Fe increased from +12 to +18. These students could not appreciate the concept of oxidation numbers. It appears from the explanations given by students that they have misconceptions as to the identification of a redox reaction. It must be appreciated that, redox reactions could be identified in terms of electron, hydrogen or oxygen transfer, or in terms of change in the oxidation state of the species in the reaction (Olson, 2020).

Table 4.6 shows students' misconceptions in the wrong answer with wrong explanation category. As shown in Table 4.6, most of the students who had the answer wrong, misconceived that the simultaneous occurrence of both oxidation and reduction half-reactions makes reaction "b" a redox reaction. They lost sight of the fact that there are nothing like oxidation - reduction reactions in reaction "b". But then, reaction "b" is the reaction between an acid and a base and for that matter a neutralization reaction.

Two (1%) students argued that reaction "b" is a redox reaction because NaOH has been oxidized to NaCl. But looking at the reaction in question, NaOH which is a base is reacting with HC1; an acid to produce NaCl; a salt and H_2O. Hence, it does not involve an oxidation process.

Seven (3.4%) students said that "b" is regarded as a redox reaction because oxygen has been added to hydrogen to form water. The mere fact that oxygen has been added to specie does not make it a redox reaction (Schmidt, 2019). Three (1.4%) students suggested that because reaction "b" contains hydrogen, it is a redox reaction. A reaction that contains hydrogen is not necessarily a redox reaction. Five (2.4%) students too decided that reaction "b" is a redox reaction because HC1 reacts with NaOH to produce salt and water only. Such students lost sight of the fact that, a reaction that involves an acid and a base producing salt and water only is a neutralization reaction but not a redox reaction. Again, two (1%) students who got the item wrong said reaction "b" is a redox reaction because it contains water (H_2O) in the equation. The presence of water in any reaction does not specify the reaction.

(a) $6Fe^{2+}_{(aq)} + 8HNO_{3(aq)} \longrightarrow 6Fe^{3+}_{(aq)} + 6NO_3^{-}{}_{(aq)} + 4H_2O_{(1)} + 2NO_{(g)}$

(b) $HCI_{(aq)} + NaOH_{(aq)}$ ----------------------► $NaCl_{(aq)} + H_2O$

(Wrong Answer with Wrong Explanation)

Table 4.8: Students' Misconceptions about a Reaction Being Considered as a Redox Reaction as in the Case of

Students' responses	No.	%
"b" is a redox reaction because NaOH have been oxidized to NaCl	2	1
"b" is a redox reaction because it contains both oxidation and reduction half reactions.	5	2.4
"b" is regarded as a redox reaction because oxygen has been added to hydrogen to form water.	7	3.4
Reaction "b" is a redox reaction because it contains hydrogen.	3	1.4
"b" is a redox reaction because HC1 reacts with NaOH to produce	5	2.4
Reaction "b" is a redox reaction because it contains water (H_2O)	2	1
"b" can be regarded as a redox reaction because there is transfer	6	2.9
"b" is regarded as a redox reaction because it has both an acid and	4	1.9
"b" is a redox reaction because oxidation and reduction take place simultaneously.	8	3.8
(N =	208)	

Also, six (2.9%) students misconceived that "b" can be regarded as a redox reaction because there is a transfer of electrons. A reaction that involves a transfer of electrons is rather a redox reaction (Olson, 2020). Finally, four (1.9%) students thought that reaction "b" is a redox reaction because it has both an acid and a base. A reaction that involves an acid and a base producing salt and water only is a neutralization reaction but not a redox reaction.

4.8 Research Question Four: How do the students perform in class when they answer questions on redox reactions?

The rationale for the fourth research question was to examine students' performance in class when they answer questions bordering on redox reaction. Performance of students was measured using a self-constructed redox reaction concept achievement test. Twenty-nine items were used. Nine of the items were easy type while 20 were multiple choice type items. The total score for all the items was converted into 100 percent in order to be graded according to the standard grading system used by the West African Examination Council (WAEC). The current performance of students with regard to redox reaction concepts were described using descriptive statistics. But as to which of the descriptive statistics to use, the researcher performed the test of normality to find out whether the distribution was normal or not. Mean and standard deviation coefficients are used when the distribution is normal while median and skewness coefficients are used when the distribution is skewed (Ary, Jacobs, Razavieh & Sorensen, 2021). According to Ary et al., (2022), in a normal distribution the mean and the median are approximately the same. The skewness values must have a threshold of -0.5 to 0.5.

The skewness values of the distribution were closer to each other and were within an acceptable threshold of a normal distribution (they were within a range of (-0.263) – (-0.433). The standard deviations (see Table 4.9) were also moderate and closer to each other, indicating the non-dispersion in a widely- spread distribution. The moderateness of the standard deviations of the distribution shows that the views of the scores obtained from students were coming from a moderate homogeneous group that is, a group with similar characteristics. That means students' performance in redox reaction within the Obuasi municipality and Adansi North District is an approximation to a normal distribution.

