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SENIOR HIGH SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDING OF CHEMICAL REACTIONS AND EQUATIONS OF CARBON COMPOUNDS

DAKORA EDMOND

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BY

DAKORA EDMOND

Thesis submitted to the Department of Science Education, Faculty of Science and Technology Education, College of Education Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Science Education.

APRIL 2023

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis 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 Signature……………….………….. Date……………………

Name: …………………………………………………………………………

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature ……………………… Date …………..………

Name: …………………………………………………………………………

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ABSTRACT

The study investigated Senior High School students' conceptual understanding of chemical reactions and equations of carbon compounds. The explanatory sequential mixed methods design was used to achieve the purpose of the study. Two-tier achievement test items and an interview were used to collect data from 320 final-year students through a simple random sampling technique. Descriptive statistics specifically, frequencies and percentages were used to analyse the quantitative data gathered and the interview data, that further explained the quantitative data, were analysed thematically. The study revealed that the conceptual understanding of students according to Structure of Observed Learning Outcome (SOLO) Taxonomy on hydrogenation, halogenation, oxidation and hydration reactions and equations is at the unistructural level, of which students scored one aspect of the answer correct. The understanding level of students in esterification reaction was multi-structural, indicating that the students scored partly both tiers correctly. In addition, students have no conceptual understanding (prestructrual level) on equations involving cyclo-compounds and/or writing the chemical formula in equation as they either scored both tiers incorrect or left the question unanswered. The study also identified reasons accounting for the students' conceptual understanding of chemical reactions and equations of carbon compounds to be teachers, home, examination reasons and Ghana Education Service rules. The study recommends that teachers should use computer assisted animations in teaching to help students imprint in themselves mental pictures of the reactions and equations. Assessment and evaluation of students' achievement in chemical concepts should be done to create conceptual structures for purposeful teaching and learning. Teachers should teach to cover the content as stipulated in the curriculum.

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KEY WORDS

Conceptual understanding

Chemical reactions

Chemical equations

Carbon compounds

Structure of Observed Learning Outcome Taxonomy

Conceptual understanding Levels

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DEDICATION

To my wife and children

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CHAPTER ONE

INTRODUCTION

Overview

This chapter discusses the background to the study, the statement of the problem, the purpose of the study, and the research questions. The rest are the significance of the study, and the delimitation of the study. The chapter will help the researcher to identify the problem and the need to investigate the problem.

Background to the Study

Over the years, literature has consistently identified carbon compounds (organic chemistry) as a difficult area for learners (Childs & Sheehan, 2009; O'Dwyer & Childs, 2017; Sirhan, 2007). O'dwyer and Childs, (2015) indicated that learners have multifaceted difficulties in learning organic chemistry concepts. According to Johnstone (as cited in O'Dwyer & Childs, 2017), the carbon compound(s) are established as a difficult area in chemistry as far back as 1971. This is a serious concern because many scientific disciplines and careers such as medical medicine, veterinary medicine, dentistry, chemical engineering, pharmacology and many more, require the knowledge and application of chemical reactions of carbon compounds in their work for the development of mankind (Helmenstine, 2020; Oppong, Addae-Mansah, & Asunka, 2008). For instance, the concept of chemical reaction of carbon compounds plays a part in the development of common household chemicals, foods, plastics, drugs, and fuels, which are mostly chemicals used for daily life. Thus, human beings depend on carbon compounds for survival in terms of the food we eat, the fertilizers we apply to crops, and the clothes we wear, among others. This indicates that if the concept of the chemical

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reaction and equations are not understood, chemists who require knowledge of chemical reactions and equations will find it difficult to identify and quantify the reactants and products of reacting species. Likewise, they will find it difficult to describe the properties and physical state of reactants and products during chemical reactions.

A chemical reaction is a process that involves converting a substance into a new group of compounds. In chemical reactions, atoms are neither re-created nor destroyed; therefore, equivalent species are required to react. Equations are used as tools to represent chemical reactions; it must be understood that each symbol represents a definite weight of an element. The amount of new substances produced in an equation is conveyed by their coefficients (Bilek, Nodzynska, Kopek-Putala & Zimak-Piekarczyk, 2018). Understanding which bonds are broken and formed and the order of events leads to an understanding of chemical reactivity (Rius -Alonso & Gonzalez Quezada, 2015). In the view of Ahiakwo (2012), the organic reaction may be simple and straightforward, but how do you prove to the students the existence of free radicals and the formation of chemical bonds and products? In a study conducted, Bhattacharyya and Bodner (2005) established that students can produce correct answer(s) to organic reactions without having an understanding of the chemical concepts behind their, answers. This is in line with Ahiakwo's (2012) opinion that students are interested in passing related examinations without a meaningful understanding of the chemical concept. The chemical reactions and equations are used to depict the product during a chemical reaction.

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To overcome the concept of carbon compounds as a difficult subject, its teaching and learning have been represented as submicroscopic (chemical particles that are invisible to the naked eye), macroscopic (tangible and visible phenomena) and symbolic/representational (symbols, equations, graph and characters used to represent phenomena within the macroscopic and submicroscopic domains) levels for easy understanding (Talanquer, 2011; Johnstone, 2006). Learners therefore need to relate the macroscopic, submicroscopic and symbolic levels in chemistry to overcome the difficulties (Odwyer & Childs, 2015). In the view of Talanquer, (2011) when the learners can experience, describe, observe, analyse and use symbols and equations to communicate concepts of chemistry, it enhances the conceptual understanding of the learner. Sanchez (2017), suggested that the Integration of the Macro-Micro-Symbolic approach in learning chemistry, and for that matter carbon chemistry, enables students to use their senses in explaining a chemical phenomenon, support qualitative descriptions of the phenomenon at the atomic structural scale, represent it as law equations, and solve problems related to it. Sanchez therefore recommended the use of the macro-micro-symbolic approach to teach organic and biological chemistry to enhance conceptual understanding. However, Hanson (2016; 2014) identified students' inability to understand chemistry concepts and how to connect among the three representational levels of the concepts as the main limiting factor in their study of chemistry. Popava and Bretz (2018) identified that students have a limited understanding of the symbolic representations of the levels of substitution and elimination reactions of carbon compounds. Popova and Bretz (2018) therefore suggest that students should be helped to recognize how

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symbolic/representation domains communicate information about the submicroscopic and macroscopic domains. Popova and Bretz's suggestion of how to communicate symbolic/representation can be achieved through this current study, which is aimed at establishing how students understand the concept of chemical reactions and equations of carbon compounds.

Literature, however, indicates that these carbon compounds are numerous with different rules governing their chemical and physical properties (Wilbert, 2015) which must be properly understood. Also, it equally has a language that the learners and educators must understand to be able to communicate and apply (Dula, 2018). The literature further revealed that learners found it difficult to understand these properties and language and their usage in solving daily life problems (Baah & Ampiah, 2012; O'Dwyer & Childs, 2017; Sirhan, 2007). As a result, Dula (2018) recommended the need to learn carbon compounds just like learning a spoken language. One of the languages that need to be understood in the concept of carbon compounds is chemical reaction and equation.

Clayden, Greeves, Warren and Wothers (2001) also noted that the ability to understand the concept of carbon compounds depends on the chemical language and the description of how the reactions occur. This makes it difficult for learners to learn these chemical equations and reactions by rote memorization (Graham, Solomons & Fryhle, 2008). That means it is when the student understands the concept that they will be able to understand what is happening in the natural and manufacturing world. In a similar view, Sirhan (2007) indicated that students have problems with conceptual understanding of carbon compounds due to the relationships that exist between information

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load, conceptual understanding and perceived difficulty. For instance, according to Sirhan's findings, when the information load decreases for students, perceived difficulty also decreases and conceptual understanding increases and vice versa.

Many studies in other parts of the world pointed to similar findings that students have difficulty understanding carbon compounds. In Ireland, it has been established through a study that the concept of carbon compounds, their reaction mechanism and equations are difficult to understand by students (O'Dwyer & Chills, 2017). Similar findings in China revealed that the complex species and functional groups in carbon compounds make learning difficult for students (Wang, 2016). In line with these, Newell (2012) indicated that the reactions that organic compounds undergo are linked to their structures and their functional groups, which makes it seem difficult for students. This suggests that teachers should teach using strategies and techniques that will enable learners to grasp the concepts of this chemical reaction and equations**.** This will help dismiss the idea that what is being taught will affect how it is learned, stored, retrieved, and interlinked with the old knowledge (Wolf, 2018). Johnstone cited in Sanchez (2017) explained that one of the sources of the difficulty of organic chemistry is the method in which it is taught. Hence, the current study will propose an appropriate method for teaching these chemical reactions and equations of carbon compounds.

In addition, Rice (2016) has identified difficulties experienced by students studying organic chemistry in understanding representations used in organic chemistry, understanding structures, understanding structure-property

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relations, identifying organic reactions, and predicting organic mechanisms. Rice (2016) argued that organic chemistry is considered difficult because of the misunderstandings and misconceptions related to the reactivity of compounds due to bonding and electron density. The misconception, and or misunderstanding of the concepts of carbon compounds is attributed to the perception of students (Donkor, 2017).

Other intrinsic and extrinsic factors militating against students in understanding chemical reactions and equations have been identified as abstract and condensed formulations of these equations which makes the learner unable to predict and explain unknown reactions (Hanson, 2017). Lack of confidence on the part of students (Dula, 2018), perception of the students and teachers (O'dwyer & Childs, 2017), and pedagogical problems (Flynn & Ogilvie, 2015) and content overload of carbon compounds have also been identified as some of the factors influencing students' conceptual challenges. If the student's conceptual understanding is not looked into and the student is made aware of their meta-cognition, they will resort to more rote memorisation and the content being learned will have no meaning to the learner (Grove & Bretz, 2012). These factors therefore need to be worked to balance the teaching and learning of the concept of chemical reactions and equations of carbon compounds.

Studies conducted established that students have difficulties in writing structural formulae from International Union of Pure and Applied Chemistry (IUPAC) names of organic compounds (Adu-Gyamfi, Ampiah & Appiah, 2013), and IUPAC nomenclature of organic compounds (Adu-Gyamfi, Ampiah & Appiah, 2017). The students' low achievement is not

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limited to one particular class of organic compounds but across most of the classes; alkanes, alkenes, alkynes, alkanols, alkanoic acids and alkyl alkanoates (Adu-Gyamfi, Ampiah & Appiah, 2017). The problem is therefore attributed to the inability of the students to identify the correct number of carbon atoms in the parent chain and to identify a substituent or functional group. Even though these studies are conducted, there is, therefore, the need to extend the study to an aspect of the carbon compounds that seeks to explain which bonds are broken and formed, and the order of events that lead towards the formation of new products during chemical reaction and the right equation thereof (Rius -Alonso & Gonzalez Quezada, 2015). This can be done through the conceptual understanding of chemical reactions and equations of carbon compounds.

In a similar view Donkor, (2017), alleges that in addition to functional group chemistry, benzenes, natural and synthetic polymers, petroleum, and alkanoic acids derivatives, the chemical reaction is one of the components of organic chemistry that is usually skipped by chemistry educators when teaching in the Senior High School. According to Donkor, chemistry teachers skip topics, especially chemical reactions, because it is considered difficult to teach or they consider it not important in the chemistry syllabus. The types of chemical reactions in carbon compounds students need to understand are substitution reactions, addition reactions, elimination reactions and rearrangement reactions. There is a need for a study to be conducted to ascertain the extent to which students understand the concept of chemical reactions and how the reactions are represented in an equation.

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Regarding chemical equations, Baah and Ampiah (2012) revealed that students have problems predicting the correct products of reactions. The study further recommended that the students be taught combustion reaction, which is a type of chemical reaction in carbon compounds. Meanwhile, the Ministry of Education (M.OE) (2010) general objective for chemistry educators and students is: (1) to learn the chemical reactions of carbon compounds and (2) also apply the chemical principles learned to explain observed daily life experiences. The syllabus further instructs teachers to use discussion methods in teaching concepts but, if the student does not understand the concept of the chemical reaction and equations of carbon compounds, it will be difficult for him/her to apply them in solving daily life problems. In effect, students will try to memorise the concept and bring it out in an examination setting without understanding it (Krajcik, 2009). Students can produce correct answers without an understanding of the concepts on which their solutions are based.

According to Hanson (2017), teachers and students are aware of the enormous benefits of organic chemistry to mankind and therefore its teaching and learning have been taken seriously at our Senior High School level. However, the academic performance of the students in general is very poor. Hanson therefore blames the poor performance of students on the following factors: low retention capabilities, low motivation, low achievement, inappropriate social groups in schools, and parental issues and the pedagogical content knowledge of teachers and how it influences the attitudes of students towards chemistry. The study of Hanson, (2017) therefore suggests an in-depth study be conducted to enhance the conceptual understanding of the

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students in organic chemistry, of which chemical reactions and equations are no exception.

Again, a study conducted by Salame, Casino and Hodges (2020) indicated that in synthesizing organic compounds, students have multistep difficulties which comprises challenges in eliciting all requirements for chemical reactions, the content and topics in organic chemistry, conceptual understanding of some topics (mechanism and problem-solving competency). Salame, Casino and Hodges therefore opined that improvement of conceptual understanding of the structure, the functions, the reactions, and the mechanisms, and thus establishing connection between these key concepts can enhance problem-solving and performance in organic chemistry synthesis. This is of concern to synthetic organic chemistry because Nicolaou (2014) lamented that the prowess and proficiency of organic synthetic chemistry are profoundly inadequate and therefore wondered about the progress and prospect of it in the future.

If students do not have a strong foundational knowledge of organic chemistry concepts, they will not be able to understand, predict and classify reactions and mechanisms.

There is, therefore, the need to investigate how Senior High School students understand the concept of chemical reactions and equations. This study therefore investigated Senior High School Students' conceptual understanding of chemical reactions and equations of carbon compounds

Statement of the Problem

Though human beings depend on organic compounds and their reactions for survival over thousands of years (Graham, Solomons, & Fryhle,

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2008), relevant literature revealed that students have difficulty understanding these carbon compounds (Childs & Sheehan, 2009; O'Dwyer & Childs, 2017; Sirhan, 2007). In line with this, Sibomana, Karegeya and Sentongo (2021), and Salame, Patela and Suleman (2019) observed that organic chemistry is considered to be conceptually a challenging field that contains similar reaction mechanisms difficult to be analysed and understood. The difficulty that students have in understanding carbon compounds appears to be a global phenomenon because it has been observed by several researchers worldwide. For instance, in the United States of America, a study conducted by Salame, Casino and Hodges, (2021) on the challenges that students face in learning organic chemistry synthesis revealed that students learn organic reactions by memorization and rote learning of the concept, which affects their problem-solving skills. The results also showed that students find it difficult to apply the chemical concept to solve daily life problems. Salame, Casino and Hodges therefore, suggested that further studies should be conducted to enhance students' conceptual understanding and nurture their problem-solving comprehension in organic reaction. In a similar study, Nedungadi and Brown (2020) explored students' thinking and thought processes in organic chemistry in New York and established that they have difficulty conceptualizing the reaction process. Nedungadi and Brown therefore concluded that students may find it difficult to use chemical thinking to solve higher-order problems if they struggle with basic chemical concepts. The researchers therefore recommended the development of a concept inventory to assess the students' alternate conception of the reactions and mechanisms of organic compounds. Another study conducted by Popova and Bretz (2018) indicated that students

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have little knowledge of the symbolic representation of organic chemistry reactions. The results revealed that students write organic reaction equations without understanding how to predict and explain the coherence formation of the product. Popova therefore proposed the need for future research to explore and assess students' understanding of the coherence formation of the product of organic compounds during reaction.

In Brazil, Santos and Arroio, (2016) revealed from a study that students find it difficult to relate the macroscopic, microscopic and symbolic levels of thinking in chemistry. They therefore recommended a study to be conducted at all representational levels of thinking in the organic chemistry concept, of which chemical reactions and equations form the basis of the symbolic level. The current study addressed this research need. In Ireland, a study by O'Dwyer and Childs (2017) revealed that students find it difficult to learn and understand carbon compounds. The findings indicated that one of the reasons why it is being considered difficult is attributed to a multitude of complex factors, which include the chemical concept. O'Dwyer and Childs therefore recommended a study to be conducted to ascertain how students understand the chemical concept of carbon compounds. In China, a study conducted by Zhou, Wang, and Zheng, (2015) indicated that students have learning difficulties of esterification reaction which they attribute to poor knowledge transfer ability and poor understanding of the nature of the organic reaction. Zhou, Wang, and Zheng, therefore, recommended to teachers to concentrate on students meaningful learning to build their cognitive structure and conceptual understanding. This study aimed to find out the conceptual

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understanding of students in some aspects of reactions and equations of carbon compounds.

In the African continent, studies conducted by researchers have revealed similar results. For instance, in Zimbabwe, Shadreck and Enunuwe (2017) identified in an investigation that learners lack conceptual understanding of basic concepts of deducing limiting reagents in chemical equations. Shadreck and Enunuwe, therefore, recommended a study to be conducted to analyse and understand students' difficulties if they are to assist the learners in becoming confident and efficient problem solvers using chemical reactions and equations. Also, Sibomana, Karegeya and Sentongo, (2021) after reviewing the literature on students' conceptual understanding of organic chemistry and classroom implications from the Rwandan perspectives, indicated that organic chemistry is considered to be a conceptually challenging field that contains similar reaction mechanisms and difficult to be separated and understood. Sibomana, Karegeya and Sentongo, therefore, considered the nature of organic reactions and equations to be a leading factor in students' low academic achievement, poor retention, and negative attitude towards the subject. There is a need for a study to be conducted to ascertain how well students understood the concept of organic reactions and equations, especially from the Ghanaian perspective.

In the Ghanaian context, studies conducted on student's understanding of IUPAC nomenclature of carbon compounds (Adu-Gyamfi, Ampiah, & Appiah, 2013), writing of the structural formulae of the organic compounds (Adu-Gyamfi, 2011; Adu-Gyamfi, Ampiah, & Appiah, 2012; Sarkodie & Adu-Gyamfi, 2015), and naming and writing the structural formulae of

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organic compounds (Adu-Gyamfi, Ampiah & Appiah, 2017) have respectively concluded that students have difficulty in writing the structural formulae, providing the correct IUPAC nomenclature and identifying the carbon atoms in the carbon chain. About these conclusions, Adu-Gyamfi, Ampiah and Appiah (2012), and Sarkodie and Adu-Gyamfi (2015) recommended the need for further studies to be conducted in chemical concepts of organic compounds. A similar study conducted by Donkor (2017) in Ghana revealed that the chemical reactions of organic compounds are usually skipped by chemistry educators during teaching and learning in Senior High School. To validate the findings of the study, Donkor (2017) suggested the need for a similar study to be conducted at the SHS level to ascertain the conceptual understanding of students on the chemical reactions of carbon compounds. Consistent with this, Hanson (2017) also observed that students find it difficult to predict and explain chemical reactions. Hanson recommended a study on the microchemistry activities to bring chemistry close to the learners to appreciate, observe and understand chemical reactions in everyday life. The current study, therefore, responded to this research need.

Similarly, a study Adu-Gyamfi and Anim-Eduful, (2022) identified that students struggle to learn and understand organic chemistry, (Anim-Eduful and Adu-Gyamfi (2022) revealed that students face factual and alternative conceptual challenges in organic qualitative analysis, (Adu-Gyamfi, & Anim-Eduful, 2021) equally identified teachers demonstrating conceptual difficulties in a concept they teach to students. Anim-Eduful and Adu-Gyamfi (2022) suggested that students' alternative conceptions stem from a lack of understanding rather than a lack of knowledge of Organic qualitative

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analysis concepts. Anim-Eduful and Adu-Gymfi (2023) conclusively established that students' alternative conceptions result from both a lack of understanding and knowledge of the concepts. Anim-Eduful and Adu-Gyamfi further observed that students perform better in declarative learning ("what is") than in explicative learning ("why"). The study did not assess students' conceptual understanding levels. The study attributed these challenges to inadequate teaching resources and instructional strategies employed in the teaching and learning processes. According to Anim-Eduful and Adu-Gyamfi (2022), a student's conceptual understanding of a concept is not complete until they can apply it appropriately within a specific context and discipline. There was a need for a study to contribute to the existing literature by analyzing students' responses to what and why questions to investigate their levels of understanding and the reasons underlying their conceptual challenges.

Apart from the aforementioned issues, the West African Examination Council (WAEC) in its Chief Examiner's report indicated that students have inadequate knowledge of chemical concepts (cracking and substitution reactions) of organic compounds (WAEC, 2021); problems interpreting and applying the equations in solving related problems (WAEC, 2018); and problems in organic reactions and equations (2013). These problems could be a result of inadequate conceptual understanding on the part of the students. It was, therefore, likely that these global issues also existed in Ghana, especially among the SHS students. There was a need for a study to be carried out to ascertain the conceptual understanding of the SHS students in the chemical reactions and equations of carbon compounds. This was because a critical review of the extant literature suggested that there was no study in the

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Ghanaian context that investigated the conceptual understanding of chemical reactions and equations of carbon compounds. Also, it appeared no study investigated the reasons that could account for the SHS students' poor conceptual understanding of the chemical reactions and equations of carbon compounds. This study, therefore, investigated the extent to which Senior High School students understood the concept of chemical reactions and equations of carbon compounds in the Upper West Region using the explanatory sequential mixed methods design.

Purpose of the Study

The purpose of this study is to investigate Senior High School students' conceptual understanding of chemical reactions and equations of carbon compounds. It identified the reasons accounting for students' conceptual understanding of chemical reactions and equations of carbon compounds.

Research Questions

Considering the purpose, the study will answer the following questions:

1. What are Senior High School students' conceptual understanding levels on chemical reactions and equations of carbon compounds?
2. What reasons account for students' conceptual understanding of chemical reactions and equations of carbon compounds?