Eleven main contents of redox reaction (See Table 4.9) were used to measure students' overall performance in redox reaction. Respective scores were assigned to the various contents with regard to the various items used in measuring students' performance on the issue. Some of the main contents of redox reaction were made up of multiple items that were used to elicit data on the issue. After scoring the test items, the scores were pooled together to form each major dimension of redox reaction. The concept of redox reaction on the other hand was measured using the 20 multiple choice items. With the help of the Statistical Product and Service Solution (SPSS) Version 19.0, the various scores were pooled together using the averages. After the pooling process, descriptive statistics such as mean and standard deviation were used to analyse the data since the distribution was normal. The results are presented in Table 4.9.

As depicted in Table 4.9, students' performance with regard to determination of oxidation numbers (Mean = 6.061, Std. Dev. = 0.815), definitions of oxidation process (Mean = 2.960, Std. Dev. = 0.961), definitions of oxidation and reduction in terms of electron transfer with examples (Mean = 2.253, Std. Dev. = 0.561) were above average.

Table 4.9: Students' Academic Performance in Redox Reactions

Dimension of redox reaction	**Mean**	**Std.Dev**	**Range of cores**
Determination of oxidation numbers	6.061	0.815	0-9
Balancing of redox reactions in acidic medium	3.304	0.872	0-6
Balancing of redox reaction in the basic medium	3.201	0.682	0-6

Definitions of oxidation process	2.960	0.961	0-3
Definitions of oxidation and reduction in terms of electron transfer with examples	2.253	0.561	0-3
Electron transfer with examples	2.253	0.561	0-3
Determination of oxidation numbers	1.517	0.472	0-3
Identification of a reducing agent	1.614	0.560	0-3
Identification of species being oxidized and reduced	2.192	0.413	0-6
Identification of a reducing agent with a reason	1.025	0.551	0-3
Identification of species being oxidized with a reason	1.216	0.713	0-3
Identification of a redox reaction with a reason	1.071	0.634	0-3
The concept of redox reaction	9.493	0.837	0-20

(N=208)

The findings show that when it comes to determination of oxidation numbers, definition of oxidation process and definition of oxidation and reduction in terms of electron transfer with examples, students within the Obuasi municipality and Adansi North District understand them as expected. With regard to students' performance regarding the balancing of redox reactions in the acidic medium (Mean = 3.304, Std. Dev. = 0.872), balancing of redox reactions in the basic medium (Mean = 3.201, Std. Dev. = 0.682), determination of oxidation numbers (Mean = 1.517, Std. Dev. = 0.472), and identification of reducing agent (Mean = 1.614, Std. Dev. = 0.560), their performance can be described as average.

However, students' performance in identification of species being oxidised and reduced (Mean = 2.192, Std. Dev. = 0.413), identification of a reducing agent with a reason (Mean = 1.025, Std. Dev. = 0.551), identification of species being oxidised with a reason (Mean = 1.216, Std. Dev. = 0.713), and identification of a redox reaction with a reason (Mean = 1.071, Std. Dev. = 0.634) were below average. In all, students' performance in the concept of redox reaction was also below average (Mean = 9.493, Std. Dev. = 0.837). This means that largely, senior high school students within the Obuasi municipality and Adansi North District performance in the concept of redox reaction are below average.

Unfortunately, despite the importance of redox reactions in nature, technological development and everyday life, both students and most teachers of chemistry within the Obuasi municipality and Adansi North District considered the concept difficult. The findings are consistent with the study reports of West African Examination Council (2003) which showed that students performed poorly in questions on redox reactions in public examinations at the senior high school level. Common areas of difficulties include the students' inability to write the correct equation for the reaction, determine which species is oxidised or reduced, determine the oxidation state of the species involved in the reaction, write and balance equations for the reduction and oxidation half reaction correctly, and balance correctly given redox equations. According to (Ekpo and Udo 2020), the poor performance of students in redox reaction is as a result of their poor mathematical background, as well as inappropriate teaching approaches used by the teachers in communicating the concept to the students. In order to better understand the problem of low performance in answering questions on redox reactions, the study formulated hypothesis to be tested for more knowledge on the issue.

H_0: There is no statistically significant difference between the performance of grade A school and grade B school students when they answer questions on redox reactions.

H_1: There is statistically significant difference between the performance of grade A school and grade B school students when they answer questions on redox reactions.

The purpose of this study hypothesis was to test the assumption that there is no statistically significant difference between the performance of school A and school B students when they answer questions on redox reaction. Fifty-three students and 42 students offering chemistry at School A and School B respectively were selected for the study. Using the redox reaction concept achievement test, data were elicited from them to compare their academic performance in redox reaction using the independent sample t-test. The results are presented in Table 4.10.

The results in Table 4.9 indicate that based on school grade, students' performance in redox reaction concepts such as determination of oxidation numbers, balancing of redox reactions in the acidic medium, balancing of redox reactions in the basic medium, and definitions of oxidation and reduction in terms of electron transfer with examples differ statistical significantly with regard to School A [(M = 7.15, SD = 0.60); (M = 3.99, SD = 0.54); (M = 3.94, SD = 0.59); (M = 2.78, SD = 0.80)] and School B [(M = 5.38, SD = 0.46); (M = 2.91, SD = 0.31); (M = 3.01, SD= 0.44); (M = 1.88, SD = 0.76)], $t(93) = -3.67$, $p < 0.01$), $t(93) = -3.51$, $p < 0.01$), $t(93) = -4.95$, $p < 0.01$), $t(93) = -3.16$, $p < 0.05$) respectively.

Table 4.10: Differences in Students Performance in Redox Reactions with regard to School A and School B

Dimensions of redox reaction	Sch	N	Mean	Std Dev.	t-value	Eta square (n^2)
Determination of oxidation	**A**	**53**	**7.15**	**0.60**	**-3.67****	**0.043**
Numbers	**B**	**42**	**5.38**	**0.46**		
Balancing of redox reaction in	**A**	**53**	**3.99**	**0.54**	**-3.51****	**0.040**
The acidic medium	**B**	**42**	**2.91**	**0.31**		
Balancing of redox reactions in	**A**	**53**	**3.94**	**0.59**	**-4.95****	**0.076**
The basic medium	**B**	**42**	**3.01**	**0.44**		
Definitions of oxidation process	**A**	**53**	**2.16**	**0.45**	**-1.60**	
	B	**42**	**2.04**	**0.35**		
Definition of oxidation and reduction in terms of electrons	**A**	**53**	**2.78**	**0.80**	**-3.16***	**0.032**
Transfer with example	**B**	**42**	**1.88**	**0.76**		
Determination of oxidation	**A**	**53**	**1.57**	**0.96**	**-1.31**	
Numbers	**B**	**42**	**1.47**	**0.82**		

Identification of a reducing	**A**	**53**	**1.53**	**0.86**	**1.41**	
Agent	**B**	**42**	**1.48**	**0.74**		
Identification of species being	**A**	**53**	**2.28**	**0.80**	**1.22**	
oxidized and reduced	**B**	**42**	**20.9**	**0.86**		
Identification of a reducing	**A**		**53**	**1.07**	**0.82**	**-1.69**
Agent with a reason	**B**	**42**	**1.01**	**0.84**		
Identification of species being	**A**	**53**	**1.03**	**0.93**	**1.34**	
Oxidized with a reason	**B**	**42**	**1.05**	**0.75**		
Identification of a redox	**A**	**53**	**1.15**	**0.67**	**1.23**	
Reaction with a reason	**B**	**42**	**0.99**	**0.59**		
The concept of redox reaction	**A**	**53**	**12.06**	**0.78**	**-3.71****	**0.044**
	B	**42**	**6.92**	**0.82**		

Where Sch = School **p<0.01; *p<0.05 (N=95)

Where N = sample size, M= mean, SD = Standard Deviation and n^2 = eta square

Based on Cohen (as cited in Cohen, Manion & Morrison, 2023) guidelines on the interpretation of the eta square, the magnitude of the differences in the mean scores were moderate for determination of oxidation numbers (eta squared = 0.043), balancing of redox reactions in the acidic medium (eta squared = 0.040) and definitions of oxidation and reduction in terms of electron transfer with examples (eta squared = 0.032) whilst for balancing of redox reactions in the basic medium (eta squared = 0.076) it was large.

The study can, therefore, conclude that only 4.3 percent of the variances in determination of oxidation numbers, 4.0 percent in balancing of redox reactions in the acidic medium, 3.2 percent in definitions of oxidation and reduction in terms of electron transfer with examples and 7.6 percent in balancing of redox reactions in the basic medium were explained by the schools.

However, with regard to the redox reaction concepts such a s definitions of oxidation process, determination of oxidation numbers, identification of a reducing agent, identification of species being oxidized and reduced, identification of a reducing agent with a reason, identification of species being oxidized with a reason, and identification of a redox reaction with a reason there were no statistically significant difference between schools 'A' and 'B' students' performance. Generally, students' performance in redox reaction among school 'A' students ($M = 12.06$, $SD = 0.78$) and school 'B' students ($M= 6.92$' $SD = 0.82$), t (93) = -3.16, $p< 0.05$), t (298) = -3.71, $p< 0.01$). The magnitude of the differences in the mean scores were moderate for students' general performance in the concept of redox reaction (eta squared = 0.044). Therefore, 4.4 percent of the variances in students' general performance in the concept of redox reaction were explained by the schools.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview

This chapter presents the summary of major findings and conclusions drawn from the study. The key findings are reported based on the objectives of the study. These are followed by the conclusions and recommendations. The last section provides suggestions for further research.

5.2 Summary

This concluding chapter presents the key findings, conclusion and recommendations with respect to the SHS students' perceived misconception and performance of the concept of redox reaction, with some suggestions made for future study. It is hoped that the findings will focus attention on critical issues for chemistry teachers, Ghana Association of Science Teachers (GAST), curriculum developers, Ghana Education Service, Ministry of Education and the West African Examination Council.