Significance of the Study

The study seeks to investigate Senior High School students' conceptual understanding of chemical reactions and equations of carbon compounds. The findings of this study will benefit society considering the role synthetic chemistry, using chemical reactions and equations, plays, for the good of

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every individual. It will help educators to understand the perception of students concerning chemical concepts of carbon compounds; to help demystify the misconception and improve their performance.

The outcome of the study may also serve as a resource material for future researchers who might have an interest in going into a similar area of study. It will also help to uncover critical areas in the chemistry classroom that many researchers have not been able to explore. The findings and recommendations may prompt school administrators and policymakers on the need to supply the necessary logistics that will help in curriculum implementation.

The findings of the study will also guide teachers in adopting the appropriate teaching methods that will improve students' understanding of these chemical reactions and equations of carbon compounds.

Delimitation

Though chemical reactions and equations occur in all topics of chemistry, this study was delimited to only the chemical reactions and equations of carbon compounds. Also, the study will be carried out in only 12 Senior High Schools in the Region. The study was delimited to the chemical reactions and equations of carbon compounds in Alkanes, Alkene, Alkynes, Alkanols and alkanoic acids. The study is restricted to reactions and equations involving: hydrogenation, halogenation, unsaturated hydrocarbons and hydrogen halide, oxidation, hydration/hydrolysis and esterification.

Limitations

The study also encountered a deficit in the number of schools covered as a result of lack of cooperation from some Heads of the institutions; and

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teachers' inability to complete the topic under which the study is conducted. The reduction in the number of Senior High Schools affected the research plan and therefore decreased the generalization of the findings. Also, the students' responses during the interview were less verifiable and therefore, could affect the validity of the data obtained from the respondents.

Definition of Terms

Chemical reaction: A process where reactants are converted to one or more different products.

Chemical equation: Using symbols and formulas to represent chemical reactions

Conceptual understanding*:* Deep and integrated development of procedural skills of chemical reactions and equations.

Structure of Observed Learning Outcome (SOLO) Taxonomy: A Taxonomy that evaluates quality of learning based on levels of understanding

Pre-structural: scored both concepts of chemical reactions and equations wrong

Unistructural: Understand one aspect of chemical reactions and equations.

Multistructural: Understand several aspects of chemical reactions and equations but unable to relate them.

Relational: Understanding and integrating the knowledge of the concept of the reactions and equations of the

Extended abstract: Understanding, generalizing, hypothesizing, and theorizing the concept of the chemical reactions and equations of the carbon compounds.

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Organisation of the Study

The research is divided into five chapters. The first chapter had the study's introduction, which included the background, statement of the problem, the purpose of the study, research questions, significance, delimitation and limitation, as well as the study's organisation. The study's theoretical framework, as well as the research conducted by other writers and experts on the issue, was evaluated in Chapter Two. Chapter three focused on the research methods such as research design, population, sample and sampling procedures, data collection procedures and data processing and analysis. Chapter four presented the results and discussion of the findings of the study while chapter five focused on the summary, conclusions and recommendations of the study

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CHAPTER TWO

LITERATURE REVIEW

Overview

This chapter presents related literature relevant to the concept under study. The theoretical framework was categorized into the adapted chemical triplets, the adapted Concorde diagram and the constructivism theory. The Constructivism Theory was aligned with the Novak Theory of meaningful learning. Some sub-headings dealt with in this chapter include students' conceptual understanding of chemical reactions and equations of carbon compounds and chemical reactions and equations of carbon compounds and their relevance in society. Other subheadings were methods of teaching chemical reactions; perception of students on chemical reaction of carbon compounds and factors accounting for the difficulties of Senior High School students' conceptual understanding of chemical reactions and equations of carbon compounds.

Theoretical Framework

The Chemical Triplet

The model of thinking in chemistry was proposed to be in levels such as the macroscopic, the sub-microscopic, and the symbolic (Johnstone, 2000, 1993, 1991, 1982). These levels are represented in triangular modes with submicroscopic and symbolic modes being at the base of the triangle, and the macroscopic mode at the apex (Johnstone, 1991; Johnstone 1982; Santos & Arroio, 2016;). Santos and Arroio therefore described it as a chemical triplet. The submicroscopic (chemical particles that are invisible to the naked eye), macroscopic (tangible and visible phenomena), and symbolic (symbols and

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characters used to represent phenomena within the macroscopic and submicroscopic domains) are the distinct domains that need to be understood and linked to have the conceptual skills of how a chemical bond is formed (Hanson, 2017)

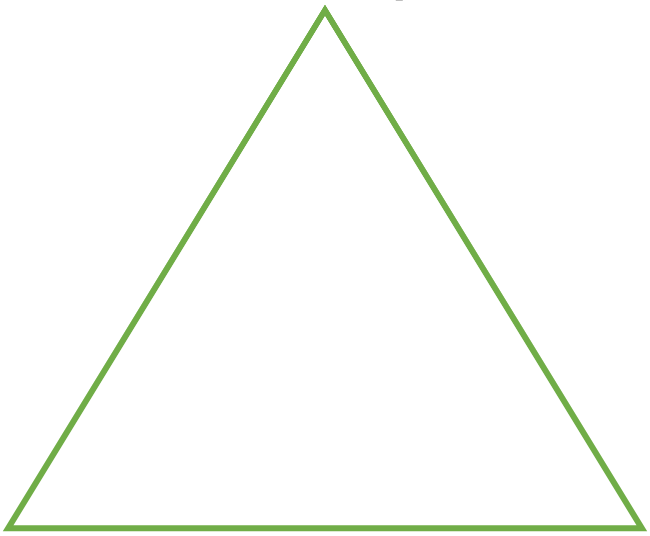

Figure 1: An adapted chemical triplet

Galloway, Stoyanovich and Flynn, (2017). Hanson (2017); Johnstone, (2006); and Talanquer, (2011) have opined that learners make a sense of multiple distinctions across domains if they seek to achieve a coherent understanding of chemistry. Conceptual understanding is enhanced when the concept of the chemical triplet is understood.

In the view of Talanquer (2011), students should be guided to understand and apply all these domains. According to Talanquer, the symbolic reaction mechanisms illustrated with the electron-pushing formalism in organic chemistry assist students with explanations about particle interactions in the submicroscopic domain that produce visible changes in the macroscopic domain. Teachers and learners, need to ensure accurate interpretation of the

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letters, lines, and arrows in reaction equations and also generate accurate mental models of the phenomena in the macroscopic and submicroscopic domains (Galloway, Stoyanovich, Flynn, 2017; Talanquer, 2011). This therefore means that teaching, learning, and understanding organic chemistry is about effectively using the representations and communicating about the chemical phenomena (Johnstone, 2006). In other words, teaching and learning are not only about imparting knowledge but also about a process of making reasonable and attainable knowledge to explain and explore concepts (Roth, 1990).

The sub-microscopic level makes chemistry real even though it appears to be abstract, thus, forms the particulate level of chemistry, which is used to describe what is observed at the macroscopic level during the movement of electrons, molecules, particles, or atoms. The symbolic level represents the use of chemical equations, mathematical equations, graphs, reaction mechanisms, analogies, and model kits.

Students with a low understanding of the symbolic domain might have difficulties representing phenomena in chemical equations, which further might impede their ability to make meaningful connections to the macroscopic and submicroscopic domains (Popova & Bretz, 2018). Teachers need to teach learners to see the integration between the Macro-micro-symbolic levels. Eticha and Ochonogor (2015) opined that understanding the concept of the chemical triplet is one of the strategies for studying and understanding organic compounds and the reactions they undergo. It is, therefore, necessary for the concept of the macro-micro-symbolic phenomena in chemistry to be adapted to help the teacher and the learner get the relationships to enhance conceptual

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understanding of organic chemistry, especially in chemical reactions and equations, which are under the symbolic level.

Learners might be able to systematically and algorithmically solve problems in chemistry without thoroughly understanding the chemical phenomena (Boujaoude & Jaber, 2012). The macro-micro-symbolic as a chemical triplet is, therefore, used to enable the learner to understand the concept of the:

1. tangible phenomena as experiments and experiences of carbon compounds
2. movement and position of atoms, molecules, ions and electrons as in carbon compounds before and after chemical reaction.
3. structural formula, empirical formula, chemical equations of the final product of organic reaction

The macro-micro-symbolic, as a chemical triplet, is therefore an integrated system that the learner needs to use to understand the molecular and product processes in the chemical reaction concept (Boujaoude, & Jaber, 2012). Teachers are therefore to teach in ways that learners will understand the meaningful linkage/integration between the macro-micro and symbolic levels for them (learners) to develop mental gymnastics (Johnstone, 1982).

The Concorde Diagram

The Concorde Diagram explains how conceptual understanding is enhanced using information load, and the perceived difficulty of the concept. Johnstone (1980) therefore explains the connection between information content, the state of conceptual development and understanding, and the

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perceived difficulty of the content in science, and for that matter chemistry (Johnstone, 1980).

In Johnstone's view, when high concept understanding and low information content meet, perceived difficulty decreases. Hence, the more complex the concept and the greater the amount of information, the harder it seems to understand. Therefore, perceived difficulty increases as concept understanding and information content increases. Furthermore, the learners perceive concepts to be understandable when the information presented during instruction is within their levels of understanding. Johnstone illustrated this in the Concorde diagram below:

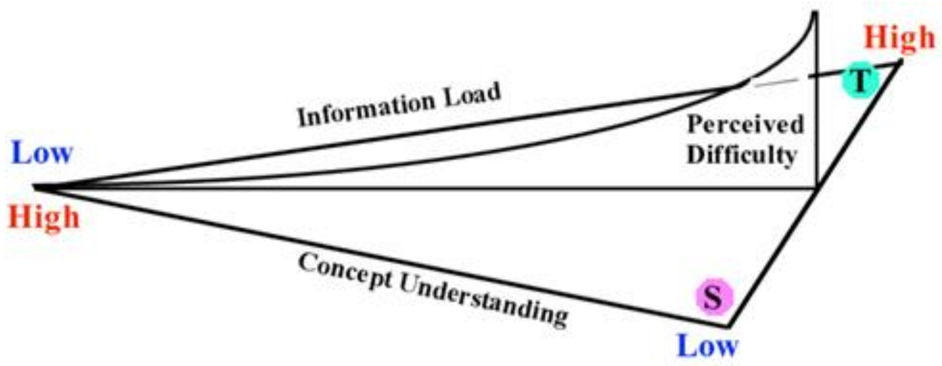

Figure 2: A diagram of the Concorde diagram adapted from Johnstone

This therefore plays a role in concept understanding as teaching and learning is concerned. According to Johnstone (1980) a

> *"beginner is at position S. if the information content is high it position will be at T. Students at S finds it difficult to understand, thus perceived content difficulty. If the teacher presents the topic at the low end of the information-content axis, the pupil at S will 'see' what is going on and will move along the concept-development axis to its higher end. Thus conceptual understanding increases. As he does so, the teacher can increase the complexity of the information but the pupil from his new position will be able to keep it in sight. As the pupil's conceptual development and*

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> *understanding increases, the information load can be broken into units so that the perceived difficulty may be seen as a constant; that is a constant number of chunks."*

Understanding of concepts depends on how the students think, get motivated and exhibit precision in the learning process. The Concorde diagram adopted is to guide the teacher on how a lesson is planned and delivered to help in conceptual understanding. It also guides the teacher on what makes students perceive a particular concept difficult. Concepts are well understood when the teacher's information to the learners is within the understanding of the learners.

These phenomena of the concept of the Concorde diagram, when combined with the chemical triplet, help promote concept understanding, avoid the accumulation of knowledge that is rote-learned, and are capable of promoting a robust foundation that seeks to support further learning (Gkitzia, Salta, & Tzougraki, 2019). When the information on the chemical concept of organic chemistry is at the low end, the macro-micro-symbolic levels in organic chemistry are understood. Thus, for a chemical concept to be understood by students, the teacher should consider the content, language, teaching strategies, and perception of the learners.

Constructivism

Noticeable among proponents of constructivism theories are Piaget, Vygotsky, Ausubel Novak and others. This theory is based on observation and scientific study, about how people learn (Olusegun, 2015). Bereiter, (1994) has indicated that people construct their understanding and knowledge of nature, through experiencing things and reflecting on those experiences. Amineh and Asl, (2015) and Sharma and Bansal, (2017) have established that Constructivism:

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1. helps students to construct their understanding of materials or concepts through mental models and exposure to hands-on experiences.
2. gives the student the impetus to engage and know what they think they know;
3. provides the opportunity for the teachers to discover what students know or what they think they know
4. help the students explore and compare what they think about with what they are observing.
5. provides the students with an explanation of the concept.
6. provides students with the skill to apply or extend/elaborate the concepts in new situations and relate their previous experiences to new ones.
7. guides the students to evaluate their conceptual understanding and ability to use skills throughout the modeling.

Oliver (2000) has added that with constructivism, the teacher makes sure their students' preexisting conceptions are understood, and their activities are guided to mould them. Therefore, learning is perceived by constructivism as a medium where learners' understanding of concepts is based on their prior knowledge and experience (Amineh & Asl, 2015). Thus, what learners encounter may not be consistent with their understanding, and their knowledge can change to accommodate new experiences. Constructivist teaching promotes learners' motivation and critical thinking and encourages independent learning (Amineh & Asl, 2015).

The constructivism learning theories are divided into social constructivism and cognitive constructivism.

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Social constructivism emphasises on the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding (Derry, 1999). According to Kim (2001), Social constructivism is based on specific assumptions about reality, knowledge, and learning. To the social constructivist, reality is constructed through human activity and not discovered. The learner therefore needs to be guided to construct and acquire knowledge. In addition, the individual creates meaning through their interaction with each other and the environment. Meaningful learning occurs when the individual interacts with social activities.

Cognitive constructivism: The cognitive approach (schema) believes that the learner has prior knowledge of the concept and therefore rote memorization and overreliance on the prior knowledge can enhance conceptual understanding (Roth, 1990). A student applying the cognitivist approach uses prior knowledge and memorisation to aid in learning. Caffarella and Merriam (1999) point out that constructivist learning is a process of constructing meaning and people themselves make sense of their experience.

Meaningful learning constructivism: This is linked to the human constructivism theory of Ausubel (1963) and Novak (1993). In the views of Ausubel and Novak, meaningful learning underlies the constructive integration of thinking, feeling, and acting, leading to human empowerment for commitment and responsibility (Bretz, 2001). The application of all these makes the learner either have a shallow or deep understanding of a concept (Badie, 2016). According to Badie, a shallow understanding of concepts means humans/learners can identify some isolated facts and matters related to that concept and a deep understanding of the concept is interpreted as the

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ability to link lots of related facts as conceptions to other complicated conceptions. Learning is efficient and systematic when the learner understands how to process the information that will lead to learning (Shimizu and Widiyatmoko, 2017). Meaningful learning is, therefore, a direct contrast to rote learning, in which new concepts are not connected in any substantive manner to prior knowledge, but are merely memorized (Bretz, 2001). Meaningful learning is achieved through the active involvement of the learner in the processes of teaching and learning (Eticha & Ochonogor, 2015).

Ausubel describes meaningful learning as new information purposefully connected to a student's existing knowledge. In meaningful learning the student: i) must have some relevant prior knowledge to which the new information can be related, ii) have material that contains concepts relatable to the existing knowledge, and iii) must consciously choose to incorporate this meaningful material into his/her existing knowledge (Bretz, 2001). According to Bretz, Ausubel's Meaningful Theory of Assimilation has setbacks in the chemistry classroom as the theory fails to address the concern of how to correct the knowledge and how to control students to ignore memorization in favor of learning meaningfully. Thus, one of the variables is left to the teacher.

In the view of the Novak Theory, the chemistry teacher is guided in how to help students achieve meaningful learning (Bretz, 2001). Novak (1993) classified experiences needed for meaningful learning into cognitive, affective, or psychomotor domains. According to Novak, the cognitive domain helps the students in their thinking and reasoning skills for a better understanding of concepts, the affective domain motivates the student to have a positive attitude

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toward learning and the psychomotor guides the student to be precise and dexterous (Bretz, 2001). When meaningful learning is prioritized over memorisation, students can connect the skills of what they do know with what they need to know. According to Bretz, (2001), Novak's Theory of Education encourages both chemistry students and teachers alike to view their shared experiences in the classroom as opportunities for meaningful learning. This therefore gives the Novak Theory greater priority over the Ausubel Assimilation Theory.

The chemical triplet presents the concept students are required to understand in chemistry. It shows the relationship of the various concepts as far as chemistry is concerned. The Concorde diagram outlines how the concept is presented for easy understanding. It indicates the barriers and perceived difficulties learners may experience during instructions. The chemical concept of carbon compounds requires the cognitive, affective and psychomotor domains to learn and understand (Bretz, 2001). The teaching and learning should be meaningful to the learner as the learner seeks to make use of it to solve daily life situations. The Novak constructivism theory of meaningful learning makes provisions for prior conceptual knowledge, existing cognitive frameworks, and relevant information to drive conceptual change or understanding of the chemical concept using the three domains of learning.

Students Conceptual Understanding of Chemical Reactions and Equations of Carbon Compounds

The quality and effectiveness of teaching and learning in any subject are measured by the academic performance of the students. It is also an

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indicator to determine the extent to which educational goals and objectives in a subject are understood (Adesoji, Omilani & Dada, 2017).

Students are required to learn the chemical reactions of carbon compounds to enable them to apply the chemical principles learned to explain observed daily life experiences (Ministry of Education, 2010). Meanwhile, Sirhan, (2007) indicates that students have problems with understanding concepts of chemical reactions. In the view of Salame, Casino and Hodges (2020) students can predict the products without understanding the reaction. Kelly and Hansen (2017) have identified four (4) fundamental places in chemical reactions capable of causing misunderstanding among students. According to Kelly and Hansen, students:

1. fail to understand that there is a change in the properties of reactants and products after the reaction
2. find it difficult to understand the bonds broken and formed during chemical reaction
3. cannot identify the nature of bonding within the reacting species
4. do not understand the energy changes that occur during chemical reactions.

All these therefore make the understanding of the chemical concept difficult. On the part of Ferguson and Bodner (2008), learners find it difficult to differentiate between reactions that look similar on the surface and reaction names that sound similar. These make learners see the chemical reaction as a difficult topic to learn (Bryan, (N.D); Helmenstine, (2019); Odwyer & Childs (2017)),

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Organic Chemistry uses terms like breaking of bonds (single double and triple bond), formation of bonds (single, double, and triple), and homolytic and heterolytic cleavages to explain the formation of ions (Oppong, Addae-Mensah, Asunka, 2008). Terminologies such as addition reaction, substitution reaction, elimination reaction, nucleophile reaction, electrophilic reaction, in situ, catalyst and 'under a particular condition' to describe how chemical reactions occur or how the chemical equations will look like (Oppong, Addae-Mensah, Asunka, 2008). These conceptual terminologies should provide a satisfying understanding, description and explanation of what happens during the interactions of molecules (Roth, 1990). Unfortunately, research indicates that students are confused as to how to apply these terminologies in the world of chemical reactions and equations (Krajcik, 2009).

Similarly, varied structural representations are used by organic chemists to explain and describe reactions through the writing of chemical equations (Zieba, 2004). Oppong, Addae-Mensah, Asunka, (2008) and Zieba (2004) further indicated that curly arrows are used to represent the movement of electrons (as a result of the breaking and formation of a bond in the reaction process and the theory of resonance); Positive (+) and negative charges (-) are used as formal charges on electronegative atoms to indicate electron shift; dot (.) to represent lone pair electrons; arrows to represent reversible, irreversible, complete and incomplete reactions. Krajeik (2009) opined that students memorize this representation and present it in an examination without the challenge of understanding the concept.

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Teaching and learning are not only about imparting knowledge but also a process of making reasonable and attainable knowledge to explain and explore concepts (Roth, 1990). Learning is efficient and systematic when the learner understands how to process the information that will lead to learning (Shimizu & Widiyatmoko, 2017). Students therefore need to know more than isolated facts and methods of chemical concepts.

Salame, Casino and Hodges, (2020) opined that there is a need to understand the content and relationships between reactions, their mechanisms, and nucleophilic and electrophilic character which will lead to improved problem-solving and performance in organic chemistry synthesis. Without these, the students resort to rote learning and memorization. Salame and Hodges, (2020) further argued that there is the need for students to move away from recall to comprehension of concepts, evaluation, analysis and synthesis. Also, the technique needed by students to understand chemical concepts in carbon compounds is to picture the carbon compound equation like a mathematical puzzle (Krajcik, 2009). This helps them understand the concept rather than memorising it.

Eticha and Ochonogor (2015) have identified the difficulties arising from organic Chemistry from the abstract, complex and dynamic nature of the concepts covered, teacher-centered teaching. According to Eticha and Ochonogor, the chemical concept of organic chemistry in Senior High School is characterized by numerous course content. Learners are expected to cover the entire content before sitting for the final exams (M.O.E, 2010). The practical component is minimal and for that matter, students do not have the hands-on activities to understand the chemical concept of carbon compounds.

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This makes them have difficulties understanding why and how reactions happen (Yan & Talanquer, 2015).

It is, therefore, necessary that a conceptual mode is identified, analysed, and characterized to help leverage students' thinking and learning opportunities about chemical concepts for better development of meaningful learning.

Chemical Reactions and Equations of Carbon Compounds and their Relevance in Society

Hanson (2017), has stated that a chemical reaction equation is a unique feature of chemistry and chemistry education that enables students to appreciate changes in chemical phenomena. Also, the chemical equations contain descriptive and conceptual details of how the species are broken and formed during the reaction process. The equation outlines the amount of new substances produced in their stoichiometric coefficients (Bilek, Nodzynska, Kopek-Putala & Zimak-Piekarczyk, 2018). Thus, the chemical reactions of organic compounds always involve the making and breaking of covalent bonds (Graham Solomons & Fryhle, 2008). The chemical reactions and equations are used to depict the product during a chemical reaction.