This study sought insights into SHS students' perceived misconception and performance of the concept of redox reaction in the Obuasi Municipality and Adansi North District of the Ashanti Region of Ghana. This was done by providing descriptive and explanatory information on students' perception of redox reactions concept, teachers' influence on SHS students' performance in redox reaction tasks, students' misconceptions in the concept of redox reactions as well as the performance of SHS 3 students on redox reactions.

The study also investigated whether there is a significant difference between the performances of (GES) SHS Grade A and (GES) SHS Grade B schools' students when they answer questions on redox reactions. The study specifically sought to find answers to four research questions.

A cross - sectional survey design was used for the study. The sample purposively selected for the study was two hundred and eight (208) elective science students for the 2022/ 2023 academic year drawn from all the schools that offered elective science in the Obuasi Municipality and Adansi North District of the Ashanti Region of Ghana.

Three instruments were used to collect data. The instruments were redox reactions questionnaire for students, achievement test and redox reaction focus group interview schedule. The data collected were analysed using means, frequencies, percentages and standard deviations. T-test statistic was used to find out whether there was any significant difference between the performance of (GES) SHS Grade A and (GES) Grade B schools students when they answered questions on redox reactions.

5.3 Key Findings

The following are the key findings of the study:

1. Fifty percent (50%) of the students generally perceived redox reaction concept as difficult to understand. In addition, 45.7 percent of the students indicated that redox reaction concept is not interesting to study. Majority (70.2%) of the students, however, were of the view that their chemistry teachers were their source of motivation in learning the concept of redox reaction. The teacher is seen as the immediate role model to students in the classroom. The teacher is the first and immediate person to motivate students in making learning of difficult and abstract concepts easy and interesting to learn.

2. Moreover, 40.9% SHS students indicated that learning of redox reaction concept requires learning of unrelated facts. In addition, 48.6% of the SHS 3 students perceived the concept of redox reaction as abstract.

Furthermore, 42.8% of the SHS 3 students, however, perceived that the abstract nature of the redox reaction concept and the lot of time it takes in learning it makes them nervous. In all, 55.3% SHS students perceived that it is appropriate to study redox reaction concept at the SHS level.

3. Redox reactions sub-topics that teachers normally skip are redox titration and balancing of redox reaction. According to the students, the chemistry teachers knew questions are usually not set on especially redox titration in WASSCE papers. The students said they learned the skipped contents on their own or they asked their colleagues who understood the contents to teach them. Practical activities are very crucial to the teaching and learning of redox reactions, but students are hardly engaged in practical activities relating to the learning of this concept.

4. Students' misconceptions on species being oxidized and those being reduced as in the case of:

   i. $Cr_2O_7^{2-} + CH_3CHO + H^+ \longrightarrow Cr^{3+} + CH_3COOH + H_2O$

   ii. $NO_3^- + Fe^{2+} + H^+ \longrightarrow NO_2 + Fe^{3+} + H_2O$

   a) The students do not appreciate the concept of oxidation numbers to tell whether or not that specie is being oxidized or reduced.

   b) Some students misunderstood the substance being reduced as a reducing agent and also, the substance being oxidized as an oxidizing agent.

   This misconception may be linked to students' difficulty in determining species involved in a redox reaction which are being reduced and being oxidized (Ekpo & Udo, 2005).

5.4 Students misconceptions on the identification of reducing agent in a redox reaction such as 2Al (s) + $Fe_2O_{3(s)}$ + H_2SO_3 → $Al_2O_{3\,(s)}$ + $2Fe_{(s)}$

a. It appears from the explanations given by students that they do not appreciate the concept of reducing agent. They, therefore, have problems identifying reactants as oxidizing or reducing agents (De Jong et al. 2019).

b. Some students reckoned that Fe_2O_3 is the reducing agent because Fe in the reaction has gained electrons. Gaining of electrons is reduction and for that matter an oxidizing agent but not a reducing agent (Toth, 2021).

5.5 Students' Misconceptions about a reaction being considered as a redox reaction as in the case of:

i. $6Fe^{2+}_{(aq)} + 8HNO_{3(aq)}$ ----- ►$6Fe^{3+}_{(aq)} + 6NO_3^{-}{}_{(aq)} + 4H_2O_{(1)} + 2NO_{(g)}$

ii. $HC1_{(aq)} + NaOH_{(aq)}$ --------- ►$NaCl_{(g)} + H_2O_{(i)}$

a. Some students failed to appreciate that, redox reactions could be identified in terms of electron, hydrogen or oxygen transfer, or in terms of change in the oxidation state of the species in the reaction (Olson, 2020).

b. Students decided that since there has been an addition of oxygen to the reaction, "i" becomes a redox reaction. An addition of oxygen to a reaction could be any reaction like acid -base reactions. It must be noted, however, that oxygen is not necessarily for every redox reaction (Schmidt, 2021).

c. Some students misconceived with a wrong reason that reaction "i" is a redox reaction because there is a loss of electrons. When there is a loss of electrons, we have an oxidation process (Toth, 2021). But for a redox reaction to take place, there must be both oxidation and reduction processes taking place simultaneously (Achimugu, 2019). It appears from the explanations given by students that they have misconceptions as to the identification of a redox reaction.

5. With regards to the performance of the SHS elective science students when they answer questions on redox reactions, generally the performance was below average (Mean =9.493, std. Dev. = 0.837). The areas of difficulties identified were identification of species being oxidized and reduced (Mean = 2.192, Std. Dev = 0.413), identification of a reducing agent with a reason (Mean = 1.025, Std. Dev. = 0.551), identification of species being oxidized with a reason (Mean =1.216, Std. Dev. =0.713), and identification of a redox reaction with a reason (Mean = 1.071, Std. Dev. =0.634).

   According to Ekpo and Udo (2020), the poor performance of students in redox reaction is as a result of their poor mathematical background, as well as inappropriate teaching approaches used by the teachers in communicating the concept to students. The following results were obtained.

1. Students' performance in redox reactions concepts such as determination of oxidation numbers, balancing of redox reactions in the acidic medium, balancing of redox reactions in the basic medium, and definitions of oxidation and reduction in terms of electron transfer with examples differed significantly with regard to grade 'A' school (M = 7.15, SD = 0.60); (M = 3.99, SD = 0.54); (M = 3.94, SD = 0.59); (M = 2.78, SD = 0.80), and grade 'B' school (M = 5.38, SD = 0.46); (M =2.91, SD =0.31); (M = 3.01, SD = 0.44); (M = 1.88, SD = 0.76), $t(93) = -3.67$, $P > 0.01$), $t(93) = -3.51$, $P < 0.01$), $t(93) = -4 .95$, $P < 0.01$), $t(93) = -3.16$, $P < 0.05$) respectively.
2. However, with regard to the redox reaction concepts such as definitions of oxidation process, determination of oxidation numbers, identification of a reducing agent, identification of species being oxidized and reduced, identification of a reducing agent with a reason, identification of species being oxidized with a reason, and

identification of a redox reactions with a reason there were no statistically significant difference between the grade 'A' and **'B'** students' performance.

5.6 Conclusions

The misconceptions students have with regard to the understanding of redox reactions as reported by the Chief examiner of Senior High School Chemistry have been confirmed and elucidated by the findings of this study. Students have difficulties in the identification of species being oxidized and reduced because of their inability to appreciate the concept of oxidation numbers to tell whether or not that a species is being oxidized or reduced. They misconceived the substance being reduced **as** a reducing agent and also, the substance being oxidized as an oxidizing agent.

Students also have difficulties in identifying why specie is a reducing agent, identifying species being oxidized with a reason and again the term why a reaction is considered as redox. The students think that oxygen always takes part in all redox reactions and that oxygen is a pre-requisite for a redox reaction. This could be due to the syllable "OX" in reDOX. The poor performance of students in redox reactions is as a result of their poor understanding of mathematical calculations, as well as inappropriate teaching approaches used by the teachers in communicating the concept to students.

5.7 Recommendations

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

1. Most of the chemistry students had misconceptions about redox reactions which were mostly inconsistent with scientifically accepted ones. Before instructing chemistry students on redox reactions, teachers should first give concept diagnostic test to find out students' preconceptions about redox reactions. Teaching should then proceed with enhancing techniques through discussion, to help reduce students' misconceptions of redox reactions.

2. Teachers teaching chemistry at the SHS level should improvise teaching and learning materials that contain detailed illustrations or riddles among others which will enable chemistry students have better perception of redox reactions.
3. Chemistry teachers must also make room to engage students in redox reaction practical activities which are very critical to the teaching and learning of redox reaction.
4. Chemistry teachers should use redox reaction models such as oxygen model, hydrogen model, electron model and oxidation number model to teach redox reactions. This will help in boosting students' ability to recall, remember and understand the concepts taught.

5.8 Suggestions for Further Research

The study concentrated on students' difficulties in understanding redox reaction concept by looking at their perception, misconception and performance of redox reaction tasks. The study, however, did not look at how teachers also understood this concept and how they presented it to the students. It is, therefore, recommended that a further research be conducted into it. The factors contributing to students' perceptions of redox reactions could also be investigated.

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APPENDICES

APPENDIX A

REDOX REACTION QUESTIONNAIRE FOR STUDENTS

This questionnaire is meant to obtain information for a research on the senior high schools' difficulties in understanding redox reaction, kindly complete all items in this questionnaire. All information you provide will kept confidential.

SECTION A: BACKGROUND INFORMATION

Kindly make a tick or write your response where appropriate

1. Sex: Female [ ] Male [ ]
2. Age………………………..
3. Name of the Senior High School……………………………………………………..

SECTION B: SHS 3 STUDENTS' PERCEPTION OF THE REDOX REACTION CONCEPT

Please use a tick to indicate whether you strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), or strongly Disagree (SD) with each of the statements.