Ahtee & Varjola (1998) in their research concluded that learners have a cognitive conflict between the observations made in the real macroscopic world and the theoretical explanations of the microscopic world when they are interpreting chemical reactions. This is taken further in Bhattacharyya and Bodner's (2005) study which established that students can produce correct answers to an organic reaction without having an understanding of the chemical concepts behind their responses/answers. There is, therefore, the

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need to guide the learner to have a 'chemical thinking' strategy and use it productively to explain, and make a relevant based prediction of chemical contexts (Weinrich & Talanquer, 2015).

Chemical thinking, therefore, gives the impetus to the integration of chemical knowledge and practices to analyze, synthesize, and transform matter for practical purposes (Sevian & Talanquer, 2014). Sevian and Talanquer further indicate that the reasoning types students are expected to develop could be organized into six major disciplinary crosscutting concepts that respond to essential questions in the discipline. These concepts and their respective questions are:

- Chemical identity: How do we identify chemical substances?
- Structure-property relationships: How do we predict the properties of substances?
- Chemical causality: Why do chemical processes occur?
- Chemical mechanism: How do chemical processes occur?
- Chemical control: How do we control chemical processes?
- Benefits-costs-risks: How do we evaluate the impacts of chemical processes?

In a similar view, Sirhan (2007) has indicated that what is taught in chemistry is not what is learned because chemistry by nature is conceptual, which is why they have problems with chemical formulae and equations. All these questions when answered outline the goal to uncover how students think about specific chemical concepts and how to improve their understanding in those areas (Weinricha & Talanquera, 2015).

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In thinking of the chemical concept, Helmenstine, (2019) has opined that the study of the chemical reaction concept helps the learner to understand: the properties of matter, how the natural world works, how to explain mysteries in the world and the changes in things. Helmenstine further explains that chemical reactions are also the tools we use to date fossils, analyze ancient materials, and better understand how our ancestors lived.

Bawden, (1992) has indicated that chemical reactions help learners and educators to classify and identify species whose feasibility can be investigated in the laboratory. This is an expression, which helps to give the identities and quantities of the substances in a chemical reaction.

The classification plays an important role in the analysis of reaction databases, reaction retrieval, reaction prediction, or synthesis planning of reacting species (Latino & Aires-de-Sousa, 2011).

Alcock et al (1991) have asserted that the existence of life on this planet is based on the chemistry of carbon. The chemistry of life and death which is the growth, development and eventual death, of every living thing involves carbon compounds. The relevance of carbon compounds and their reactions can therefore not be over-emphasised.

Methods of Teaching Chemical Reaction

One of the major factors responsible for effective teaching and learning in any subject is dependent on the instructional strategies applied (Zhou, et al, 2016). Learning difficulties in the subject areas are solved to a greater extent when the appropriate teaching methods are used. It is therefore necessary to look at other strategies applicable to teaching the concept.

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Talib et al, (2012) have alleged that the teaching approach used in explaining organic reaction is usually rigid, with mostly the application of the talk-and-chalk method. In the view of Yan & Talanquer, (2015), chemistry courses are often delivered using an explanation–application format which is characterised by the teacher giving information and then applying the information to solve specific problems. According to Zhou et al (2016), traditional teaching methods applied to the chemical concept in organic chemistry cannot catch up with the pace of the times and therefore do not meet the student's needs. This therefore does not encourage meaningful learning of concepts.

Cañas, Lazo, and Carcamo (2016); Pareek, (2015); Sket, Glazar and Vogrinc (2015); have suggested the use of concept maps to teach the concept of completing reaction. Concept mapping strategies retain information learned and improve the performance of students (Pareek, 2015). Sket, Glazar and Vogrinc (2015), further evaluated the impact of using a concept map on solving tasks in organic reactions and concluded that it improves students' achievement. Sket, Glazar and Vogrinc added that when the students make their map and compare it with the expert's map, the differences will help support teaching to avoid misconceptions and contribute to understanding of concepts. Concept maps stimulate the students' interest in conducting organic chemistry reactions. Meanwhile, the idea of concept mapping in teaching and learning is not recommended in the teaching and learning chemical concepts of carbon compounds in Senior High Schools.

Bharathy (2015) has identified computer-assisted teaching and learning methods as a technological method, which helps students to acquire high-

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quality mental models in learning. According to Bharathy, Computers and software improve teaching and learning and motivate students to understand challenging concepts in the curriculum which increases their achievements. Otieno (2017) indicated that computer-assisted teaching and learning help in student classroom achievement. It helps teachers and learners to make teaching and learning real.

One of the computer programmes which helps the teaching and learning of chemical concepts is Simple Explicit Animation (SEA). Talib, Nawawi, Ali, and Mahmud (2012) have identified the SEA method as one of the methods that have the potential to increase students' understanding of the chemical reaction of organic compounds. Students have the opportunity to understand abstract dynamic concepts (Bongers, Beauvoir, Streja, Northoff & Flynn, 2019) by observing how the electrons are transferred and the molecules added in addition, substitution, or elimination reactions. Animation and videos create and bring reactions alive as they appear in real life and help to promote students' learning achievements (Shi-Jer, Hui-Chen, Ru-Chu & Kuo-Hung, 2012)

In a similar opinion, it provides teachers the opportunity to demonstrate and explain the three-dimensional course of organic reactions and the skills required by students to design and investigate their reaction examples (Coleman & Wildman, 2003). Kelley and Hansen, (2017) have also identified that animation helps students develop their conceptual understanding to enable them to navigate between symbolic, macroscopic and submicroscopic levels of learning chemistry. Despite the use of animation as a technological tool to teach chemical reactions, Bongers, Beauvoir, Streja,

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Northoff and Flynn (2019) have identified the inability of students to transfer the mental models seen through the animation to reasoning in a limited time as a problem they face. Using 3D videos and molecular simulations improves students' understanding and learning achievements in organic reactions.

Rius-Alonso and González- Quezada (2015) has recommended a molecular modeling programme for teaching reactions of carbon compounds. According to Rius-Alonso and González- Quezada 3D molecular modeling improves the competencies of students in the understanding of particular Chemical Reactions. Sibomana, Karegeya and Sentongo (2021) also recommended student cooperative learning models such as the Think-Pair-Share approach; Jigsaw approaches; reverse jigsaw; Reciprocal peer teaching approach; Student Achievement Divisions (STAD); Think-Aloud Pairwise Problem Solving Approach (TAPPSA); Group Grid approach; Approach to group writing assignments; Basic group learning; Numbered Head Together and many other innovative teaching strategies to minimise students' misconception about organic chemistry.

Sabitu, Talib, Abdul Rahman, and Kamaruddin (2021) also proposed the use of an organic reactions and mechanism teaching model for teaching and learning as the reactions and equations consist of complex and dynamic principles that are necessary and need to be simplified through a robust model developed with mechanistic reasoning, language symbolisms and visual representation for a better understanding of advanced organic reactions. Sabitu et al believed that the model would assist students in understanding and relate what they have learned to the advanced concepts.

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Although several teaching methods are recommended for teaching the chemical reactions of carbon compounds, the SEA is the appropriate method of teaching the concept. It conveys reaction procedures and molecular motion (Bongers, et al, 2019) by showing clearly how the electrons are transferred, the bonds are broken and formed and the arrangement of the atom in the final product.

Perception of Students on Chemical Reaction of Carbon Compounds

Students and teachers usually perceive concepts differently. Johnstone, (1982) has categorized the perception of students concerning chemical phenomena into three, namely concept understanding, information content and perceived difficulty. Johnstone added that these three factors are interdependent. Therefore, to develop useful learning progressions, we need to understand how students conceptualise and reason about core ideas of an aspect of a learning discipline.

The chemical concept of organic chemistry is perceived by students to be difficult (Odwyer and Childs, 2012; Woldeamanuel, Atagana & Engida, 2014). According to Odwyer and Childs (2012), this problem arises because students find it difficult to interpret the concept according to the way they understood it due to the high information load. Rice (2016) has indicated that students only perceive what is familiar to them as difficult or easy if it can pass through the working memory space to the long-term memory and be understood. In the view of Odwyer and Childs (2012), concepts perceived by students to be difficult are due to the high information load. The concept of information that will be given by the teacher and how that information is understood makes students perceive it to be difficult (Childs and Sheehan,

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2009; O'Dwyer and Childs, 2012; O'Dwyer and Childs, 2015; Jimoh, 2005; Ratcliffe, 2002; Schroeder and Greenbowe, 2008;). Therefore, the information should be presented within an approach that seeks to stimulate observation; questioning and argument to enable students to understand the concept of chemical reaction.

Furthermore, when there is difficulty in understanding and recalling the concept from long-term memory, students are often forced to turn to rote learning (Rice, 2016). The rote learning method is used because teachers use the explanation-application technique in the context of teaching and learning organic concepts (National Research Council (NRC), 2011). NRC (2011) and therefore opined that students are hardly engaged in exploratory activities involving mechanistic explanations of how the reactions proceed in systems under consideration. In a similar view, the teachers' inclination towards organic reaction has contributed to the students' negative perception of the organic chemistry concept (Donkor, 2017). These, therefore, make the concept understanding difficult.

Eticha and Ochonogor (2015) have opined that chemistry teachers' teaching methods; the nature of the organic reaction and students' experience of learning are factors affecting the ability of the student to understand the concept. According to Eticha and Ochonogor, students lack algorithms to enable them to see the learning of organic reaction as a process and thus believe in being spoon-fed by teachers with chemical information. This therefore results in the tendency of students to memorize chemical concepts of organic chemistry rather than trying to have a deeper understanding of the concepts to enable them to apply it.

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In the view of Yan and Tanlanquer (2015), there are topic-specific problems regarding the understanding of organic chemistry. The students perceive organic reactions to be characterized by so many conditions, hence, they have problems understanding the concept. They have difficulties understanding why and how some types of reactions occur. The difficulty is perceived as they see some chemical reaction processes to be abstract.

Uchegbu, Amandze & Ahuchaogu (2017) have identified that students perceived organic chemistry to have so many theories and molecular structures, and which makes them have difficulty understanding its chemical reaction concept. Oppong, Addae-Mensah and Asunka, (2008) added that a single compound has so many isomers which have different chemical properties, thus the students find it difficult to conceptualise the products formed when it reacts with different chemical species. This makes them lose interest in learning it.

There is heterogeneity in the way people think or hear about concepts in different contexts (Mortimer & El-Hani, 2014). Students are afraid of the chemical concept of organic chemistry before they start studying it because their friends tell them it is too difficult (Uchegbu, Amandze & Ahuchaogu, 2017). Students who believe in the negative comments made by friends tend to have misconceptions about the content (Eticha & Ochonogor, 2015). Peers who complain influence the negative perception of students towards the chemical concept of organic chemistry. Students with a poor perception of some aspects of a course find it difficult to pass the course (Uchegbu, Amandze & Ahuchaogu, 2017).

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In the opinion of Yan and Talanquer, (2015), students learn the chemical concept of carbon compounds for examination, and for that matter summative assessment. Yan and Talanquer therefore bemoan the examination misconception's effect on students' understanding and performance as their problems may strongly vary from one point to another (from saturated to unsaturated hydrocarbons to functional group chemistry). This can be described as a lack of vision on students' part as they will not be able to understand the concept and apply it in the world of work. Students need conceptual understanding to have constructed knowledge (Eticha and Ochonogor, 2015).

MolokoMphale & Mhlauli (2015) have also identified students' study habits as one of the perceptions derailing their academic performance. According to MolokoMphale & Mhlauli, students who have the perception to read books to search for relevant information, schedule time to learn concepts considered to be challenging, attend tutorials and ask teachers relevant questions, and understand the concepts taught, are signs of good study habits. Bad study habits emerge as the students behave the opposite.

Factors Accounting for the Students' Difficulties of Chemical Reactions and Equations of Carbon Compounds

Carbon compounds are made up of complex species and functional groups, thus, students generally find it difficult to learn (Wang, 2016). There is a need to relate the micro-macro-symbolic concepts to understand structures, physical and chemical characteristics and the reaction mechanisms (symbolism) (Hanson, 2017). Hanson, however, contended a lack of evidence to confirm students relating the chemical triplet (macro-micro-symbolic

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phenomena) when they are asked to describe and explain chemical reactions. There is therefore the need to understand and relate the various levels of representation in the concept of carbon compounds and their reactions.

Carbon compounds have been identified to have a complex language which is needed to be understood to enable proper understanding of its concept (Claytoden, Greeves, Warren & Wothers 2001). The scientific language remains constant while the meanings of the terms change which may be misleading to the learner (Sirhan, 2007). There are therefore misconceptions and alternative conceptions for word meanings of carbon concepts e.g. radicals, electrophile, carbonyl, etc. (O'dwyer and Childs, 2012), the symbols and meaning of the reversible and irreversible reactions signs (Alcock, et al 1991)

In another development, O'dwyer and Childs (2012) have indicated that students find it difficult to recognise the linking between the theoretical and practical work of carbon compounds. The theoretical aspect leads students to the overview of chemistry concepts and the hands-on activities enhance quality learning and conceptual understanding of how reactions proceed to yield results (Zakaria, Latip & Tantayanon, 2011). The practical work is supposed to be characterized by a demonstration of manipulative skills using tools, machines and equipment for practical problem-solving. Teaching should involve projects, case studies and field studies where students will be intensively involved in practical work and the search for practical solutions to problems and tasks (M.OE, 2010). Meanwhile, adequate practical activities in the school to enable students to understand the concept of a chemical reaction

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is a factor capable of militating in favour of the understanding of students in the chemical concept of carbon compounds.

O'dwyer and Childs (2012; 2017) have opined that Organic formulae, structures and reactions are limited to the boundary of the chemistry class, without real-life applications in the curriculum. Odwyer and Childs (2017) specifically indicate that when learners have low meta-cognitive awareness and lack the requisite cognitive ability necessary to learn and understand the topics, they become unaware and indifferent towards their learning, which can therefore lead to rote memorization and meaningless learning.

According to Cañas, Lazo, and Carcamo (2016), the learning achievement of students in chemistry concepts increases with the application of the zone of proximal development and conceptual mapping. Meanwhile, Poon (2004) has identified student shyness, lack of confidence, and fear of embarrassment as barriers hindering their participatory process in organic chemistry classes to enable them to understand the concept. This therefore makes them perform poorly in chemistry classes.

Austin, Ben-Daat, Zhu, Atkinson, Barrows & Gould (2014) have identified higher-level cognitive skills to correlate with students' performance in organic chemistry. According to Austin et al, cognitive abilities influence performance better than rote memorization of concepts. Without cognitive skills imagistic strategies, analytic problem-solving strategies, or their combination are lacked by students in solving organic chemistry problems, especially chemical reactions and equations (Hegarty, Stieff & Dixon, 2012) This explains why high cognitive demand is needed to understand abstract concepts without any concrete representations (O'dwyer, 2012).

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O'dwyer (2012), opined that the information processing Model affects the understanding of students in organic chemistry concepts. According to O'dwyer, different representations of organic formulae, rules of IUPAC nomenclature and reactions can cause memory overload and lack of prior knowledge. This may affect students' perception filters. Johnstone (1980) therefore, opined that for concept development in learning to increase, the information content must decrease to the level of learners to improve conceptual understanding. The understanding of concepts, especially in carbon compounds, depends on the concept development, the information processing (low or high information relay) and the perceived difficulty of the content. The processing of the information influences the learning style of the student (Woldeamanuel, Atagana & Engida, 2014). According to Johnstone (1980) the learner's conceptual development, the information load can be broken into simpler units for the perceived load to be constant. This when broken aids in the conceptual understanding.

Chemical reactions and equations of carbon compounds are abstract, non-intuitive concepts that are not based on, and/or derived from, and/or interrelated logically with one another, at least not in a simple and straightforward sense (Zoller, 1990). There is therefore a misconception that organic reactions and equations are difficult to understand (Bryan (N.D). Bryan therefore identifies the causes of misconception as the misinterpretation of the content as it appears in the notes and the issues perpetrated by the chemistry teachers. Misconception influences the understanding of students on more complex concepts (Anam Ilyas, 2018; National Academics of Sciences, 1997) including chemical reactions and equations

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CHAPTER THREE

RESEARCH METHODS

Overview

The study investigated the Senior High School Students' conceptual understanding of reactions and equations of carbon compounds. This chapter describes the methodology used in the study. The chapter explains the research design, population, sample and sampling procedures, data collection instruments, pilot testing, data collection procedures, validity and reliability of instruments as well as data analysis procedures.

Research Design

The study adopted the explanatory sequential mixed method design which consists of two phases (quantitative and qualitative methods). The quantitative phase was dominant, meaning more weight was placed on it (Ary, Jacobs & Sorensen, 2010; Cohen, Manion, & Morrison, 2005; Creswell, 2014; Creswell & Plano Clark, 2007) to investigate students' conceptual understanding of chemical reactions and equations of carbon compounds. A sequential explanatory design enabled data from the interview to be used to help explain specific quantitative findings that need additional explanation (Ary, Jacobs & Sorensen, 2010). The two sets of data were collected and analysed separately and mixed at the discussion stage. The quantitative data was collected and analysed followed by the qualitative data.

The quantitative data comprised of data collected from achievement test items of the student's conceptual understanding of chemical reactions and equations of carbon compounds. In the qualitative phase, an interview was conducted after administering the achievement test. The data was collected,

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analysed separately, and therefore, the qualitative phase helped inform the quantitative phase.

According to Creswell (2014), and Creswell and Plano Clark (2011), the combination of both quantitative and qualitative methods will draw on the strengths and minimise the weaknesses of each of the two types of data collection techniques; thus, providing a comprehensive understanding of investigating the students' conceptual understanding of chemical reactions and equations of carbon compounds. Their combination eliminates possible biases, explains the true nature of the phenomenon and improves various forms of validity or quality criteria in the study (De Vos, Strydom, Fouche, & Delport, 2011). A cross-sectional survey design was used to support the mixed method; and to provide the researcher with both quantitative and qualitative data for a retrospective and a prospective inquiry into the conceptual understanding of chemical reactions and equations of carbon compounds among SHS students. The essence of using this design is to examine and describe the extent to which senior high school students understand the concept of chemical reactions and equations of carbon compounds which are essential aspects of the chemistry curriculum at the SHS level in Ghana. This design helped the researcher to compare the retrospective understanding of the concept and a prospective approach to handling the concept with a group of students (Cohen, Manion, & Morrison, 2007). This design also specifies the nature of a given phenomenon, or practice, and helps to determine and report the way things are (Amedahe & Asamoah-Gyimah, 2014). It involves collecting snapshot data for more points in time (Cohen, Manion, & Morrison, 2007) to answer the research questions concerning the subject under study. The data that was

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collected was used to assess the conditions affecting students' understanding of the concept of chemical reactions and equations of carbon compounds. The cross-sectional design is useful for assessing a group of people's preferences, attitudes, concerns, interests, practices and perceptions. In addition, the data are usually collected through questionnaires, achievement tests, interviews, or observations (Creswell, 2012).

The research question "What are Senior High School students' conceptual understanding level of chemical reactions and equations of hydrogenation reactions; halogenation reactions; reactions involving unsaturated hydrocarbons and hydrogen halide; oxidation reactions; hydration/hydrolysis and esterification reactions?" identified the characteristics and trends of conceptual understanding levels. Therefore, the data collected to respond to the needs of these questions described the extent to which the students understood the concept of chemical reactions and equations of carbon compounds. A two-tier researcher-made-achievement test item was responded to by students to ascertain the extent to which the concept of chemical reaction and equations are understood. Achievement tests measure mastery and proficiency in different areas of knowledge by presenting subjects with a standard set of questions involving the completion of cognitive tasks.

An interview was conducted to provide explanations to the quantitative data on the question: What reasons account for the student's conceptual understanding of chemical reactions and equations of carbon compounds? The interview data was used to verify the quantitative data to gather detailed information about how students understood and applied principles, theories,

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laws, and rules of the concept under study. It provided an in-depth justification for the performance of the test items.

Study Area

The Upper West Region is one of the sixteen regions of Ghana located in the north-western corner of Ghana. The Upper West Region shares border to the north with Burkina Faso, east with the Upper East Region, south with the Northern Region and Côte d'Ivoire to the west. The region covers a geographical area of 18,476 square kilometers, about 12.7% of the total land area of Ghana (Ghana Statistical Service, 2021). The Region has a population of 901,502 inhabitants (Ghana Statistical Service, 2021).

Since its creation in 1983, the Upper West Region has had Wa as its capital, and the seat of government. The Upper West Region of Ghana contains 11 administrative districts consisting of 5 municipal and 6 District Assemblies as follows: Daffiama Bussie Issa (DBI), Jirapa, Lambussie- Karni, Lawra, Nadowli –Kaleo, Nandom, Sissala East, Sissala West, Wa East, Wa Municipal and Wa West (Ghana Statistical Service, 2013).

Upper West Region has 46 second-cycle institutions (33 public and 2 private SHTS) and 11 technical and vocational training institutes (MOE, 2020/2021 School Year Data). These schools offer various programmes including general science, general arts, home economic, agricultural science, general art (visual art), business and other technical/vocational studies. Each of these courses has its respective elective subjects. These courses and their respective elective subjects seek to prepare the students for the world of work and further studies.

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Population

The study population is selected from Senior High School/Senior High Technical schools (SHS/SHTS) in the Upper West Region which offer elective chemistry subjects. In the upper west region, 12 SHS/SHTS offers elective chemistry. The study's target population comprises all form 3 elective chemistry students in the SHS/SHTS. The form 3 students were selected because organic chemistry is scheduled to be taught and learned in the final year. These students comprise all general and agricultural science students and some home economics students. However, the population was selected based on the schools in which organic chemistry was taught at the time of the data collection. Therefore, the population was made up of a total number of one thousand eight hundred and fifty-six (1856) final-year students of the 12 SHS.SHTS. This consists of 1237 males and 619 females.

Sample and Sampling Procedures

A sample of Three hundred and twenty (320) final-year students were selected for the study. The sample was selected from 7 schools in which organic chemistry was taught. This sample was selected using the Krejcie and Morgan’s (1970) table of sample size determination. A sample from a population of 1856 is 320. The sample distribution is shown in Appendix F

The simple random sampling technique was used to select the sample for the quantitative phase of the study. This method gives all the respondents an equal and independent chance of being selected for the study (Amedahe & Asamoah-Gyimah, 2014; Cohen, Manion, & Morrison, 2007). Also, this technique provided reliable results as the information was provided by homogenous elective chemistry students with specific characteristics and

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interests (Amedahe & Asamoah-Gyimah, 2014) in studying chemistry and chemical reactions and equations of carbon compounds. According to Amedahe and Asamoah-Gyimah (2014), this technique helps in selecting samples that truly represent the population therefore, the results of the study can be generalized.

A simple random sampling technique was employed to select schools for the study. The purpose of using this method is to create equal opportunities for all schools (Creswell, 2014). Intact classes were selected from the schools to participate in the study. The classes were selected based on the content in organic chemistry covered in the teaching and learning processes. This enabled the researcher to use students who may be available (Ary, Jacobs & Sorensen, 2010) to respond to the achievement test items and the interview. According to Ary, Jacobs and Sorensen, (2010) the intact class helps the researcher to choose several schools randomly from a list of schools and then include all the students in those schools in the sample. Ary, Jacobs and Sorensen, (2010) further explain that, even though selection bias may occur, the researcher may use the pre-existing classes in the various schools to set up an independent plan for the study. It also provided counterbalancing opportunities to all schools and classes to identify differences that might exist between the classes to get accurate results.

In using this method, the researcher constructed a sampling frame. Hence, a list of all the SHS in the Upper West Region that offer elective chemistry and have taught organic chemistry were written. The appropriate table of random numbers which contained all the numbers included in the sampling frame was obtained. The researcher then entered the table randomly.

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Here, the researcher started at a point on the table of random numbers. The researcher picked the numbers from the table randomly and registered, the names in the sampling frame which corresponded to the numbers being picked. The researcher proceeded vertically using the appropriate number of digits. This process continued until the 320 respondents were obtained.

For the qualitative phase, Purposive sampling was used to select 7 respondents to participate in the interview. According to Oduro (2015), purposive sampling allows the researcher to select the appropriate sample that will provide the required information. Students were stratified and interviewed based on their performance on the achievement test to determine the reasons accounting for students' conceptual understanding of the concept under study. The strata were done based on excellent, very good, good, or poor performance respectively. The stratification was done concerning the schools. The purpose of the interview is to get in-depth complementary information to support the quantitative data that was gathered.

Data Collection Instruments

In this study, an achievement test and an interview guide were used to collect the data. Thus, this research employed both quantitative and qualitative techniques in the data collection. As Creswell (2014), and Creswell and Plano Clark (2011) argued, their combination will draw on the strengths and minimise the weaknesses of each of the two types of data collection techniques (achievement test and interview guide) and thus, provide a comprehensive understanding of investigating the SHS students' conceptual understanding of chemical reactions and equations of carbon compounds. Their combination also eliminates the different kinds of biases and explains

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the true nature of the phenomenon and improves various forms of validity or quality criteria in the study (De Vos, Strydom, Fouche, & Delport, 2011).

Achievement test

A two (2) Tier Researcher-made Achievement test item was used to collect data on the Senior High School students' conceptual understanding level of chemical reactions and equations of carbon compounds. It was also used to identify the strengths and weaknesses of students in chemical reactions and equations. The first tier allowed students to write the reactions or equations with the required conditions. The second tier of the test provided an open-ended option for students to apply the rules, principles and laws guiding organic reactions and equations to explain how they arrived at the answers. This was to ascertain the students' understanding of the concept. The achievement test item was validated by professional chemistry teachers and my supervisor. 35 test items were pilot-tested to ensure their reliability. The achievement test items sample is shown in Appendix A.

Semi-Structured Interview guide

This instrument was used to collect data on the reasons that account for the SHS students' conceptual understanding of the chemical reactions and equations of carbon compounds**.** It is through the interaction with the students that more information on the concept under study will emerge (Cohen, Manion, & Morrison, 2007). Therefore, this enabled the researcher and the respondents to deliberate on issues within the context of the test and their conceptual understanding of chemical reactions and equations of carbon compounds. The interview guide sample is in Appendix B.

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By using a semi-structured interview guide, the researcher had the opportunity to clarify the reasons for the students' conceptual understanding. It also allowed the researcher to ask follow-up questions and probe further in case of incomplete answers. This approach gave the researcher discretion to direct the discussion and ensure that important topics were addressed (Cohen, et al., 2007; Creswell, 2007; Amedahe & Asamoah-Gyimah, 2014). It provided in-depth information on the reasons for students' conceptual understanding and offered the respondents the opportunity to express their thoughts freely (Cohen, et al., 2007).

Gay, et al. (2009), lamented that the greatest challenges researchers who employ this approach face are respondents' unwillingness to be interviewed and their inability to attend interview sessions as scheduled. Specifically, the interview guide covered the following concepts: teaching and learning organic chemistry and its reactions and equations; motivational factors for learning chemical reactions and equations; and the role of the school and home in the students' learning.

Pilot Test

The two (2) Tier Researcher-made Achievement test items and the questionnaire were pilot-tested on students who were not included in the study in the Upper East Region. The purpose of the pilot testing was to bring to light whether the instruments were void of ambiguity or not. In total, 35 respondents participated in the process. The pilot test also helped to establish the internal consistency of the instrument. The result of the pilot test indicated that the instruments (Researcher–made achievement test and questionnaire) were reliable enough to be used to collect the data for the study.

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Reliability of the Achievement Test Instrument

Kuder Richardson 20 (KR 20) reliability estimate was used to establish the reliability of the achievement test instrument. In the view of Kimberlin and Winterstein (2008), Kuder-Richardson 20 (KR 20) reliability is applicable for testing items with differences in difficulty level. The KR 20 has a correlation coefficient ranging in value from 0 to 1. The closer the coefficient value is to 1, the more reliable the test, while the closer the coefficient value is to 0, the less reliable the test (Gay, Mills, & Airasian, 2009). Muijs (2011) suggested that a KR 20 alpha of 0.70 or more is an accepted reliability level. The reliability statistics is shown in D

Validity of the Instruments

According to Gay, Mills and Airasian, (2009), content validity of data collection instruments can be determined by expert judgment. Therefore, the validity of the instruments was assessed by my supervisors and experienced chemistry teachers taking into consideration the purpose of the study and the research questions, as well as the variables of the study.

Data Collection Procedures

Before the data collection procedure commenced, I forwarded an introductory letter to the Heads of institutions to get permission to conduct the study. This letter enabled the researcher to get the needed assistance from the respondents and the schools.

A meeting was held between the researcher, the Head of Department, chemistry teachers and students of the selected schools. The purpose of the meeting was to brief them on the intended research and what it seeks to achieve. It also ensured that the data collection procedure did not interfere

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with any school activity. It prepared the students psychologically to respond favorably to the questions (achievement test, the questionnaire and the interview).

The researcher-made achievement test items were given to 320 students for a response within 3 hours. The students were from seven schools in the Upper West Region. The test items were marked and the marks were recorded and analyzed. The achievement test items were 2 tier questions. The purpose of the two (2) tier questions was to enable the students to justify a choice of answer. This helped the researcher to ascertain the extent to which the concept is understood. Hence, the questions were structured from simple questions to application questions, to enable the researcher to measure the understanding of the students. There was a marking scheme to guide the marking process. Both tiers were marked and rated by the Structure of Observed Learning Outcomes (SOLO) scoring system (Biggs & Collins, 1982). This was to enable the researcher to rate the students according to their understanding levels. The test scores samples are in Appendix E.

The researcher identified students who scored extreme levels (excellent, very good, good, fair and poor) in the achievement test item for qualitative data. The quantitative data was then followed up with an in-depth qualitative study to explain why these results occurred. An interview was conducted with the students after the teacher-made achievement test items were administered. The interview data were tape-recorded with the permission of the respondents. The recorded pieces of information were transcribed and analysed. The transcribed interview data is presented in Appendix C. The students' interview data provided more information to substantiate and explain

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the quantitative data that was collected. The overall purpose of this was that the qualitative data help explain or build upon the initial quantitative results (Creswell & Plano Clark, 2011).

Data Processing and Analysis

The two-tier Achievement Test results were analysed using frequency and percentages. The purpose is to outline the information on each question and report on the information for easy understanding. The data analysis was done by the Structure of Observed Learning Outcome (SOLO) Taxonomy, scoring as; No Answer (0), Prestructural (1), Unistructural (2), Multistructural (3), Relational (4), or Extended Abstract (5) (Biggs & Collins, cited in Karaksha, Grant, Nirthanan, Andrew, Davey, & Anoopkumar-Dukie, 2014). The SOLO taxonomy examines students' responses to open-ended questions in multiple disciplines (Decker, Margulieux & Morrison, 2019). Decker, Margulieux & Morrison, added that it is appropriate to use the Taxonomy to evaluate students' level of understanding instead of relying on their grades. A guide to the interpretation of the SOLO scoring system according to Karaksha, Grant, Nirthanan, Andrew, Davey, and Anoopkumar-Dukie (2014) is presented in Table 1:

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Table 1: A guide to the interpretation of the SOLO scoring system

SOLO	SOLO level descriptor
(0) No answer	No answer, or there are written words, but not relevant to the question
(1)Prestructural	Scored both tiers wrong. Here students do not have any kind of understanding but use irrelevant information and/or miss the point altogether. Scattered pieces of information may have been acquired, but they are unorganized, unstructured, and essentially void of actual content or relation to a topic or problem
(2) Unistructural	Scored one of the tiers correct. Students can deal with one single aspect and make obvious connections. Students can use terminology, recite (remember things), identify names, and so forth
3) Multistructural	Scored both tiers partially correct. At this level students can deal with several aspects but these are considered independently and not in connection. They are able to enumerate, describe, classify, combine, apply methods, structure, execute procedures, and without reasons.
(4) Relational	Scored both tier nearly correct. At level four, students may understand relations between several aspects and how they might fit together to form a whole. The understanding forms a structure. They may have the competence to compare, relate, analyze, apply theory/rule, explain with reasons.
(5) Extended abstract	Scored both tiers fully correct. At this level, which is the highest, students may generalize structure beyond what was given, may perceive structure from many different perspectives, and transfer ideas to new areas. They may have the competence to generalize, hypothesize, criticize, theorize, and so forth

The SOLO Taxonomy helped the researcher to ascertain whether the concepts of chemical reactions and equations of carbon compounds were understood. It also enabled the researcher to answer the research question "What are Senior High School students' conceptual understanding level of chemical reactions and equations of carbon compounds?" The results of the

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achievement test items were collected and analysed according to conceptual understanding levels separately.

The qualitative data were analysed by Braun and Clarke (2006) steps of analyzing qualitative data. Braun and Clarke (2006) prescribed steps for analyzing qualitative data thematically as:

1. Familiarising yourself with your data
2. Generating initial codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

These steps, according to Braun and Clarke (2006), seek to guide the researcher to generate themes from the transcribed interview results and analysed thematically. Therefore, phrases/words were assigned to the issues that emanated from the interview and analysed inductively. The selections of the phrases/words were guided by environmental, extrinsic and intrinsic reasons that have the propensity to influence students' learning and grasping of concepts. The respondents to the interview were named student 1, student 2, and student 3 to student 7. The interview data were analysed separately from the Researcher-made achievement test. The interview results were further used to interpret and explain the quantitative data in detail regarding students' conceptual understanding of reactions and equations of carbon compounds. The achievement test results and interviews provided concrete information to answer the research questions.

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CHAPTER FOUR

RESULTS AND DISCUSSION

This study investigated SHS students' conceptual understanding of chemical reactions and equations of carbon compounds. It also determined the conceptual understanding level of Senior High School chemistry students on test items involving chemical reactions and equations of carbon compounds; the factors influencing students' perception of chemical reactions and equations of carbon compounds and identified reasons accounting for conceptual difficulties of students on chemical reactions and equations of carbon compounds. The conceptual understanding of the students was determined by hydrogenation reaction, halogenation reaction, reactions of unsaturated hydrocarbons with hydrogen halide, oxidation reaction, reactions involving hydration or hydrolysis, and esterification. Chapter four was presented in line with the research questions.

General Performance of Students on the Achievement Test

The first research question sought to investigate the conceptual understanding levels of students on test items involving chemical reactions and equations of carbon compounds. Students responded to a two-tier achievement test comprising reactions and equations of carbon compounds. The data obtained indicated that students scored between 1 (1%) and 1 (87%) as total scores on the test. The measure of the student's performance in the achievement test is presented in Table 2.

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Table 2: Results of students' performance in the achievement test item

Students	Frequency	Performance (Highest Test Score (%)
1 - 5	10	7%
6 - 10	13	12%
11 - 15	38	17%
16 - 20	38	22%
21 - 25	34	27%
26 - 30	21	33%
31 - 35	41	38%
36 - 40	17	43%
41 - 45	33	49%
46 - 50	24	54%
51 - 55	16	59%
56 - 60	11	67%
61 - 65	13	74%
66 - 70	8	83%
71 - 75	3	87%
	320	

From Table 2, even though the highest score was 87%, nearly 24.06% scored above 50% while 75.94% of the students scored below 50%. Therefore, students have performed poorly as shown. This performance could correlate with conceptual understanding.

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The SOLO Taxonomy categorizes understanding levels as follows:

- Prestructural level (Level 1): At this level, the student has scored both tiers incorrectly. The student does not have any understanding of the concept and therefore provides irrelevant information in the context.
- Unistructural level (Level 2): At this level, the student has scored one of the tiers correctly. The student uses one of the terminologies, identifies names, or deals with a single aspect of the concept.
- Multistructural level (Level 3): At this level, the student has partly applied the roles/principles and therefore scored part of both tiers correctly. The student can enumerate, describe, classify, apply methods, and execute procedures without reasons.
- Relational level (Level 4): At this level, the student has almost applied the roles/principles and therefore nearly scored both tiers correctly. The student has the competence to compare, relate, apply theory/rules, and explain with reasons.
- Extended Abstract level (Level 5): At this level, the student has a full understanding of the concept. The student perceives the reactions and equations from different perspectives and can transfer ideas to new areas. Additionally, the student has the competencies to generalize and theorize.

The data presented in Tables 3 to 8 and Figures 3 to 8 provides an understanding of the students' comprehension in organic chemistry across various thematic areas. These include hydrogenation reaction, halogenation reaction, reactions and equations of unsaturated hydrocarbons and hydrogen halide, oxidation reaction, reactions involving hydration or hydrolysis, and

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esterification reaction. The tables and figures illustrate achievements based on predetermined standards of accuracy and completeness, enabling them to grasp the broader concepts of reactions and equations of carbon compounds.

Students' Conceptual Understanding of Hydrogenation Reaction

The test items in this section assessed students' understanding of how pi-bonds in unsaturated hydrocarbons are broken by hydrogen in the presence of a metal catalyst to form a sigma bond. Students were required to explain that hydrogen breaks the pi-bond to form a sigma bond in order to demonstrate their understanding of the concept. Additionally, students had to write chemical equations based on word reactions. The results of the analysis can be found in Table 3 and Figure 3.

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Table 3: Distribution of test scores according to students' levels of understanding in Hydrogenation reactions

ITEM	Levels of Understanding According to students' performance in percentages N=320					
	No Answer	Prestructural Level Both tiers incorrect	Unistructural level one tier correct	Multistructural level Both tier partially correct	Relational Level Both tier nearly correct)	Extended abstract Both tier fully correct
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
CH_2=$CHCH_3$ + H_2/Pt →	3 (0.9)	20 (6.3)	72 (22.5)	197(61.6)	21(6.4)	7 (2.3
CH Ξ CH + H_2 /Pt →	14 (4.4)	43 (13.4)	229 (71.6)	26 (8.1)	5 (1.6)	3 (0.9)
Ethyne partially reacts with hydrogen cyanide to form ethylcyanide (vinyl cyanide) which is fully hydrogenated in the presence of nickel to produce propane.	1 (0.3)	274 (85.3)	30 (9.4)	10 (3.1)	5 (1.6)	1(0.3)
Hydrogenation of 2-butene to produce butane	3 (0.9)	47 (14.7)	248 (77.7)	14 (4.4)	7 (2.2)	1(0.3)
Partial hydrogenation of but-2-yne produced but-2-ene	1 (0.3)	41 (12.8)	247 (77.2)	21 (6.6)	6 (1.9)	2 (0.6)

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It is evident from Table 3 that only 7 (2.3%) of the students had a full understanding of the concept of hydrogenating an alkene (CH_2=$CHCH_3$). Thus, they were excellent in understanding the content as they were able to apply the rule to explain how the pi-bonds were broken to form the product. On the other hand, 3 (0.9%) were not able to answer it while as many as 20 (6.3%) provided incorrect responses. Also, as many as 197 (61.6%) of the students provided responses that were partially correct and can therefore not be considered full understanding. These responses indicated that the students did not understand the concept of hydrogenation reaction. Similarly, it can be observed from Table 3 that a reaction involving alkyne (CH Ξ CH) and one molecule of hydrogen had only 3(0.9%) students understanding fully the concept, while as many as 14 (4.4%) and 43 (13.4%) of the students who responded to the items did not answer or provided incorrect responses respectively. A large number of the students, 229 (71.6%), scored only one tier of the questions. This indicated that the students did not understand the concept of hydrogenating an alkyne.

With regards to writing a chemical reaction from a word equation, only 1 (0.3%) student was able to write the equation involving ethyne, hydrogen cyanide and hydrogen gas in the presence of nickel. As many as 274 (85.3%) provided incorrect responses. This indicated that most of the students did not understand the concept. This could be attributed to students' inability to understand the formula and/or structure of some organic compounds. Also, with regards to writing chemical equations from butene undergoing hydrogenation reaction, only 1 (0.3%) student was able to provide the correct response whereas many as 47 (14.7%) of the respondents were not able to

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write the equation. It could also be observed from Table 3 that most of the students, 248 (77.7%) scored only one of the tiers in the question. In addition, partial hydrogenation of but-2-ene had only 2 (0.6%) of the students fully understanding the concept, while 41 (12.8%) of the students were not able to provide the correct equations. Also, as many as 247 (77.2%) of the students provided responses that had only one tier correct. The majority of the respondents were able to score only one of the tiers correctly.

Furthermore, the students' responses regarding their understanding of the hydrogenation reaction are represented in Figure 3.

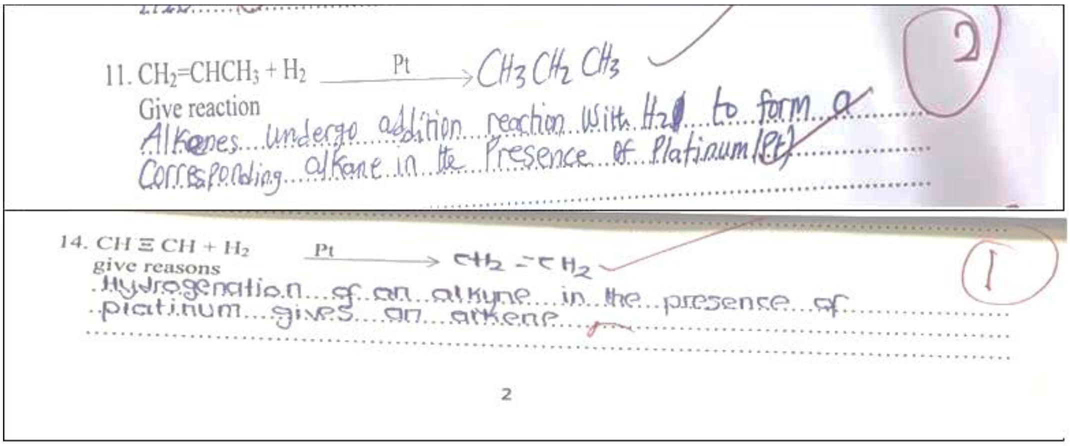

Figure 3: Students Conceptual Understanding of Hydrogenation Reaction

In both questions and in Figure 3, both students correctly scored the product by indicating that CH_2=$CHCH_3$ reacts fully with H_2/Pt to form an alkane ($CH_3CH_2CH_3$) and that CHΞCH partially reacts with one molecule of H_2/Pt to produce CH_2=CH_2. Both students understand the full and incomplete hydrogenation of the alkenes and alkynes to form the corresponding products. However, the students lack understanding of how the product is formed. They failed to explain that one mole of hydrogen in the two equations was able to break only one pi-bond in the CH_2=CH_2 and CHΞCH to produce $CH_3CH_2CH_3$

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and $CH_2=CH_2$, respectively. The explanations provided to substantiate how the products are formed show that they only partly understand the concept and therefore lack a full understanding of the concept of hydrogenation reactions. These results indicated that most students did not fully understand the concept of hydrogenation reaction. A further observation from Table 3 and Figure 3 shows that most students scored only one tier correctly in hydrogenation reaction, therefore their understanding level is unistructural (level 2).

Students' Conceptual Understanding of Halogenation Reaction

The test items under this thematic area assessed the students' knowledge and understanding of the concept of homolytic and heterolytic cleavages as applied in halogens and hydrocarbonhydrocarbon reactions respectively to form halo-alkanes. The students were required to exhibit knowledge and understanding that halogens (Cl_2 or Br_2) will undergo homolytic cleavage to form free chlorine radicals while the Carbon and Hydrogen in the hydrocarbons undergo heterolytic cleavages to form alkyl radicals to enable them to react**.** Table 4 shows the data distribution of students' responses to the concept of halogenation reaction.

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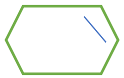
Table 4:- Distribution of Test Scores accords to students' levels of understanding in Halogenation Reactions.