Statement	Response to Statement				
	SA	A	U	D	SD
1. My chemistry teacher rushed through the redox reaction concept.					
2. My chemistry teacher devoted much of his time in teaching redox reactions.					
3. I did not like the way my chemistry teacher taught redox reaction					
4. I did not understand the redox					

reaction concept contents I was taught					
5. Redox reactions concept is boring					
6. Redox reactions concept is most difficult compared to the other chemistry concepts					
7. Redox reactions concept is difficult to learn					
8. Redox reactions concept requires the learning of too many unrelated facts					
9. I do not like redox reactions concept because it makes me nervous					
10. Redox reactions concept is easy to understand					
11. Redox reaction concept is abstract					
12. It takes a lot of time to read and understand redox reactions concept compared to other chemistry concepts					
13. My chemistry teacher did not allow us to ask questions on redox reactions concept in class					
14. My chemistry teacher told us redox					

reaction concept is difficult to study					
15. Learning redox reactions concept is time consuming					
16. I did not understand redox reactions concept because of the way my class was taught the concept					
17. I found redox reactions concept interesting					
18. My chemistry teacher did not mind whether or not the class understood the redox reactions concept.					
19. Redox reactions concept questions are difficult to answer					
20. Redox reactions concept questions demand a lot of recall of facts					
21. Redox reactions concept should not be studied in senior high schools.					

APPENDIX B

REDOX REACTION CONCEPT ACHIEVEMENT TEST

General Instructions

(a) The test consists of nine essay and 20 objective questions and you are required to answer all on your answer sheets within 60 minutes.

(b) An additional mark is awarded for correct explanation of your answer.

1. What is the oxidation state of the underlined elements in each of the following compounds?

   a) $H\underline{Cl}O_2$

   b) $K\underline{Mn}O_4$ *and*

   c) $H\underline{Br}$

2. Balance each of the following redox reactions in acidic medium;

   (a) $MnO_4^- + H^+ + I^- \rightarrow Mn^{2+} + H_2O + I_2$

   (b) $Cu_2O + NO_3^- + H^+ \rightarrow Cu^{2+} + NO + H_2O$

3. Balance each of the following redox reactions in basic medium;

   (a) $Bi^{3+} + MnO_4^- + OH^- \rightarrow BiO_3^- + MnO_2 + H_2O$

   (b) $ClO^- + CrO_2^- + OH^- \rightarrow CrO_4^{2-} + Cl^- + H_2O$

4. (a) Give three different definitions of oxidation.

   (b) Explain the following terms using electron transfer:

   i. Oxidation;

   ii. Reduction.

Give one example in each case.

5. (a) Determine the oxidation number of

   (α) Chromium in $K_2Cr_2O_7$;

   (β) Vanadium in V_2O_5

(b) Consider the reaction represented by the following equation:

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

(α) Name the reducing agent,

(β) State one other reducing agent that can be used.

6. Consider the redox reaction, which occur in acidic medium;

(a) $Cr_2O_7^{2-} + CH_3CHO + H^+ \longrightarrow Cr^{3+} + CH_3CHOOH + H_2O$

(b) $NO_3^- + Fe^{2+} + H^+ \longrightarrow NO_2 + Fe^{3+} + H_2O$;

State with reasons species which are being oxidized and those being reduced.

7. Identify with a reason the reducing agent in the reaction

$$2Al_{(s)} + Fe_2O_{3(s)}\ H_2SO_3 \longrightarrow Al_2O_{3(S)} + 2Fe_{(s)}$$

8. Consider the reaction given below:

$2Fe^{3+}_{(aq)} + S^{2-}_{(aq)} \longrightarrow 2Fe^{2+}_{(aq)} + S_{(S)}$

Which of the ions in the reaction above is oxidized? Give one reason for your answer?

9. Which of the following can be regarded as a redox reaction and why?

a) $6Fe^{2+}_{(aq)} + 8HNO_{3(aq)} \longrightarrow 6Fe^{3+}_{(aq)} + 6NO_3^-{}_{(aq)} + 4H_2O_{(l)} + 2NO_{(g)}$

b) $HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

OBJECTIVE TEST

1. Which of the statements below describes an oxidation process?

   A. the removal of oxygen from a compound

   B. the addition of hydrogen

C. the removal of electron(s) from a substance

D. the acceptance of electron(s) by a substance.

2. The reducing agent in the reaction $2Al_{(s)} + Fe_2O_{3(s)} + H_2SO_3 \rightarrow Al_2O_{3(s)} + 2Fe_{(s)}$ is … A. $Al_{(s)}$

   B. $Fe_{(s)}$

   C. $Al_2O_{3(s)}$

   D. $Fe_2O_{3(s)}$.

3. Which of the following equations does not show a redox reaction?

   A. $Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

   B. $2FeCl_{3(aq)} + H_2S_{(aq)} \longrightarrow 2FeCl_{2(aq)} + 2HCl_{(aq)} + S_{(s)}$

   C. $CuSO_4(aq) + H_2S(aq) \longrightarrow CuS(s) + H_2SO_4(aq)$

   D. $2H_2S(g) + SO_2(g) \longrightarrow 2H_2O(1) + 3S(s)$.

4. The ionic equation for the reaction between potassium tetraoxomanganate (VII) and sodium ethanedioate in acidic medium is $2MnO^-_4 + 5C_2O^{2-}_4 + 16H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 10CO_2$; which of the species is the oxidizing agent?