	Levels of Understanding According to students' performance in percentages N=320					
ITEM	**No Answer (0)** Freq **(%)**	**Prestructural Level (1) Both tiers incorrect** Freq **(%)**	**Unistructural level (2) one tier correct** Freq **(%)**	**Multistructural level (3) Both tier partially correct** Freq **(%)**	**Relational Level (4) Both tier nearly correct** Freq **(%)**	**Extended abstract (5) Both tier fully correct** Freq **(%)**
$CH_4 + 4Cl_2$ UV light $\rightarrow$	11(3.4)	109 (34.1)	132 (41.3)	42 (13.1	9 (2.8)	17 (5.3)
$HC\Xi CCH_3 + Br_2 \rightarrow$	16 (5)	50 (15.6)	243 (76)	11 (3.4)	0 (0)	0 (0)
 $+ Br_2/CCl_4 \rightarrow$	51(15.9)	258 (80.6)	9 (2.8)	2 (0.6)	0 (0)	0 (0)
Ethane reacts with bromine in the presence of ultra violet light to form bromo ethane and hydrogen bromide.	12 (3.6)	63 (19.6)	226 (70.6)	15 (4.7)	2 (0.2)	2 (0.6)
Methane reacts with free radical chlorine to form tetrachloromethane	2 (0.6)	36 (11.3)	16 (5)	260 81.3)	0 (0)	2 (0.6)

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It can be observed from Table 4 that only 17 (5.3%) of the students fully understood the concept of methane reacting with chlorine in the presence of sunlight to produce tetrachloromethane and hydrogen chloride. But as many as 11 (3.4%) and 109 (34.1%) respondents did not answer or provided incorrect responses respectively. Also, the the majority of the respondents, 132 (41.3%) students scored only one of the tiers correctly, and for that were within the unistructural level (2) of understanding the concept. This indicates that many of them did not fully understand the concept of reacting methane and chlorine to form tetrachloromethane. The result from Table 4 further shows that, no student fully understood how to write and explain the equation involving alkyne ($HC\Xi CCH_3$) and bromine while as many as 16 (5%) and 50 (15.6%) students were not able to answer or provided incorrect answers respectively. Similarly, no student showed full understanding of reacting cyclo-alkane with Br_2/CCl_4, whereas 51 (15.9%) students and as many as 258 (80.6%) students did not answer or provided incorrect responses respectively. This indicated that the majority of the students did not understand the concept of halogenation reaction in organic chemistry.

With regards to writing equations from word reactions, the results from Table 4 show that only 2 (0.6%) of the students fully understood the concept of ethane reacting with bromine in ultraviolet light, whereas 12 (3.6%) and 63 (19.6%) respectively provided no answer and scored both tiers wrongly. A large number of 226 (70.6%) students scored only one of the tiers in the test correctly. Likewise, 2 (0.6%) fully understood the concept of writing equations from methane reacting with free radical chlorine to form

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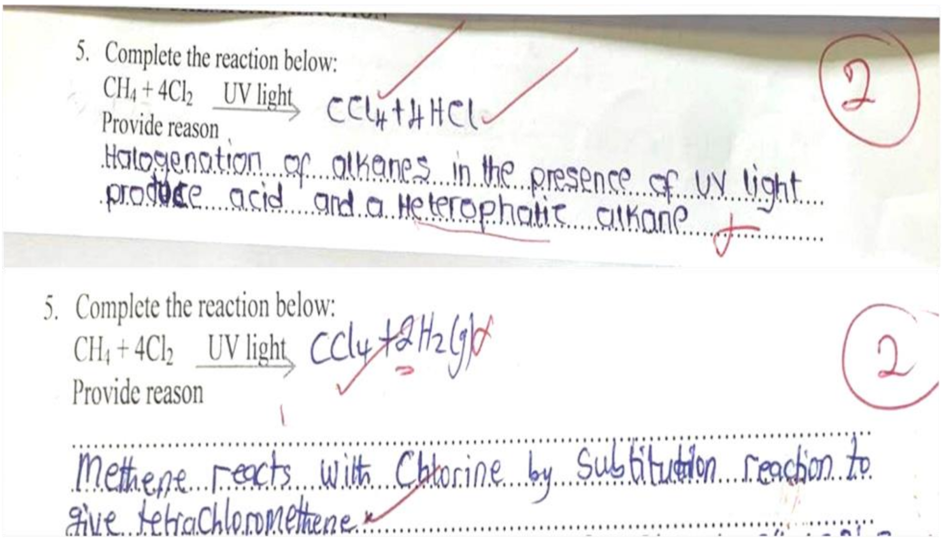
tetrachloromethane, while 2 (0.6%) and 36 (11.3%) were not able to answer the item or provided incorrect responses respectively.

The student's demonstration of conceptual understanding of the halogenation reaction is shown in Figure 4


5. Complete the reaction below:
$CH_4 + 4Cl_2$ UV light → CCl4 + 4HCl
Provide reason
Halogenation of alkanes in the presence of UV light produce acid and a Heterophalic alkane
2

5. Complete the reaction below:
$CH_4 + 4Cl_2$ UV light → CCl4 + 2H2(g)
Provide reason
Methene reacts with Chlorine by Substitution reaction to give tetrachloromethene
2

Figure 4: Students Conceptual Understanding of Halogenation Reaction

In Figure 4, two students discussed the main product (CCl_4) formed when CH_4 is halogenated in ultraviolet light. However, one of the students only included the balanced equation for the major and minor products of the reaction. This student correctly indicated that CH_4 reacts with $4Cl_2$ in ultraviolet light to produce CCl_4. The students also provided an explanation to support their answers. The reaction of CH4 and $4Cl_2$ is indeed a substitution reaction. However, the student needed to explain the cleavages occurring in C-H and Cl-Cl bonds to form the radicals and the product. Most of the students in this item provided partially correct responses in both tiers. The students have demonstrated that they were at the unistructural level of understanding of the concept by dealing with only one aspect of the concept of halogenation

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reactions and equations. These results show that students have insufficient conceptual understanding of halogenation reactions.

Students Conceptual understanding of Reaction of Unsaturated Hydrocarbons with Hydrogen Halide

Questions under this concept tested the knowledge and understanding of students in applying Markovnikov's rule to provide the products and write the equations of reactions involving unsaturated hydrocarbons with hydrogen halide. The students were required to apply Markovnikov's rule to explain which carbon, bearing the double or triple bond, receives the hydrogen and halogen respectively to show a full understanding of the concept. The results of the analysis are presented in Table 5.

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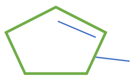
Table 5: Distribution of Test Scores according to Students' levels of understanding in Reactions and Equations of Unsaturated Hydrocarbon with Hydrogen Halide

Item	Levels of Understanding According to students' performance in percentages N=320					
	No Answer (0)	**Prestructural Level (1) Both tiers incorrect**	**Unistructural level (2) one tier correct**	**Multistructural level (3) Both tier partially correct**	**Relational Level (4) Both tier nearly correct**	**Extended abstract (5) Both tier fully correct**
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
$CH_3CH(Cl)CH{=}CH_2 + HBr \xrightarrow{AlBr3}$	2 (0.6)	76 (23.8)	216 (67.5)	20 (6.3)	3 (0.9)	0 (0)
 $CH_3 + HCl \rightarrow$	5 (1.6)	240 (75)	63 (19.7)	0 (0)	0 (0)	12 (3.7)
$C(CH_3)_2\ C{\Xi}C\text{-}H + 2HCl \rightarrow$	0 (0)	1 (0.3)	11 (3.4)	32 (10)	273 (85.3)	3 (0.9)

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It is evident in Table 5 that no student had a full understanding of the reaction between CH_3CH (Cl) $CH=CH_2$ and HBr in $AlBr_3$. Also, 2 (0.6%) students did not answer the question while 76 (23.8%) answered and scored it wrongly. As many as 216 (67.5%) students scored only one of the tiers correctly to be in the unistructural level (2) of understanding. This is an indication that the concept was not understood. The $AlBr_3$ might have confused the students in responding to the equation involving the CH_3CH (Cl)$CH=CH_2$ reacting with HBr. The students might have thought that the catalyst, AlBr3was part of the product. Similarly, only 12 (3.7%) students had a full understanding of the reaction between cyclo-alkane and HCl while 5 (1.6%) did not answer the question and as many as 240 (75%) students answered but scored both tiers wrongly. The inability of many students to understand the concept of applying Markovnikov's rule to write an equation involving cyclohexene and HCl could be due to a lack of conceptual understanding, and or teachers' inability to teach the concept. The results further show that only 3 (0.9%) had a full understanding of the reaction between $C(CH_3)_2$ CΞC-H and hydrogen chloride while 1 (0.3%) student had both tiers incorrect. It can also be observed that as many as 273 (85.3%) students nearly scored both tiers. Students might have understood this test item better than others.

In another view, Figure 5 presents students' responses and their conceptual understanding of reactions involving unsaturated hydrocarbons and hydrogen halides.

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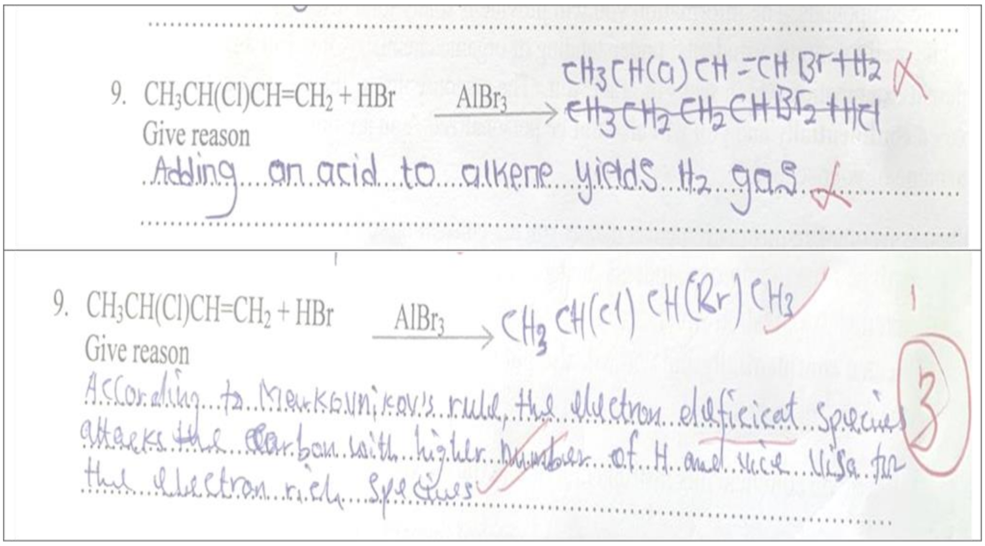

Figure 5: Students Conceptual Understanding of Reactions Involving Unsaturated Hydrocarbons and Hydrogenhalide

The responses of students in Figure 5 show that one of the students scored one of the tiers correct and was also able to apply Markornikov's partly to explain the concept of $CH_3CH(Cl)CH{=}CH_2$ reacting with HBr in $AlBr_3$ to form the haloalkane. However, the student was not able to generalize structure beyond what was given or perceived structure from many different perspectives and transfer ideas to show full understanding. The second student scored both tiers incorrectly because they responded essentially void of actual content or relation to the concept. The student has copied down the equation and the reaction. In general, the students have therefore demonstrated unistructural level of understanding of the reactions involving unsaturated hydrocarbons and hydrogen halides

Students' Conceptual Understanding of Oxidation Reaction

Test items in this area tested the knowledge of students on the products formed when alkanes, alkenes, alkynes and alkanols (primary and secondary

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alkanols) undergo oxidation reactions. The students needed to understand that the reaction of alkane and alkene with oxygen molecules forms CO_2 and H_2O and full oxidation of primary alkanol forms alkanoic acid. The results of the student's responses are shown in Table 6.

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Table 6: Distribution of Test Scores According to Students' Levels of Understanding in Oxidation Reactions

Item	Levels of Understanding According to students' performance in percentages N=320					
	No Answer (0) **Freq (%)**	**Prestructural Level (1) Both tiers incorrect** **Freq (%)**	**Unistructural level (2) one tier correct** **Freq (%)**	**Multistructural level (3) Both tier partially correct** **Freq (%)**	**Relational Level (4) Both tier nearly correct** **Freq (%)**	**Extended abstract (5) Both tier fully correct** **Freq (%)**
$CH_3CH_2CH_2CH_2CH_3 + 5O_2 \xrightarrow{heat}$	4 (1.3)	90 (28.1)	21 (6.6)	164 (51.2)	24 (7.5)	17 (5.3)
$CH_3CH{=}CH_2 + 9/2O_2 \xrightarrow{Excess\ air}$	7 (2.2)	103 (32.2)	171(53.4)	25 (7.8)	5 (1.6)	9 (2.8)
$CH_3CH_2CH_2OH + KMnO_4/H^+ \rightarrow$	6 (1.9)	49 (15.3)	253 (79.1)	4 (1.3)	1(0.3)	7(2.2)
Propan-1-ol is reacts with acidified potassium permanganate to produce propanoic acid	12 (3.8)	37(11.6)	261(81.6)	3 (0.9)	5(1.6)	2 (0.2)

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Table 6, shows that 17 (5.3%) students had a full understanding of the concept of $CH_3CH_2CH_2CH_2CH_3$ undergoing oxidation reaction while 4 (1.3) and 90 (28.1%) respective students provided no answer and scored both tiers wrongly. It can also be observed that 164 (51.2) students had both tiers partially correct as they scored the first tier of the question correctly and applied one aspect of the principles of the alkane undergoing combustion to form water and carbon dioxide through the free radical mechanism. This is an indication the concept is not well understood. Correspondingly, in reacting $CH_3CH{=}CH_2$ and oxygen, only 9 (2.8%) students had a full understanding of the concept; 7 (2.2%) students failed to answer it and as many as 103 (32.2%) students scored both tiers wrongly. As many as 171 (53.4%) students had only one of the tiers correct. The double bond in $CH_3CH{=}CH_2$ might have confused them in understanding the reactions. Similarly, the oxidizing agent, $KMnO_4/H^+$, might have confused the students to understand that $CH_3CH_2CH_2OH$ is oxidized by $KMnO_4/H^+$ to form CH_3CH_2COOH. As low as 7 (2.2%) students' responses show that they fully understood the concept, while 6 (1.9) students failed to answer the question, and 49 (15.3%) provided incorrect responses. As many as 253 (79.1%) students attempted and scored only one tier correctly. Comparatively, 7 (2.2%) students accurately wrote the equation involving propan-1-ol and acidified potassium permanganate to produce propanoic acid, while as many as 12 (3.8%) students did not write the equation and 49 (15.3%) students wrote the equation but scored both tiers wrongly. The students might have had problems writing the chemical formula of some organic compounds.

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To show full conceptual understanding, the students needed to indicate the complete oxidation/combustion of alkanes and alkenes from CO_2 and H_2O. A balanced equation is required to show the number of CO_2 and H_2O molecules formed after the combustion. The results of the student's responses are in Figure 6

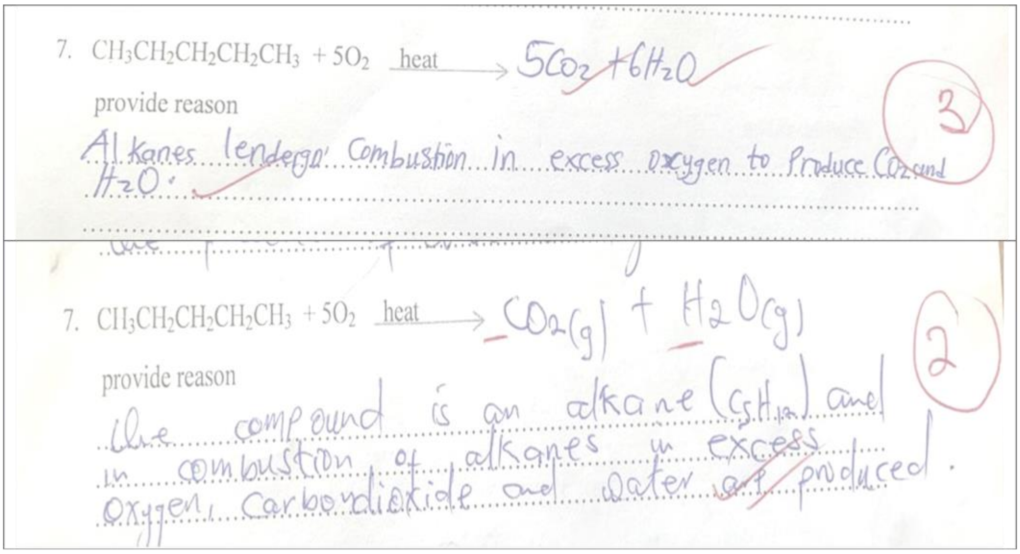

Figure 6: Students Conceptual Understanding of Reactions involving Oxidation

In Figure 6, A Student demonstrated an understanding that the combustion of $CH_3CH_2CH_2CH_2CH_3$ resulted in the formation of $5CO_2$ and $6H_2O$. Partial credit was achieved for this response. The student also mentioned that "the combustion of hydrocarbons produces CO_2 and H_2O," showing an obvious connection. However, the student failed to explain that during the combustion process, oxygen reacts with hydrogen to form water and with carbon to form carbon monoxide and carbon dioxide if there is an excess of carbon present. The explanation provided demonstrates a unistructural level of understanding, as the equation was provided accurately but lacked a substantiating explanation.

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In another student's response, the equation did not receive credit because it was not balanced. Additionally, although the students were able to identify the expected product, they did not provide a clear explanation of how the product is formed. Therefore, the students exhibited a unistructural level of understanding of the oxidation reaction. This is an indication that the concept is not well understood. Generally, students who responded to reactions and equations under oxidation provided the products without reasons and therefore the conceptual understanding level of students was at the unistructural level (level 2).

Students' Conceptual Understanding of Reactions Involving Hydration or Hydrolysis

The students were tested on applying the concept of Markovnikov's rule to respond to reactions and equations involving unsaturated hydrocarbons and water. The students were to show/explain which carbon in the alkene or alkyne received the H^+ and OH^- formed from water to break the pi-bonds to form sigma bonds. Table 7 shows the data distribution of the levels of understanding of students based on their responses.

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Table 7: Data Distribution of Test Scores According to Students' Levels of Understanding in Reactions Involving Hydration/Hydrolysis

Item	Levels of Understanding According to students' performance in percentages N=320					
	No Answer (0) Freq (%)	Prestructural Level (1) Both tiers incorrect Freq (%)	Unistructural level (2) one tier correct Freq (%)	Multistructural level (3) Both tier partially correct Freq (%)	Relational Level (4) Both tier nearly correct) Freq (%)	Extended abstract (5) Both tier fully correct Freq (%)
$CH_2 = CH_2 + H_2O \xrightarrow{} H_2SO_4$	5 (1.6)	4 (1.6)	22 (6.9)	85 (26.6)	182 (59.1)	15 (4.7)
$CH_3C \equiv CH + \rightarrow H2O$ $HgSO_4$/Heat	2 (0.6)	44 (13.8)	257 (80.3)	15 (4.7)	2 (0.6)	0 (0)
Hydration of 2-methylpropene to produce –methylpropan-2-ol	12 (3.8)	42 (13.1)	168 (52.5)	87 (27.2)	5 (1.5)	6 (1.9)

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It can be observed from Table 7 that only 15 (4.7%) of the students had a full understanding of the concept of reacting CH_2=CH_2 with water, whereas 5 (1.6%) did not answer and 4 (1.3%) answered but scored both tiers wrongly. It is also clear from Table 5 that as many as 182 (59.1%) students’ responses were nearly correct. In CH_2=CH_2, only one pi-bond is broken by the hydrogen in water, which might be the reason why 182 (59.1%) students in level 4 scored the content and applied partly the rules to explain how the product is formed. This performance still shows that the students did not understand the concept fully. In applying the same principles to write the product of reacting CH_3C Ξ CH with one molecule of water, no student fully understood the concept, while 2 (0.6%) students did not answer, as many as 44 (13.8%) provided incorrect responses. A large number of 257 (80.3%) students scored only one tier correctly. Students might have failed to understand that one pi-bond in CH_3C Ξ CH is broken. Similarly, the performance of students in writing an equation of hydrating methylpropene was also fair as many of the students scored only the content. It can be observed that only 5 (1.6%) of the students had a full understanding of the concept, 12 (3.8%) and 42 (13.1%) did not answer and provided incorrect responses respectively. It is, therefore, clear that a large number of 168 (52.5%) scored only one tier correctly. This is evident that the concept is not well understood. The methyl substituent might have confused the students in not writing the equation very well.

The students failed to apply Markovnikov's rule to explain the reaction of unsaturated hydrocarbons with water to prove that the concept is understood. The students' responses to show how the concept was understood are depicted in Figure 7.

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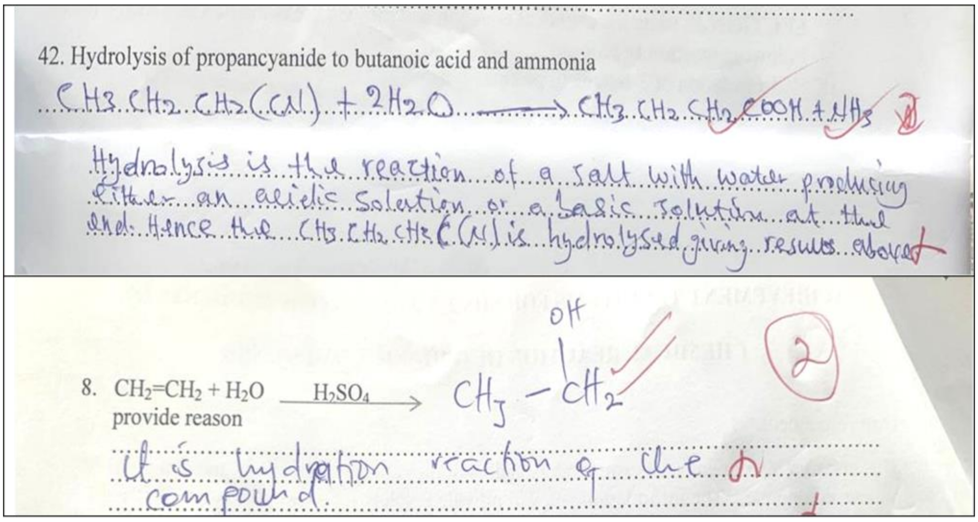
42. Hydrolysis of propancyanide to butanoic acid and ammonia

CH3.CH2.CH2(CN) + 2H2O → CH3.CH2.CH2COOH + NH3

Hydrolysis is the reaction of a salt with water producing either an acidic solution or a basic solution at the end. Hence the CH3.CH2.CH2C(N) is hydrolysed giving results above

8. CH_2=CH_2 + H_2O $\xrightarrow{H_2SO_4}$ CH3 – CH2 (OH)
provide reason

It is hydration reaction of the compound.

Figure 7: Students Conceptual Understanding of Hydration Reaction

The student response for item 42 in Figure 7 indicates a correct understanding of the equation for the hydrolysis of propancyanide to produce butanoic acid and ammonia. However, the student did not mention that the H_2O molecule breaks the pi-bonds in the CΞN and gets oxidized to form the butanoic acid. In item 8, the student correctly indicated that CH_2=CH_2 reacts with H_2O in H_2SO_4 to produce CH_3CH_2OH. However, both students failed to explain how the product formed relates to the concept of Markovnikov's rule. The students' responses indicate an unistructural level of conceptual understanding in hydration/hydrolysis reactions and equations, as they only provided responses that allowed them to score one tier of the questions correctly. Generally, the data, as in Figure 7, described the conceptual understanding level of students in hydration/hydrolysis reaction as Unistructural level (level 2), as many scored only one of the tiers correct.

Students’ Conceptual Understanding of Esterification Reaction

Test items in this concept assessed the knowledge and understanding of students on the Fischer esterification reaction process between primary alkanol and alkanoic acid in the presence of an acid catalyst, heat to form alkyl

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alkanoate and water. The students were required to understand which species (alkanol or alkanoic acid) donate the proton (H^+) or hydroxyl (OH^-) respectively to form water. The results are displayed in Table 8.

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Table 8: Data Distribution of Test Scores according to students' Levels of understanding on Esterification Reaction

	Levels of Understanding According to students' performance in percentages N=320					
Item	**No Answer (0)** **Freq (%)**	**Prestructural Level (1) Both tiers incorrect** **Freq (%)**	**Unistructural level (2) one tier correct)** **Freq (%)**	**Multistructural level (3) Both tier partially correct** **Freq (%)**	**Relational Level (4) Both tier nearly correct)** **Freq (%)**	**Extended abstract (5) Both tier fully correct** **Freq (%)**
$CH_3COOH + CH_3OH/H_2SO_4 \rightarrow$	9 (2.8)	17 (5.3)	56 (17.5)	209 (65.3)	3 (0.9)	26 (8.1)
Ethanol reacts with ethanoic acid in the presence of conc sulphuric acids and heat to produce a sweet scented ethyl ethanoate.	9 (2.8)	89 (27.8)	171 (53.4)	22 (6.9)	3(0.9)	26 (8.1)

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From Table 8, only 26 (8.1%) applied the principles of the Fischer esterification reaction process in writing the equation and providing the appropriate explanation to substantiate the product formed; therefore can be described as having a full understanding of the concept. It has also been observed that 9 (2.8%) students did not answer the question, while as many as 17 (5.3%) students provided incorrect responses. It is also clear from Table 8 that as many as 209 (65.3%) of the students had scored partly both tiers in the reaction involving CH_3COOH and CH_3OH. Likewise, the responses of students in writing the equation from the reaction between ethanol and ethanoic acid in the presence of sulphuric acid and heat had similar responses of 26 (8.1%) students having a full understanding of the concept, 9 (2.8%) providing no answer and as many as 89 (27.8%) providing incorrect responses. The results further indicated that as many as 171 (53.4%) of the students scored only one tier of the question. It can, therefore, be juxtaposed that students had problems understanding the concept of esterification reactions and equations.

Furthermore, the student's responses and demonstration of conceptual understanding of esterification reactions and equations are in Figure 8

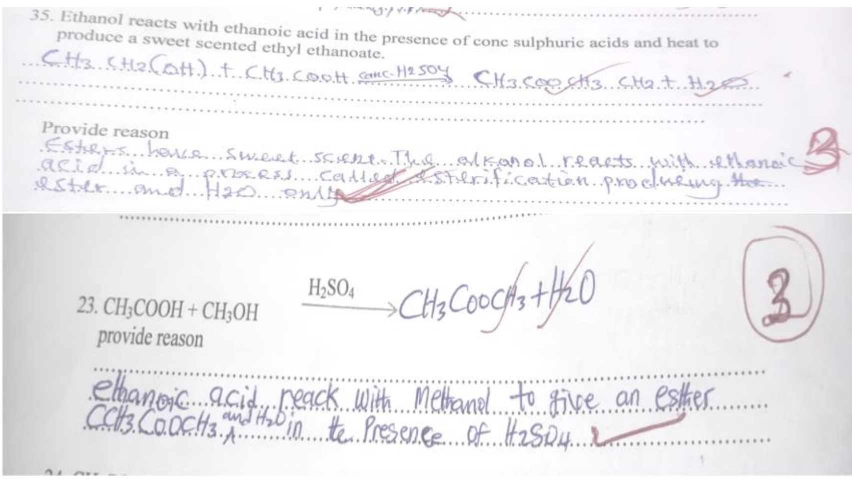

Figure 8: Students understanding of esterification reaction

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In items 35 and 23 of Figure 8, the students have correctly provided the chemical reactions for the production of alkyl alkanoates from ethanoic acid and ethanol, as well as from ethanoic acid and methanol in the presence of sulphuric acid. In item 35, the student has included a partial explanation, demonstrating some content knowledge. However, the student failed to provide a clear explanation of the reactants producing H+ and OH- respectively. The explanation provided in item 23 indicates that the student lacks a full understanding of the concept, as they provided an incorrect reason. The assessment score of 3 shows that the students partially met both tiers, indicating a multistructural level of understanding. The inability of many students to understand the concept could be a result of teachers' inability to teach the chemical equations along with the formula of organic compounds**.**

Reasons accounting for students' conceptual understanding of chemical reactions and equations of carbon compounds

The objective of the third research question was to identify the reasons accounting for SHS students' conceptual understanding of chemical reactions and equations of carbon compounds. Interview data were used to answer this research question. Seven students who sat for the achievement test were interviewed. The interviewees were selected based on their scores in the test. The number of interviewees was determined as a result of saturation of responses. According to Briones, Dagamac, David and Landerio (2021) parenting style, characteristics of the students, effective internet, teachers The objective of the third research question was to identify the reasons accounting for SHS students' conceptual understanding of chemical reactions and equations of carbon compounds. Interview data were used to answer this

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research question. Seven students who sat for the achievement test were interviewed. The interviewees were selected based on their scores on the test. The number of interviewees was determined as a result of saturation of responses. According to Briones, Dagamac, David and Landerio (2021) parenting style, characteristics of the students, effective internet, teachers' effectiveness, motivation, and student's career choice are inside and outside factors influencing students' academic performance. Based on Briones et al (2021) view the interview data was analysed thematically as teacher-related reasons, home-related reasons, examination-related reasons and Ghana Education Service rules.

Teacher Reasons

The interview conducted revealed that teachers teach the concept of reaction and equations of carbon compound in abstract and this makes the learning of the concept difficult. Excerpts are:

Student 2 "*Sir, When the teacher does not write the chemical equations, for instance some teachers, they only tell you that the reaction between alkanoic acid and alkanol acid will produce an ester. But if he says this without illustrated examples, I may not get the understanding well; also… So when illustrations and a lot equations and examples are used during teaching, I think I get the understanding better...*"

Student 1*: "aaam organic chemistry is taught mostly in class, we don't go to the laboratory"*

Students 3*: "Okay, so on our part, organic chemistry is just taught on board, so we don't have access to do experiments or even illustration for us to understand."*

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Student 6*: "We don't do practicals to to enable us understand what we need to know"*

These excerpts have explained that organic chemistry, and for that matter its reactions and equations are taught in abstract. The inability of teachers to illustrate the concept on board to enhance conceptual understanding may be due to a lack of knowledge of the concept.

Some teachers did not cover the syllabuses under study before the students sat for their mock and WASSCE examinations. This may affect their performance because they have not been taught. Excerpts are:

Student 1 "*…emm yes because for now we are preparing for our mock and there are some topics we have not gotten to…" and "Teachers do not even get there properly, so we don't understand* "

Student 2 *Student: "yea we have not gotten there with the teacher*"

Student 6*:* *"Eeeh, Sir, organic chemistry, I learnt it on my own. This is because we have no reach there yet"*

Student 7: "*Please Sir, organic chemistry, we have not reach there, I read it on my own to understand. It is this year we have a chemistry teacher" …Yes. Since the teacher came we have not had any lesson on organic chemistry. eeem we have not done any practical to make us understand what we need to know…"*

These statements revealed that teachers did not teach some of the topics in chemistry, especially organic chemistry. Students may perform poorly when they are not taught. The inability of teachers to cover an aspect of the syllabus could be due to the difficult nature of the concept or the syllabus being too loaded. It could also be that the teacher is lazy or truant.

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Teachers' inability to incorporate Information Communication Technology (ICT) and computer stimulation makes the teaching and learning of chemistry difficult. According to:

Student 2 "*…when the teacher uses a computer to project the chemical reactions, to show how the reaction comes about, for instance, emm let say combustion, decomposition reaction when illustrated on the board to show how molecules are broken down to form a product. Next time when I am asked such a question or anything related to that, and I visualise or try to picture out what the teacher did on the board, I think I get it…"*

Student 4 "*Sir the reaction in the, the lessons on reaction, if they are taught, like in, by abstract means without the practicals, it becomes difficult for us to understand because we have to see. I ever saw a teaching with computer and it was understandable. But here, sir, no computers for the teachers to use. That is making organic chemistry difficult"*

The inability of teachers to integrate ICT in their lesson delivery could be due to inadequate ICT tools in the schools. Teachers might lack the pedagogical knowledge to use the ICT tools in their lesson delivery. The inability to use computer simulation in teaching reactions and equations has the propensity to affect students' achievement. Computer simulation enhances conceptual understanding as students see the bonds broken and the bonds formed in animation.

The Home reason

It was also revealed that parents engage their wards in house chores and economic activities which prevents them from studying after school. Students who are not able to constantly learn concepts perceived to be difficult

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are bound to develop conceptual understanding problems. Parents engaging their wards in activities to prevent them from learning may be due to illiteracy or poverty. With this, **Student 6** in an interview had this to say, '*Sir I am from a village. After school I don't always eeeh have enough time to study. if I don't go to farm my father will refused to give me lorry fare to come to school…… Yes Sir. Sir the farm, the food preparation. By the time I finish doing all, sir I am always tired…*

On the part of **Student 7** "*Sir as I said, cooking, fetching of water and farm will not allow me learn. I am always tired after all these work. I can't study after all these Sir"* These make the students not able to study during holiday. There is therefore the possibility that they may forget concepts learnt.

Examination Reason

The study revealed that students study the concept of reactions and equations to pass the examination. Three students have something to say regarding studying for examinations and studying to develop conceptual understanding. For instance, according to the interview:

Student 3 said, "…*So I keep learning, them just, for exams purposes, and, maybe whatever comes next. But for now, the motivation is just for exams."*

In view of **Student 6** "… *In fact, sir I try to chew and when it it comes in exams I try to pour. Sir but that one too, it is difficult sir... All that I am doing is just to enable me pass my WAEC chemistry."*

Student 7*: Sir, My biggest worry is the Mock and WAEC. I am praying that WAEC shouldn't set plenty questions from organic chemistry, if not I will fail chemistry.*

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Students are focusing on passing the West African Senior Secondary Certificate Examination (WASSCE) without necessarily developing a deep understanding of the concepts. This means they may not be able to apply what they have learned to solve real-life problems. Instead of truly grasping the concepts and using them to tackle challenges, students are primarily concerned with performing well in exams. This approach could result in mere memorisation of information.

Ghana Education Service Rules

The study has revealed that students use smartphones, computers and data to access internet for information when they are at home. **Student 4** indicated that '…*Ammm my family personally provided me with a computer with which I can study certain things with it* …' *"...In addition I am also provided with computer or this thing, a smartphone that I can download the organic chemistry reactions and things so that I can learn and get the understanding* **Student 2**. *I only have access to one You Tuber. That's Melissa Marebel, she is an organic chemistry tutor. And then there's even another YouTube channel that is organic chemistry, tutors (Student 3).* In development, student 4 said *" ammm basically if you follow GES website, if you follow youtube and programmes you can get them. I don't have a concrete website I can mention for you".*

Student 5 *"Sometimes, when I want to watch videos, I go to youtube and sometimes I go to bitmit. Most at times too I go to google so that I will go and search to see how the reaction undergo and when they write on a paper then I will see how this one will go and bond and there all those things"* All these statements suggest that students use computers, smartphones and data to

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access information online. It further revealed that students know the relevant websites (YouTube, GES website, Google, chemistry teacher, etc) to get videos and animations to aid their learning. Therefore, students apply 21st-century skills to learn privately during holidays.

However, Ghana Education Service rules and regulations do not permit SHS to possess and use mobile phones, computers and their accessories in school. These facilities are not made available in some schools for students and teachers to use for teaching and learning. The accessibility of students to the internet, computers and smartphones may help teachers and students to design and adopt other models of teaching and learning to enhance conceptual understanding. When these are not provided, it hinders students' ability to understand the concept.

Discussion of Results

The discussion was conducted in line with the research questions. The first research question aimed to explore students' understanding of chemical reactions and equations involving carbon compounds. The discussion covered the following thematic areas: hydrogenation reaction, halogenation reactions, reactions of unsaturated hydrocarbons with hydrogen halide, oxidation reaction, reactions involving hydration or hydrolysis, and esterification.

In general, less than 25% of the total 320 students demonstrated a full understanding of the concepts related to chemical reactions and equations. This included hydrogenation, halogenation, oxidation, hydration/hydrolysis, esterification, and the addition of hydrogen halide to unsaturated hydrocarbons. This might be attributed to Newell's (2012) perspective that the reactions of organic compounds are associated with the type of reaction, the

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compound's structure, and the functional group, making it challenging for students. The students' performance could also be linked to their inability to study at home and teachers skipping certain aspects of the reactions and equations. Additionally, the teachers' inability to teach without the necessary teaching and learning resources (such as computer-assisted animations and molecular models), as well as the students' lack of access to computers, smartphones, and the internet for personal studies, may also contribute to the reasons behind the students' performance. An interview statements from **Student 6** "*We have not not reach there with the teacher. mmmh, I tried learning it on my own and I don't get the understanding because of the terminologies and language"...* and **(Student 1**) "*…emm yes because for now we are preparing for our mock and there are some topics we have not gotten to. The teacher hasn't taken us through and me per-say when I learn them on my own the understanding is not as compared to the teacher teaches me, I want to be taught before the final exam…"* have confirmed that students sometimes are not taught some of the concepts. "*… After school I don't always eeeh have enough 19time to study. if I don't go to farm my father will refused to give me lorry fare to come to school" (***Student 6)"** and *"…The farm and cooking will not allow me to learn…* **(Students 7)"** are statements to suggest that the home is a contributory factor to students' inability to study instructional hours. The students, therefore, lack conceptual knowledge on the principles of proposing products and conditions of the types of reaction.

It was found that many students did not fully understand chemical equations and word chemical reactions. As a result, they either left these test items unanswered or answered them incorrectly. A possible reason for this is

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that the students may have had difficulty with the naming and chemical/structural formula of some organic compounds. This supports the view expressed by Adu-Gyamfi, Ampiah & Appiah (2013) that students struggle with the structural formulae of organic compounds. It is also possible that the assertion made by Kelley & Hansen (2017) that students have difficulty relating symbolic equations to the particulate nature of events in a chemical reaction is true. Additionally, many students may be focused on passing examinations rather than developing a conceptual understanding. The majority of the students failed to provide a clear explanation for the chemical equations, leaving the space unanswered or filling it with irrelevant content, indicating inadequate understanding. It is likely that teachers may have lacked the pedagogical knowledge to effectively incorporate ICT and other teaching aids to make their lessons more tangible and concrete. Therefore, the understanding level of students in responding to test items that required a chemical equation when given the chemical reaction was at a prestructural level (level 1). Furthermore, it was revealed that students do not have a full conceptual understanding of hydrogenation reactions and equations. Many students scored only one of the tiers correct in test items related to hydrogenation reactions. While students were able to provide the product and/or write some equations, they failed to substantiate their answers with an explanation, indicating a lack of full conceptual understanding. They also failed to apply the rules or principles underlying the reactions and equations. It is possible that these students may have memorized the reactions and equations without truly understanding them. **Student 6** statement"…*Infact, sir I try to chew and when it it comes in exams I try to pour. Sir but that one*

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too, it is difficult sir" has confirmed that students sometimes memorised concepts to reproduce in examination. These have confirmed Bhattacharyya and Bodner's, (2005); Salame and Hodges', (2020) assertion that students are able to predict answers without understanding how the answers are arrived at. Also, this finding is in line with the view of Krajcik (2009) that students try to memorise concepts and bring them out in an examination setting without understanding. These could mean that students are interested in passing examination rather than developing conceptual understanding. Statement from **Student 6** "*eeeh Sir. my problem is the WAEC we are about to write. I am learning but I am praying that WAEC doesn't bring a lot of organic questions. All that I am doing is just to enable me pass my WAEC chemistry. I don't want to sit for NOVDEC"* has confirmed some students learning to pass examination. Some teachers' inability to cover the teaching content may have led students to learn on their own, impacting their performance. This has been established by **Student 1** statement that "*emm yes because for now we are preparing for our mock and there are some topics we have not gotten to. The teacher hasn't taken us through and me per-say when I learn them on my own the understanding is not as compared to the teacher teaches me, I want to be taught before the final exam".* The inability of students to watch videos or animations of how some reactions proceed could be the reason underlying the low conceptual understanding. Furthermore, a student who needed to explain that H_2/Pt breaks one pi-bond in CH≡CH to form CH_2=CH_2 provided a general explanation that "*adding hydrogen to an alkyne in the presence of platinum catalyst gives an alkene."* This suggests that the student is capable of presenting equations without detailed explanation. This observation supports

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Anim-Eduful and Adu-Gyamfi's (2023) assertion that students may possess alternative conceptions, indicating a lack of understanding rather than a lack of knowledge. The understanding level of students in hydrogenation reactions were unistructural level.

In halogenation reaction, the findings show that students do not have conceptual understanding, especially reactions and equations involving cyclo-compounds. This is because many of the students scored both tiers incorrect or provided no answers to reactions and equations involving cyclo-compounds. A student scored the product of cyclohexene reacting with Br_2/CCl_4 but unable to explain how the cleavages occurred between the C-H bonds in the cyclohexene and the Br-Br bonds to form the 1,2-dibromo hexane. In an attempt, the student explained that " *the Br_2 attacks the double bond thus reducing it to a single bond"*. This explanation is inaccurate and void of the content. Also, **Student 1** statement "…*Yea actually, the concept yes the type of reaction part especially the reaction part, the halogenation and the other concept is very difficult to understand"* has confirmed that the students perceived halogenation reactions and equations to be difficult. The assertion of Donkor (2017) suggests that teachers may skip certain concepts during teaching, which may be true when comparing the test results of cyclo-compounds and other areas. It is possible that the students lacked a sufficient understanding of halogens undergoing homolytic cleavage and the carbon and hydrogen (C-H) in hydrocarbons undergoing heterolytic cleavage to form free radicals, which would enable them to react and form the product. Additionally, the involvement of parents in extracurricular activities might have affected the students' study time. This is consistent with the findings of MolokoMphale and

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Mhlauli (2015), who reported that inadequate study time, is one of the factors hampering academic performance, as students with less study time tend to perform poorly.

Similarly, in reactions and equations involving unsaturated hydrocarbons and hydrogen halide, the results show that students did not fully understand the concept. The catalyst, $AlBr_3$, might have confused the students to score only one of the tiers correct. In attempting to explain how they arrived at the answers regarding the reaction of $CH_3CH(Cl)CH{=}CH_2$ and $HBr/AlBr_3$ to produce $CH_3CH(Cl)CH(Br)CH_3$, the students indicated that "*it is the reaction of an alkene with a hydrogen halide (Br, Cl or I) in the presence of $AlCl_3$*" and "*adding an acid to an alkene yields H_2 gas."* HBr is an acid, however, its reaction with CH_3CH $(Cl)CH{=}CH_2$ is different from typical acid-base reactions. These responses therefore, indicate that the students lack a conceptual understanding of Markovnikov's rule in chemical reactions and equations. Equally, the methyl substituent in the cyclo-compound might have confused the students not to apply the Markovnikov's rule to write the product and explain the procedure accurately. The performances mentioned confirm Johnstone's (1980) Concorde diagram concept, suggesting that certain information may hinder students from understanding some concepts and cause them to find them difficult. This is supported by O' Dwyer & Childs (2017), Baah & Ampiah (2012), and Sirhan (2007), who believe that learners struggle to comprehend the chemical properties of carbon compounds due to language barriers. As a result, students may end up with a superficial understanding, (Badie, 2016). Shallow conceptual understanding influences the students to practice rote memorization to pass their examination (Krajcik, 2009).

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Superficial understanding could lead students to resort to rote memorization for passing exams, which goes against the meaningful learning advocated by the human constructivism theory of Ausubel (1963) and Novak (1993). The difficulties students face in grasping concepts may be attributed to teachers' pedagogical methods and their inability to effectively teach the content. Additionally, the lack of utilization of computer simulations and 3D models in teaching, as noted by Kelley and Hansen (2017) and Shi-Jer, Hui-Chen, Ru-Chu, and Kuo-Hung (2012), may impede students' development of a conceptual understanding of chemical properties. Teachers who fail to incorporate these tools may inadvertently contribute to students' superficial understanding of the concepts. Consequently, students learning chemistry may not perceive organic reactions as difficult if these teaching obstacles are addressed.