   A. $C_2O_2{}^-{}_4$

   B. H^+

   C. Mn^{2+}

   D. MnO^-_4.

5. In which of the following reactions does oxidation occur? I. $Mg^{2+} + 2e^- \longrightarrow Mg$

II. $Na - e^- \longrightarrow Na^+$ III. $H_3O^+ + OH^- \longrightarrow 2H_2O$ IV. $CuSO_4 + Zn \longrightarrow ZnSO_4$ $+ Cu$

A. I and II only

B. II and IV only

C. II, III and IV only

D. I, II and III only.

6. Which of the following reactions is a redox reaction?

A. $Cu_{(x)} + 4HNO_{3(aq)} \longrightarrow Cu(NO_3) + 2NO_{2(g)} + 2H_2O_{(l)}$

B. $H_2S0_{4(aq)} + CuO_{(s)} \longrightarrow CuSO_{4(aq)} + HO_{(l)}$

C. $H_2SO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + 2\ H_2O_{(l)}$

D. $FeCl_{3(aq)} + 3NaOH_{(aq)} \longrightarrow Fe(OH)_{3(aq)} + 3NaCl_{(aq)}$.

7. Which of the following species in the reaction below is an electron donor?

$Cr_2O_7{}^{2-}{}_{(aq)} + 5H_3O^+{}_{(aq)} + 3H_2SO_{3(aq)} \longrightarrow 2Cr^{3+}{}_{(aq)} + 9H_2O_{(l)} + 3HSO^-{}_{4(aq)}$

A. $Cr_2O_7{}^{2-}{}_{(aq)}$

B. $H_3O^+{}_{(aq)}$

C. $H_2SO_{3(aq)}$

D. $Cr^{3+}{}_{(aq)}$.

8. A redox equation is said to be balanced if …

A. protons are added to the oxidant

B. elections are added to the reductant

C. charges and atoms are balanced

D. molecules and neutral atoms are balanced.

9. Which of the following compounds has reducing properties?

A. CO

B. CO_2

C. $K_2Cr_2O_7$

D. $KMnO_4$.

10. Select from the following reactions the ones in which both oxidation and reduction take place. I. $2KOH + H_2SO_4 \longrightarrow K_2SO_4 + 2H_2O$ II. $2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + 2NaI$ III. $Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$ IV. $Cr_2O_7^{2-} + 2Cl^- + 14H^+ \longrightarrow 2Cr^{3+} + Cl_2 + 7H_2O$

A. I and II only

B. II and III only

C. II and IV only

D. I, II, and IV only.

11. Consider the following redox reaction $A_{(s)} + B^{2+}_{(aq)} \longrightarrow A^{2+}_{(aq)} + B_{(s)}$. The half equation for the reduction reaction is ……….

A. $B^{2+}_{(aq)} \longrightarrow B_{(s)} + 2e^-$

B. $A_{(s)} \longrightarrow A^{2+}_{(aq)} + 2e^-$

C. $B^{2+}_{(aq)} + 2e- \longrightarrow B_{(s)}$

D. $A_{(s)} + 2e^- \longrightarrow A^{2+}_{(aq)}$.

12. Consider the following redox reaction. $3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$. Which of the following statements about the reaction is correct?

A. Copper is oxidized and hydrogen is reduced

B. Copper is reduced and nitrogen is oxidized

C. Copper is reduced and hydrogen is oxidized

D. Copper is oxidized and nitrogen is reduced.

13. In which of the following reactions is sulphur (IV) oxide acting as an oxidizing agent? A. $Cl_2 + SO_2 + 2H_2O \longrightarrow 2HCl + H_2SO_4$