The results show that the students did not have full conceptual understanding of oxidation reaction. In oxidation reaction, they provided a balanced equation and lack the requisite rules and principles underpinning the reaction. The student was able to predict the products of the reaction between $CH_3CH_2CH_2CH_2CH_3$ and $5O_2$ in excess air, which produces $5CO_2$ and $6H_2O$. However, they did not explain the process of how the oxygen and hydrogen combine to form water, or how carbon forms carbon monoxide and carbon dioxide if present in excess. This suggests that while the student can predict the products, they struggle to interpret the underlying reactions. The statement by Anim-Eduful and Adu-Gyamfi (2023) suggests that students are better at providing factual responses than explaining the reasoning behind those responses. In this case, the student demonstrated partial understanding by

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predicting the products correctly, but failed to fully grasp the conceptual understanding of the reaction. The students might have understood structure-property relationship between alkane and oxygen molecule (Sevian and Talanquer, 2014) which is why they scored both tiers partly to be in the multistructural level (level 3). The hydroxyl functional group might have also confused the students not to understand the product formed when primary alkanol is fully oxidized. **Student 3** statement that "*organic chemistry is just taught on board, so we don't have access to do experiments or even illustration for us to understand. Most of the things are just theoretical. Sometimes it can be very complex"* could be the reason some student getting confused on some concepts. This confirms Uchegbu, Amandze & Ahuchaogu's (2017) opinion that students perceive organic chemistry to have so many theories and molecular structures, and which makes them have difficulty understanding its chemical reaction concept. Students viewing YouTube videos and animations on their smartphones and computers could improve their conceptual understanding. However, the ban on the use of personal computers and smartphones, and teachers' inability to download and use these tools in teaching could be the reason for the low conceptual understanding.

The results further revealed that the students did not have full understanding of organic compounds undergoing chemical reaction with water. That might explain why a student scored both tiers of item 15 wrong when asked to provide the product of $CH_3CH{\equiv}CH$ reacting with H_2O in $HgSO_4$ at 60°C to produce $CH_3CH(OH)CH_3$. The student incorrectly explained that "*hydration of an alkyne gives alkene*." This explanation doesn't

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relate to the topic, indicating that the student has factual difficulties (Anim-Eduful & Adu-Gyamfi, 2022) with the hydration reaction. The students might have problem understanding that water undergoes ionization to form H^+ and OH^- to enable it react. The students might not have understood that reactions between unsaturated hydrocarbons and water obey Markovnikov's rule. These might have influenced their understanding that only one pi-bond would be broken by the one molecule of water. All these are in line with O'Dwyer's (2012) assertion that students have conceptual problem because they find it difficult to interpret the concept. Adu-Gyamfi, Ampiah & Appiah (2013) are of the opinion that students have problem with the structural formulae of organic compounds could be the reason why the students have problems understanding the concept of writing an equation from 2-methylpropene undergoing hydration to form methylpropan-2-ol. The respond "*Alkenes react with water in the presence of* $HgSO_4$ *to yield alcohols*" inaccurately describes the reaction of 2-methylpropene with water to produce 2-methylpropan-2-ol. Students not having enough time to study and teachers pedagogy could be the reason underlying the conceptual difficulty. Therefore, the understanding level of students in reactions that required hydration/hydrolysis was at the unistructural level (level 2).

The results showed that students have partial conceptual understanding of esterification reaction. For example, when presented with an equation involving esterification reaction, most students correctly identified that CH_3COOH reacts with CH_3OH in the presence of H_2SO_4 to yield CH_3COOCH_3 and H_2O. However, they failed to fully explain how the reaction occurs, particularly in identifying which species donated the H^+ and OH^- to

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form the product. Responses such as *"in esterification reaction, the reaction occurs between alkanoic acid and alkanols, alkyalkanoates or esters"* or "*neutralization reaction of two bases in the presence of* H_2SO_4 *making one of the bases an acid, thus yielding salt and water*" or "*Alkanoic acids react with alcohol, giving an ester and water*" are inappropriate to demonstrate full conceptual understanding of how alkylakanoates are formed in esterification reaction. The students' performance indicates that they have dealt with two aspects of the concept; therefore, their understanding is at a multistructural level (level 3).

Adversely, the conceptual understanding of students in translating word reaction into chemical equation is at the unistructural level. In view of **Student 2** "*…When the teacher does not write the chemical equations, for instance some teachers, they only tell you that the reaction between alkanoic acid and alkanol acid will produce an ester. But if he says this without illustrated examples, I may not get the understanding well"* might have been the underpinning reason for their performance. Teachers might have taken their students through practical activities which is why **Student 1** made the statement that "*…but for example this esterification we are told any anything mostly the esters they are sweet scented. I don't know the sweet scented chemicals are esters and when I am learning I get new ideas…"* The chemical formula of some organic compounds might have influenced their performance. The students have mentioned that they are aware of websites where they can access videos, simulations, animations, and other helpful learning tools to assist in their studies. Some parents have also provided their children with smartphones and computers. However, according to Aggor, Tchao, Keelson,

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and Daiwuo (2020), the rules of the Ghana Education Service (GES) prohibit students from using mobile phones in schools. Additionally, some Senior High Schools lack computer laboratories, and the few laboratories available do not have internet connectivity for students to use for learning. The use of computers, smartphones, and internet facilities would enable students to access educational videos and integrate information and communication technology (ICT) into their learning process (Aggor, Tchao, Keelson & Daiwuo, 2020). The use of ICT tools would have also assisted students in studying areas they struggle with or have not covered with their teachers. Therefore, the G.E.S rules prohibiting students from using mobile phones, personal computers, and related accessories appear to hinder students from engaging in independent studies aimed at improving their conceptual understanding, especially in the chemical concept of organic chemistry. Overall, the students' understanding levels of concepts such as the hydrogenation reaction, halogenation reactions, reactions of unsaturated hydrocarbons with hydrogen halide, oxidation reactions, and reactions involving hydration or hydrolysis were at a basic level, while the understanding of esterification reaction was at a more advanced level. The reasons contributing to the students' performance were attributed to teachers, home environment, exams, and the rules of the Ghana Education Service.

Chapter Summary

Research question one used achievement test items to determine the students' conceptual understanding levels based on SOLO Taxonomy on hydrogenation reaction, halogenation reaction, reactions of unsaturated hydrocarbons with hydrogen halide, oxidation reaction, reactions involving

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hydration or hydrolysis, and esterification. The SOLO Taxonomy guide was applied to analyse the achievement test results and categorise students under the following conceptual understanding levels: prestructural level (level 1), unistructural Level (Level 2), multistructrual level (level 3) relational level (level 4) and extended abstract level (level 5). The general performance of students were as bad as 1% and as good as 87%. However, students' conceptual understanding in esterification reactions were multistructural (level 3). This means that the students were able to write the reactions and equations and substantiated their answers with part one way of the reason.

Generally, in halogenation reaction; oxidation reaction; hydration reaction; reaction involving unsaturated hydrocarbons and hydrogen halide the data revealed that students' conceptual understanding was at the unistructural level (level 2). This is means that majority provided reactions and equations correctly without indicating how they arrived at the answers. The students might have memorised the concept and reproduce it. Students generally have problems writing the chemical equations when the reactions are given. This was attributed to teachers, home, examination and Ghana Education Service rules as reasons difficulty in writing chemical formula of organic compounds.

An interview guide was also used to collect data for the reasons accounting for students' conceptual understanding of chemical reactions and equations of carbon compounds. The interview data provided reasons under the following thematic areas: teacher-related reasons, home-related reasons, examination related reasons and Ghana Education Service rules.

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CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Overview

This chapter highlights the key findings, recommendations and conclusions on chemistry students' conceptual understanding of chemical reactions and equations of carbon compounds. The chapter also makes suggestions for future research to enable educators and researchers deal with all facets of the concept.

The purpose of the study was to investigate Senior High School students' conceptual understanding in chemical reactions and equations of carbon compounds. To achieve this, the following research questions were answered:

1. what are Senior High School students conceptual understanding levels on chemical reactions and equations of carbon compounds?
2. What reasons account for students' conceptual understanding of chemical reactions and equations of carbon compounds?

The study utilised the explanatory sequential mixed method. Quantitative data on reactions and equations involving hydrogenation, halogenation, unsaturated hydrocarbons, hydrogen halides, oxidation hydration/hydrolysis, and esterification was collected using an achievement test from a sample of 320 students in the Upper West Region. Additionally, 7 students were interviewed to better explain and understand the reasons for the conceptual understanding of the students in the study area. The achievement test results were analyzed using descriptive statistics, precisely, frequencies, and percentages.

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The SOLO Taxonomy guide was adopted to help determine the conceptual understanding levels of the students on achievement test items involving chemical reactions and equations of carbon compounds. The purpose of using the SOLO Taxonomy was to help put the students into understanding levels.

The qualitative portion of the study, particularly the interview data, was analyzed using thematic analysis (Braun & Clarke, 2006). The qualitative data was utilized to provide additional insight into the quantitative data. The interview results offered explanations for the conceptual understanding of carbon compound reactions and equations. The interview data was further used to determine the reasons behind students' comprehension of chemical reactions and equations involving carbon compounds..

Summary of Key Findings

The key findings are presented in line with the research questions of the study as follows:

1. a) Students did not fully understand the concept of hydrogenation reaction. Therefore, their understanding level according to SOLO Taxonomy was unistructural. In hydrogenation reaction, most of the students scored one of the tiers correct but failed to apply the rules/principles/theories to explain how the pi-bond is broken in the unsaturated hydrocarbon by the hydrogen. Therefore, the students' performance in the achievement test shows that most of the students did not grasp the concept of reactions and equations of carbon compounds.

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b) In halogenation reactions the results of the study revealed that the students did not have full conceptual understanding. The conceptual understanding level of students in writing equations and or deducing reactions involving cyclo compounds and halogens was prestructural level. This indicated that majority scored both tiers incorrectly or provided no answers

c) The results of the study further revealed that the students have inadequate conceptual understanding of reactions involving unsaturated hydrocarbon and hydrogen halide. The study revealed that reactions and equations with catalysts were poorly understood. Many students failed to apply the Markovnikov's rule to respond to the test item and therefore scored one of the tiers correct. Their understanding level is unistructural (level 2), according to the SOLO Taxonomy.

d) For reactions involving hydration/hydrolysis, it was established that the students have conceptual problem in writing an equation of hydrating methylpropene. The students also had insufficient conceptual understanding of partially hydrating an alkyne. Their understanding level is unistructural as they were able to score one of the tiers correctly.

e) In esterification reaction, students' conceptual understanding level was at the multistructural in writing the products from the reacting species. However, in deducing the equation from the reaction, the conceptual understanding of students was at the unistructural level. Students therefore, had conceptual understanding challenges in deducing the chemical formulae of organic compounds in chemical reactions.

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2. In research question two, it was revealed that the reasons that accounted for the students' conceptual understanding of chemical reactions and equations of the carbon compounds were:

   a) The teacher reason:

   (i) The study has established that teachers failed to use teaching and learning resources that seek to motivate learners to develop interest in studying organic chemistry, especially the concept of the chemical reaction and equations. The schools have laboratories, however, the students are not engaged in these laboratories to aid in discovery learning. This makes the lessons abstract.

   (ii) Also, teachers failed to teach to cover some topics in the chemistry syllabuses, especially the concept of organic chemistry, and for that matter the reaction and equations; which made it difficult for students to grasp the concept by studying on their own.

b) The home reason:

   Most parents engage their wards in house chores and that makes them tired, thereby preventing them from personal studies. After school, students do not have extra tuition or remedial lessons to enable them have a relook at areas they have problems understanding.

c) The examination reasons: it was established that students learn to pass examinations; and that makes them not able to develop conceptual understanding.

d) The results of the study have revealed that students know relevant websites to access information to aid in conceptual understanding. The students are familiar with websites like www.youtube.com (Melissa

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Maribel organic chemistry tutorials), www.google.com/videos, www.vidmate.com for tutorials, as well as www.website.world/video and www.alison.com.courses and others. Therefore, some of the students have access to internet to watch tutorials, videos, simulations and animation at home. However, the GES rule for second cycle students not to possess and use private computers and smartphones while in school is negatively affecting the academic performance of students as they are unable to incorporate 21st Century skills to access information in schools.

Conclusions

The following conclusions were drawn from the study. Most of the students failed to apply the requisite rules/principles/theories governing the various reactions and equations to provide accurate information to indicate full understanding of the concept as in the extended abstract. It can, therefore, be concluded that their level of conceptual understanding according to SOLO Taxonomy was unistructural (level 2). These were attributed to teachers' inability to use the appropriate Teaching and Learning Resources to teach the concept, and their inability to complete the subject content as stipulated in the syllabus from WAEC and GES. In addition, it can be concluded that students did not fully understand the concept of hydrogenation, halogenation, oxidation and hydration reactions and equations and therefore the conceptual understanding levels of the students was unistructural (level 1). It was also established that students had no understanding of reactions and equations that involved cyclo-compound and halogens and or hydrogen halide as in halogenation reactions, and reactions involving unsaturated hydrocarbon and

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hydrogen halide. Their understanding level in this concept was at the prestructural level as most of them scored both tiers incorrectly or provided no answers. In esterification reactions and equations, the understanding levels of students in responding to the equations was at the multistructural while in the reaction it was at the unistructural. It can therefore be concluded that students had problems deducing the chemical formulae of organic compounds in chemical equations

It was established that the reasons that account for the students' conceptual understanding were teachers' reasons, the home reasons, examination reasons and GES rules respectively. It can be concluded that teachers failed to use the appropriate teaching and learning resources to facilitate conceptual understanding. Also, teachers were not able to finish the course content as stipulated in the MOE and GES teaching syllabus. In addition, parents equally engaged their wards in domestic activities and that made them unable to study privately when on holidays. It also emerged from the study that teaching and learning in the second cycle institutions are mostly towards passing examinations, and not merely for conceptual understanding what is being taught. It therefore concluded that students practice rote memorization to pass examinations and to enable them proceed to the next level of studies. Therefore, the teachers teach the students to pass their examination as their final test items will not require the students to explain how particular organic reactions proceed. Therefore, teachers and students are not concerned about conceptual understanding, but passing examinations. It can also be concluded that the GES ban on students using private mobile phones and computers while in school is negatively affecting students'

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application of 21st century skills in the learning process. Therefore, viewing videos, animations and simulation to aid conceptual understanding is affected.

Recommendations

The following recommendations are made based on the findings of the study:

a) Teachers should utilize appropriate teaching and learning resources, such as 2D and 3D models (computer-assisted animation), to help students visualize the bonds broken and formed in organic reactions. This will enhance their understanding of the principles and rules governing these reactions and the equations of carbon compounds.

b) Teachers should involve students in practical activities in the laboratory, allowing them to learn through discovery and apply the rules in the reaction process. This hands-on experience will help students understand the nature, appearance, and characteristics of the products formed from the chemical reaction.

c) Teachers should cover the content of the GES/WAEC syllabus to ensure that students learn what is required. They should also use team teaching to tackle challenging concepts together.

d) Additionally, teachers should incorporate 21st-century skills such as ICT, critical thinking, and communication skills to provide students with different perspectives, stimulate creativity and innovation, and enhance group problem-solving and conceptual understanding during lessons.

e) Parents and guardians should create a positive learning environment for their children. They should encourage good learning habits and

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ensure that students have enough time to study, especially during holidays. This will allow students to use different study methods and learn effectively.

f) The examinations and other forms of assessment should evaluate students' conceptual understanding and be based on the application of concepts to solve everyday problems, rather than simple recall of information. Therefore, rote memorization should not be encouraged among students. These assessments should help in developing critical thinking skills and the ability to explore different principles, laws, theories, and facts related to organic chemistry reactions and equations.

g) Schools should provide controlled access to ICT gadgets (computers and internet) for educational purposes, allowing Senior High School students to access information and discover things for themselves. The Ghana Education Service should relax its rules on the use of phones and personal computers, enabling parents to support their children with these items to complement the inadequate ICT resources in schools for learning purposes. It is important for students to stay updated with current technological trends.

Suggestion for Future Research

The study used the SOLO Taxonomy guide to assess students' conceptual understanding of reactions and equations of carbon compounds. However, the study did not take into account the chemistry teachers' knowledge of organic chemistry and how they teach these concepts to students. It is suggested that future research should focus on the pedagogical content knowledge of chemistry teachers regarding chemical reactions and

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equations of carbon compounds. Additionally, a future study should be conducted to examine assessment practices in organic reactions and equations and their impact on students' conceptual understanding for real-world applications.

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APPENDICES

APPENDIX A

ACHIEVEMENT TEST ITEMS FOR SHS 2 & 3 CHEMISTRY STUDENTS ON CHEMICAL REACTION OF ORGANIC COMPOUNDS

Dear respondent,
This research instrument seeks your understanding of the concept of reactions and equations of organic compounds. The information you will provide is solely for a research purpose; which will be used to improve students' understanding of organic chemistry. It is **Not** any external or internal examination which seeks to grade you. The response that will be provided will be treated **confidentially** and you will also **not** be personalized. You are **not** to write your name or the name of your school.
When you complete this instrument it means you are consenting to be part of the research.
Kindly read through the instructions and respond favorably to all the items according to your understanding.

SECTION A: Tick the appropriate response

1. SEX: Male [ ] Female [ ]
2. Age [ ]
3. **Level: SHS 2 [ ] SHS 3 [ ]**
4. Do you have a chemistry teacher; Yes [ ] No [ ]

SECTION B: CHEMICAL REACTION

5. Complete the reaction below:
   $CH_4 + 4Cl_2 \xrightarrow{\text{UV light}}$
   Provide reason
   ……………………………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………
   …………………………………………………………………
6. $CH_3CH_2CH_2Br + 2Na \xrightarrow{\text{Dry/ethoxyethane}}$
   provide reason
   ……………………………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………
   …………………………………………………………………

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7. $CH_3CH_2CH_2CH_2CH_3 + 5O_2 \xrightarrow{\text{heat}}$
provide reason
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
……………………………………………………………

8. $CH_2{=}CH_2 + H_2O \xrightarrow{H_2SO_4}$
provide reason
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
……………………………………………………………

9. $CH_3CH(Cl)CH{=}CH_2 + HBr \xrightarrow{AlBr_3}$
Give reason
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
……………………………………………………………

10. $CH_3CH{=}CH_2 + 9/2O_2 \xrightarrow{\text{Excess air}}$
Give reason
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
……………………………………………………………

11. $CH_2{=}CHCH_3 + H_2 \xrightarrow{Pt}$
Give reaction
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
……………………………………………………………

12. $CH_2{=}CH_2 + NaCN/HCl \rightarrow$ --------------------------- $+ 2H_2/Pt \rightarrow$
give reason
…………………………………………………………………………
…………………………………………………………………………
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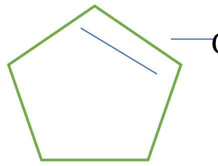
13.  CH_3 + HCl →

Provide reason

……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
………………………………………………………………

14. CH Ξ CH + H_2 $\xrightarrow{Pt}$

give reasons

……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
………………………………………………………………

15. CH_3C Ξ CH + H2O $\xrightarrow[60^oC]{HgSO_4}$

provide reason

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……………………………………………………………………………
……………………………………………………………………………
………………………………………………………………

16. HCΞCH_3 + Br_2 →

Provide reasons

……………………………………………………………………………
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……………………………………………………………………………
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17. C$(CH_3)_2$ CΞC-H + 2HCl →

Provide reason

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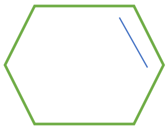
18.  + Br_2/CCl_4 $\longrightarrow$

provide reason

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....

....

....

19. CH_3OH + 2Na $\longrightarrow$

Provide reason

....

....

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....

20. $CH_3C(CH_3)_2OH$ + HCl $\xrightarrow[25^oC]{}$

Provide reasons

....

....

....

....

21. CH_3CH_2OH + Conc H_2SO_4 $\xrightarrow[heat]{}$

Give reason

....

....

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....

22. $CH_3CH_2CH_2OH$ + $KMnO_4/H^+$ $\longrightarrow$

Give reason

....

....

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23. $CH_3COOH + CH_3OH \xrightarrow{H_2SO_4}$
provide reason
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……………………………………………………………………………
……………………………………………………………………………
…………………………………………………………………

24. $CH_3COOH + NaHCO_3 \longrightarrow$
Provide reason
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SECTION C: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

25. Which of the following compounds reacts with Propan-1-ol ($OHCH_2CH_2CH_3$) in the presence of H_2SO_4 to form ethylpropanoate ($CH_3COOCH_2CH_2CH_3$) and water?
   A. CH_3CH_3
   B. CH_3CHO
   C. CH_3CH_2OH
   D. CH_3COOH
   Provide reason
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……………………………………………………………………………
……………………………………………………………………………
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26. Which of the following products is formed when ethanol reacts with excess acidified potassium dichromate($K_2Cr_2O_7/H^+$)?
   A. $CH_3CHOK_2Cr_2O_7$
   B. CH_3CHO
   C. CH_3COOH
   D. CH_3CO
   Provide reason
……………………………………………………………………………
……………………………………………………………………………
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27. When 2-propanol reacts with acidified potassium permanganate, the product formed is …….
    A. $CHCOCH_3$
    B. $CHCOOCH_3$
    C. CH_3CH_2COOH
    D. $CH_3CH{=}CH_3$

Provide reason

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…………………………………………………………………………
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28. The products formed when $CH_3C\Xi C\text{-}H$ react with $KMnO_4/H^+$ are…..
    A. CH_3COOH, CO_2 and H_2O
    B. CH_3COOH and HOOCH
    C. CH_3COOH and CO_2
    D. CH_3COOH and H_2O

    Provide reason

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…………………………………………………………………………
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……………………………………………………………

29. The product(s) form when $CH_3CH_2CH_2CH{=}CH_2$ reacts with HBr is …
    A. $CH_3CH_2CH_2CH_2CH_3$
    B. $CH_3CH_2CH_2CH_2CH_2Br$
    C. $CH_3CH_2CHBrCH_2CH_3$
    D. $CH_3CH_2CH_2CH(Br)CH_3$

    Provide reason

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SECTION D

Write balanced chemical equations when the following compounds react:

30. Ethane reacts with bromine in the presence of ultra violet light to form bromo ethane and hydrogen bromide.

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Provide reason
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31. Propane heated to produce propene and hydrogen gas
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Provide reason
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32. Propan-2-ol is being dehydrated with dilute tetraoxosulphate (vi) acid to produce propene.
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provide reason
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33. 1,2-dibromoethane reacts with potassium hydroxide in the presence of ethanol to produce ethyne, water and a salt.
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provide reason
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34. Ethyne partially react with hydrogen cyanide to form ethylcyanide (vinyl cyanide) which is fully hydrogenated in the presence of nickel to produce propane.