B. $2KMnO_4 + 5SO_2 + H_2O \longrightarrow K_2SO_4 + 2H_2SO_4 + 2MnSO_4$

C. $2FeCl_3 + SO_2 + 2H_2O \longrightarrow 2FeCl_2 + 2HCl + H_2SO_4$

D. $2H_2S + SO_2 \longrightarrow 2H_2O + 3S$.

14. Potassium is a stronger reducing agent than sodium because potassium

A. has a higher atomic number

B. has higher electron affinity

C. donates electron more readily

D. has greater atomic radius.

15. Which of the following substances can act as both an oxidizing and reducing agent?

A. tertraoxosulphate(VI) acid

B. Sulphur (IV) Oxide

C. Hydrogen

D. Ammonia.

16. The oxidation state of manganese in $KMnO_4$ is…….

A. 0

B. +4

C. +5

D. +7.

17. An element N which readily undergoes the reaction $N \longrightarrow N^+ + e^-$ is

A. an electron acceptor

B. a reducing agent

C. a proton acceptor

D. an oxidizing agent.

18. The oxidation number of iron in the complex $[Fe(CN)_6]^{3-}$ is…

A. +1

B. +2

C. +3

D. -3.

19. Consider the following redox reaction $3Mg + xCr^{3+} \rightarrow 3Mg^{2+} + xCr$. What is the value of x?

A. 2

B. 3

C. 4

D. 6.

20. Which of the following processes is reduction?

A. Gain of electrons

B. Gain of oxygen

C. Loss of electrons

D. Loss of hydrogen.

APPENDIX C

REDOX REACTION FOCUS GROUP INTERVIEW SCHEDULE FOR STUDENTS

This focus group interview schedule is meant to obtain information for a research on teachers' contribution to students' abysmal performance in Redox Reactions. Discuss and provide responses to the following questions.

1. a. Were you taught redox reaction?

   b. When were you taught redox reaction?

   c. Did the time you were taught redox reaction affect your performance in redox reaction exams?

2. a. Did your teacher give you contents as reading assignments without teaching them?

   b. How often did this occur?

3. a. Did your chemistry teacher skip some redox reaction contents?

   b. Which contents did he/she skip?

   c. Why did he/she skip them?

   d. How did you learn these contents?

4. a. Which of the redox reaction contents did your teacher teach to your understanding and which did you not understand at all?

   b. Why did you not understand these contents?

   c. Which redox reaction contents did your teacher not teach at all?

5. The senior high school redox reaction is difficult and should have been studied at the university. What do you think about this suggestion?

6. a. Were you engaged in practical activities as part of redox reaction lesson\\\s?

   b. What were the practical activities for?

APPENDIX D

RESULTS ON TEST FOR RELIABILITY

RELIABILITY STATISTICS PERFORMANCE TEST

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.802	.754	29

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
A2	17.04	164.043	.566	.	.795
A3	17.30	172.312	-.140	.	.805
A4	17.00	169.091	.154	.	.802
A5	17.13	168.028	.267	.	.800
A6	17.09	166.356	.392	.	.798
A7	17.22	169.996	.118	.	.802
A8	16.70	165.312	.480	.	.796
A9	17.35	172.510	-.222	.	.805
A10	17.00	171.364	-.021	.	.805
A11	17.04	170.407	.055	.	.804
A12	17.00	169.818	.098	.	.803
A13	17.22	168.178	.300	.	.800
A14	16.96	165.043	.464	.	.796

A15	17.17	168.332	.259	.	.800
A16	16.83	167.605	.265	.	.800
A17	17.13	170.755	.033	.	.804
A18	17.00	172.273	-.090	.	.806
A19	16.91	174.992	-.290	.	.810
A20	17.00	167.909	.246	.	.800
A1	17.09	169.447	.137	.	.802
B1	14.74	120.747	.710	.	.771
B2	16.74	150.565	.505	.	.787
B3	17.30	168.312	.264	.	.800
B4	14.70	121.221	.545	.	.799
B5	15.74	125.656	.780	.	.762
B6	16.52	145.443	.603	.	.780
B7	16.96	152.043	.604	.	.784
B8	16.70	144.312	.728	.	.774
B9	16.39	152.704	.439	.	.790

Reliability

Reliability Statistics

Cronbach's Alpha	N of Items
.760	22

	Cronbach's Alpha if Item Deleted
My chemistry teacher rushed through the redox reaction concept	.755
My chemistry teacher devoted much of his time in teaching redox reaction concept	.764
I did not like the way my chemistry teacher taught redox reaction concept	.769
I did not understand the redox reaction concept contents i was taught	.761
Redox reaction concept is boring	.746
Redox reaction concept is most difficult compared to other chemistry concepts	.738
Redox reaction concept is difficult to learn	.735
Redox reaction concept requires the learning of too many unrelated facts	.741
I do not like redox reaction concept because it makes me nervous	.741
Redox reaction concept is easy to understand	.778
Redox reaction concept is abstract	.769
It takes a lot of time to read and understand redox reaction concept as compared to other chemistry concepts	.742

My chemistry teacher did not allow us to ask questions in redox reaction concept class	.747
My chemistry teacher told us redox reaction concept is difficult to study	.749
Learning redox reaction concept is time consuming	.754
I did not understand the redox reaction concept because of the way my class was taught the concept	.748
I found redox reaction concept interesting	.774
My chemistry teacher did not mind whether or not the class understood the redox reaction concept	.758
Redox reaction concept questions are difficult to answer	.741
redox reaction concept questions demand a lot of recall of facts	.729
Redox reaction concept should not be studied in senior high schools	.747

Item-Total Statistics