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Provide reason

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35. Ethanol reacts with ethanoic acid in the presence of conc sulphuric acids and heat to produce a sweet scented ethyl ethanoate.

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Provide reason

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36. Propan-1-ol is reacts with acidified potassium permanganate to produce propanoic acid

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provide reason

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37. Cyclohexanol reacts with aluminium oxide in the presence of heat to produce cyclohexene and water

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Provide reason

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SECTION E: write the chemical equation and provide the **condition necessary** for the following reaction to proceed

38. Hydrogenation of 2-butene to produce butane

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Provide reason

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39. Partial hydrogenation of but-2-yne produced but-2-ene

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Provide reason

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40. Methane reacts with free radical chlorine to form tetrachloromethane

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Provide reason
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41. Butan-2-ol is being dehydrated to produce But-2-ene
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Provide reasons
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42. Hydrolysis of propancyanide to butanoic acid and ammonia
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Provide reason
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43. Reaction of ethyne with sodium metal to produce ionic salt and hydrogen gas.
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provide reason
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44. Cracking of butane to form ethane and ethene
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provide reason
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45. Hydration of 2-methylpropene to produce 2-methylpropan-2-ol.
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Provide reasons
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SECTION F: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

46. Which of the following carbon compounds is capable of reacting to form hydrogen bond
    A. CH_3CH_2OH
    B. CH_3-O-CH_3
    C. CH_3CHO
    D. CH_3CH_3

Provide reasons
…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………
………………………………………

47. Which of the following compounds has 2 pi-bonds that can react with acidified water to produce diol
A. $CH_3CH_2CH_3$
B. CH_3CCH
C. CH_3CHCH_2
D. CH_2CCH_2

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Provide reasons

………………………………………………………………………
………………………………………………………………………
………………………………………………………………………
…………………………………………………………

48. The type of breakage which occurs in Chlorine when it reacts with methane in the presence of ultra violet light is…

A. Homolytic cleavage
B. Heterolytic cleavage
C. Catalytic cleavage
D. thermal cleavage

Provide reasons

………………………………………………………………………
………………………………………………………………………
………………………………………………………………………
…………………………………………………………

49. During chemical reaction to form a product, the species which is formed between successive reaction step and consumed is termed as

A. Reaction mechanism
B. activation energy
C. intermediate
D. rate determining step

Provide reasons

………………………………………………………………………
………………………………………………………………………
………………………………………………………………………
…………………………………………………………

50. Which of the following bonds is/are capable of making some organic compounds very reactive?

A. covalent bond
B. hydrogen bond
C. pi bond
D. sigma bond

provide reason

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………………………………………………………………………
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APPENDIX B

STUDENTS INTERVIEW GUIDE TO ASCERTAIN THE FACTORS THAT ACCOUNT FOR THE PERCEPTION OF SENIOR HIGH SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDING OF CHEMICAL REACTIONS AND EQUATIONS OF CARBON COMPOUNDS

1. Explain how organic chemistry (especially the chemical reaction and the equations) is taught for you to understand or not to understand
2. Explain what the school has done to enable you learn and understand organic chemistry especially the concept of chemical reactions and the equations.
3. Explain what is motivating you to study organic reaction and equations
4. Explain how your home is motivating you to learn the concept of organic chemistry, which includes the chemical reaction and equations.

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APPENDIX C
TRANSCRIBED INTERVIEW RESULTS

STUDENT 1

Researcher: Good afternoon

Student: Good afternoon

Researcher: please talk louder, my brother

Researcher: explain how organic chemistry, especially the reaction Part is taught for you to understand.

Student: aaam organic chemistry is taught mostly in class, we don't go to the laboratory. and when the teacher is taking us through this topic specifically he he tries to explain to our understanding, especially the reaction side.

Researcher: is there any concept you don't always understand?

Student: The concept. Yea actually, the concept yes the type of reaction part especially the reaction part, the halogenation and the other concept is very difficult to understand.

Researcher: what is making you not to understand?

Student: yea we have not gotten there with the teacher. but I tried learning it on my own and I am not getting the understanding.

Researcher: Now may you please explain what the school has done to enable you learn and understand chemistry, especially the organic chemistry reaction?

Student: chemistry, actually when we we use not to have a teacher, but for now we have a teacher. The school has put enough efforts to get us a teacher to teach us this topic. So the school has done well

Researcher: so apart from the teacher is there any other issue?

Student: about the organic chemistry, no, there isn't any issue

Researcher: now what is motivating you to learn organic reaction?

Student: Organic reaction. eem organic reaction when you learn, when you are learning it it becomes interesting since you fine, you try to get things you use not to know. you see them like, like naturally you see them, but you don't always know what it is about. but for example this esterification we are told any anything mostly the esters they are sweet scented. I don't know the sweet scented chemicals are esters and when I am learning I get new ideas. That motivate me.

Researcher: may you please explain how your home that is you house is motivating you to learn organic chemistry especially the reaction part

Student: aam for the home eem I am from a local home so for the organic part I don't have much to say about it but i know this local chemical like saltpeter and stuff I get, when I go home practically I tried to identify these things

Researcher; In your house, apart from the school, do you learn organic chemistry, especially the reaction apart

Student: apart from the school in my house I learn chemistry, but theoretically

Researcher: but in the school you learn it practically

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Student: yes
Researcher: do you have emm do they give you chance to learn in the house?
Student: yes at house I get chance to learn chemistry
Researcher: do you attend extra classes?
Student: no, I don't attend extra classes
Researcher: you don't attend extra classes
Student: yes I don't attend extra classes
Researcher: it there any issue you want to say regarding to the questions I have just asked

Student: emm yes because for now we are preparing for our mock and there are some topics we have not gotten to. The teacher hasn't taken us through and me per-say when I learn them on my own the understanding is not as compared to the teacher teaches me, I want to be taught before the final exam The teacher hasn't for me
Researcher : thank you very much

STUDENT 2
Researcher: I am just starting. Good afternoon my brother
Student: Good afternoon sir
Researcher: amm may you please explain how organic chemistry is taught for you to understand?

Student: organic chemistry it involves a lot of chemical equations, and so when they are teaching and with a lot of illustrations on the board and especially when the teacher uses a computer to project the chemical reactions, to show how the reaction comes about, for instance, emm let say combustion, decomposition reaction when illustrated on the board to show how molecules are broken down to form a product. Next time when I am asked such a question or anything related to that, and I visualise or try to picture out what the teacher did on the board, I think I get it. I remember everything so easily. So when illustrations and a lot equations and examples are used during teaching, I think I get the understanding better.

Researcher: Apart from what you just said, what will they also do and you will not understand the concept?

Student: Sir. When the teacher does not write the chemical equations, for instance some teachers, they only tell you that the reaction between alkanoic acid and alkanol acid will produce an ester. But if he says this without illustrated examples, I may not get the understanding well.
Researcher: amm Thank you very much. What is the school doing to enable you learn the organic chemistry?

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Student: Oh okay. I think my school, the lab is here. So often they take us to a lab and they take us through certain things. For instances some of the organic substances. You know, yea they are shown to us. And then we also do, emm reactions and the substance added to show how they react, the product formed and how it looks and all that. So the school take us to the lab because all this, I think these are the efforts of the school in helping us to understand.
Researcher: What is motivating you to learn chemistry, organic chemistry?

Student: emm I think, organic chemistry and with my chemistry teacher, and he is very active . And what I also want to go and do in future. For instance I want to go and do pharmacy which involves a lot of chemistry. So with information from others and with the enthusiasm, like my organic chemistry teacher he motivates me in the sense that he teaches with much interest. Ahaa, so with that, am much motivated and I also like how things occur in nature, it is also a factor that enables me to learn and motivate me in anything regarding learning.

Researcher: Explain how your home is motivating you to learn the concept of organic chemistry, which include the chemical reactions and equations

Student: Okay, I think my my in my house, they, I request, I place a request for some of the chemicals, or substances, and then the buy it for me to do my personal or individual this thing, eee reactions and test in order to see how it is like, and when I learn in the book, they tell me that adding this reagent to the other will produce this, I tell my dad and then he provide me with his things and I also do. In addition I am also provided with computer or this thing, a smartphone that I can download the organic chemistry reactions and things so that I can learn and get the understanding.

Researcher: Thank you very much. So with the phone, do you know some of the websites you can do to get animations to learn the reactions in organic chemistry?

Student: Oh, OK. for me, what I usually do is just type organic chemistry. And when I do that the this thing, the topics will come and I will go to the site that I like, that is just what I know.

Researcher: So you don't know any site you can go to get the animations on the reactions equations?

Student: No sir

Researcher; Thank you very much

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STUDENT 3

Researcher: Yeah, good afternoon to you. Yeah. Please explain how organic chemistry is taught for you to understand, especially the reaction, and equations.

Student: Okay, so on our part, organic chemistry is just taught on board, so we don't have access to do experiments or even illustration for us to understand. Most of the things are just theoretical. Sometimes it can be very complex.

Researcher: So does that mean that you do not understand the concept based on that?

Student: Yes. Personally, I I try to understand, just the concept aspect. OK. Mm-Hmm. Yeah.

Researcher: So what about the understanding? do you have parts that you don't always understand?

Student: Yes, especially when it gets to the part where there are ions, movement of ions, especially inductive effects, that apart and their explanations is difficult.

Researcher: how is the concept taught for you not to understand

Student: Teachers do not even get there properly, so we don't understand.

Researcher: So what is the school doing or what has the school done to enable you learn and understand organic chemistry especially the reaction part?

Student: Basically initially that our HOD of science department, he took some time off to take us through, but ever since that school has not done anything.

Researcher. Yea. What is motivating you to learn organic reactions and equations?

Student: Personally, I have motivation from family, eeh for my sister. So I keep learning, them just, for exams purposes, and, maybe whatever comes next. But for now, the motivation is just for exams.

Researcher: OK, so what is also your home, your family doing to motivate you to learn the concept organic chemistry, especially the reactions and equations?

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Student: My family make sure they buy me all the books I request for, so that I can learn, and then sometimes I do get assistance from other family members who understand the concepts.

Researcher: So in the House, do you have remedial classes?

Student: Personally, I don't go for remedial classes just online. Right. Yes.

Researcher: So do they provide you with smart phone?
Student: Yes.

Researcher: Do you know some website, you can go to get animations based on how they reaction proceed?

Student: I only have access to one You Tuber. That's Melissa Maribel, she is an organic chemistry tutor. And then there's even another YouTube channel that is organic chemistry, tutors.,

Researcher: Do you know other website you can go to learn organic chemistry?

Student: yes just on you tube

Researcher: Thank you very much. Thank you.

STUDENT 4
Researcher: Yea Good evening

Student: Good evening sir

Researcher: Explain how organic chemistry, especially the reaction, and equations is taught for you to understand.

Student: Sir with the organic chemistry with the, especially with the chemical reactions and equations. The best way I can understand those things is over here is through the practical.

Researearher: So, do you have practical activities on them?

Student: Sir not frequently. But we do have some practicals over there, the lab.

Researcher. How is it taught for you not to understand?

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Student: Sir the reaction in the, the lessons on reaction, if they are taught, like in, by abstract means without the practicals, it becomes difficult for us to understand because we have to see. I ever saw a teaching with computer and it was understandable. But here, sir, no computers for the teachers to use. That is making organic chemistry difficult

Researcher: So now what has the school done to enable you learn and understand organic chemistry, especially the concept of the reactions and the equations?

Student: Hmm. So well, we can't comment the school. Since we started our chemistry study, we have had, as I said, main chemistry practical, but a few cases have been provided for us to study. But we we think more should still be done to individuals to enable us understand.

Researcher: what is motivating you to learn organic chemistry, especially the reactions and equations?

Student: Sir beginning the topic organic chemistry you would realize that almost everything around us has to do with organic chemistry and most of the compounds we use here. I think if you have good knowledge on organic chemistry then you would have better understanding of what happens around us, that is my motivation to learning organic chemistry.

Researcher: May you please explain how your home, your family is motivating you learn the concept organic chemistry which include the chemical reactions and equations

Student: mmm sir the difficulty of the chemical reaction, let me say organic chemistry in total is what our families are all aware of. In our house for instance we are either with like computers or what you can use to do research. When we do internet search on such a topic I think we get videos and other things which can help us to understand. ammm our families I think, are helping us. Ammm my family personally provided me with a computer with which I can study certain things with it

Researcher: Do you other website you can go to view animations on chemical reactions and equations?

Student: ammm basically if you follow GES website, if you follow youtube and programmes you can get them. I don't have a concrete website I can mention for you.

Researcher: Have you been going to those sites?

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Student: yes sir. Not frequently, because emmm, emmm I have gone there a few times and not so many times

Researcher; Thank you very much.

Student: You are welcome.

Student 5
Researcher: Good afternoon

Student: Good afternoon Sir

Researcher: Please, emm May you please explain how organic chemistry, especially the reaction, and equations are taught for you to understand.
Student: actually we have a teacher which is helping us when it comes to the chemical reaction and the equation of the organic chemistry. our teacher he makes sure that he differentiate the functional groups to our understanding when he is teaching us chemical reaction, he makes us to understand that it is coming from this functional group and then the other emm the reaction they undergo and the properties and all those physical properties that will be seen when they react practically. He makes sure he send us to the chemistry lab to do some of the reaction, so that we will see how they undergo their reaction

Researcher: is there any concept that you don't always understand?
Student: mmm actually for me, I think I always understand all the concepts that he explains to us

Researcher: mmm what is the school doing or what has the school done to enable you learn and understand organic chemistry, especially organic reaction.

Student: mmm school, I think the school provided the teacher. Some of the chemicals are being bought by the school, so that we do the practical concept of the reaction.

Researcher: Thank you. what is motivating you to learn organic chemistry, especially the reaction and equation/

Student; One thing that is motivating me is the way the teacher has digested the subject. And then, he has made my understanding very easy, then how to write the chemical reaction because now I know the functional group, and the reaction they undergo. So when I pick any organic compound and I know how

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to name it and I know how to write the reaction they undergo. That is motivating me to learn organic chemistry.

Researcher: How is your home family motivating you to learn organic chemistry, especially the reaction and equations?
Student: Well, my home, I think they have been buying me books and they have motivating me all the time. Thy have been talking to me to be concentrated. I think the books, I think it is from the books that I learn the subject and the topics of organic chemistry.

Researcher: Apart from that, do they give you computer or smartphone for your personal study at home?
Student: mmm, my brother bought me a smartphone which aids me to do research on myself. I think that one is helping me to learn organic chemistry.

Researcher: which website do you go to learn organic chemistry, especially the reaction and equations?

Student: Sometimes, when I want to watch videos, I go to youtube and sometimes I go to vidmate. most at times too I go to google and Alison so that I will go and search to see how the reaction undergo and when they write on a paper then I will see how this one will go and bond and there all those things

Researcher: Do you get the concept when you study alone?

Student: sometimes I get the concept but most at time too, when I search for the reaction and how they always do sometimes they always confuse me a lot.

Researcher: do you ask for assistance from colleagues or teachers to aid your learning?

Student: yes: sometimes, mostly I go to our chemistry teacher to ask him some questions if I don't understand them.
Researcher: Thank you very much

STUDENT 6
Researcher: Good evening

Student: Good evening Sir
Researcher: please fill free and talk louder for me to me hear

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Student: Ok, Sir.

Researcher: Explain how organic chemistry, especially the reaction Part is taught for you to understand.

Student: Eeeh, Sir, organic chemistry, I learnt it on my own. This is because we have no reach there yet. Even the exam, exam I done know I am going to write

Researcher: is there any concept you don't understand when you read?
Student: The concept. The concept, yes. I don't have problem with the properties, emmm and naming but I have problem with the the reaction part. I have problem with the conditions, when I read alone. I try to eeeh chew them. Yes actually, the reaction part is a problem, especially the terms, eii the language, I don't always understand. Infact, sir I try to chew and when it it comes in exams I try to pour. Sir but that one too, it is difficult sir.

Researcher: what is making you not to understand?

Student: We have not not reach there with the teacher. mmmh, I tried learning it on my own and I don't get the understanding because of the terminologies and language. There are some arrows that confuses me.

Researcher: Now may you please explain what the school has done to enable you learn and understand chemistry, especially the organic chemistry reaction?

Student: We use to have a part time teacher, but for now we have a teacher. I think the school has done well for us to have a teacher.
Researcher: so apart from the teacher is there any other issue?

Student: Yes Sir. We don't do practicals to to enable us understand what we need to know.

Researcher: now what is motivating you to learn organic reaction?

Student: What is motivating me is what to do in future. In future, I want to be a pharmacist. If I learnt without organic chemistry one cannot do pharmacy.
Researcher: may you please explain how your home that is you house is motivating you to learn organic chemistry especially the reaction part

Student: Sir I am from a village. After school I don't always eeeh have enough time to study. if I don't go to farm my father will refused to give me lorry fare to come to school.

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Researcher; In your house, apart from the school, do you learn organic chemistry, especially the reaction apart

Student: Not all the time, Sir

Researcher: You mean you don't have enough time to learn organic chemistry in the house?

Student: Yes Sir. Sir the farm, the food preparation. By the time I finish doing all, sir I am always tired

Researcher: do you attend extra classes?

Student: no, Sir

Researcher: it there any issue you want to say regarding to the questions I have just asked

Student: eeeh Sir. my problem is the WAEC we are about to write. I am learning but I am praying that WAEC doesn't bring a lot of organic questions. All that I am doing is just to enable me pass my WAEC chemistry. I don't want to sit for NOVDEC.

Researcher : thank you very much

STUDENT 7
Researcher: Good evening

Student: Good evening Sir
Researcher: please relax and talk louder for me to me hear and record

Student: No problem.

Researcher: Explain how organic chemistry, especially the reaction Part is taught for you to understand.

Student: Please Sir, organic chemistry, we have not reach there, I it on my own to understand. It is this year we have a chemistry teacher.

Researcher: is there any concept you don't understand when you read?

Student: I don't have problem with the naming but as for the reaction dear, sir it difficult. I don't understand the terms they always use. Sir I try to chew, but it doesn't enter.

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Researcher: what is making you not to understand?

Student: I don't know which bond is broken and how the product is formed. I am always confused with the arrows and terms, Sir.

Researcher: My friend, may you please explain what the school has done to enable you learn and understand chemistry, especially the organic chemistry reaction?

Student: We are in form three and about to write our final exam and now we have a chemistry teacher. I think the school has done well for us to now have a teacher.

Researcher: so apart from the teacher is there any other issue?

Student: Yes. Since the teacher came we have not had any lesson on organic chemistry. eeem we have not done any practical to make us understand what we need to know.

Researcher: Let me asked, what is motivating you to learn organic chemistry, especially the organic reaction on your own?

Student: Sir, my career. Please Sir, I want to to be a pharmacist or laboratory technologist. I understand if I don't have any knowledge in organic chemistry, I will suffer in the pharmacy or lab tech class.

Researcher: Kindly explain how your home is motivating you to learn organic chemistry especially the reaction part

Student: The farm and cooking will not allow me to learn. My parents will not give me chance to to learn.

Researcher; In your house, apart from the school, do you learn organic chemistry, especially the reaction apart

Student: No please

Researcher: You mean you don't have enough time to learn organic chemistry in the house?

Student: Sir yes. Sir as I said, cooking, fetching of water and farm will not allow me learn. I am always tired after all these work. I can't student after all these Sir.

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Researcher: So do you attend extra classes?
Student: no, please

Researcher: it there any issue you want to say regarding to the questions I have just asked

Student: Sir, My biggest worry is the Mock and WAEC. I am praying that WAEC shouldn't set plenty questions from organic chemistry, if not I will fail chemistry. Please Sir, mmmh I am praying not to fail chemistry. I can't get money to register NOVDEC.

Researcher : I have heard you. Thank you very much

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APPENDIX D

RELIABILITY OF ACHIEVEMNET TEST ITEM

Reliability Statistics

Cronbach's Alpha	N of Items
.939	46

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APPENDIX E

RELIABILITY OF QUESTIONNAIRE ITEM

Reliability Statistics

Cronbach's Alpha	N of Items
.797	46

APPENDIX F

DISTRIBUTION OF SCHOOLS' SAMPLES

S/N	NAME OF SCHOOLS	SAMPLE
1	Nandom SHS	60
2	Kaleo SHTS	40
3	Queen of Peace SHS	48
4	Jirapa SHS	40
5	Lassie Tuolo SHS	50
6	Piina SHS	40
7	Kanton SHS	45
		320

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APPENDIX F

SAMPLES OF STUDENTS' TEST ITEMS

ACHIEVEMENT TEST ITEMS FOR SHS 2 & 3 CHEMISTRY STUDENTS ON CHEMICAL REACTION OF ORGANIC COMPOUNDS

Dear respondent,

This research instrument seeks your understanding of the concept of reactions and equations of organic compounds. The information you will provide is solely for a research purpose; which will be used to improve students' understanding of organic chemistry. It is **Not** any external or internal examination which seeks to grade you. The response that will be provided will be treated **confidentially** and you will also **not** be personalized. You are **not** to write your name or the name of your school.

When you complete this instrument it means you are consenting to be part of the research.

Kindly read through the instructions and respond favorably to all the items according to your understanding.

SECTION A: Tick the appropriate response

1. SEX: Male [✓] Female [ ]
2. Age [19]
3. **Level: SHS 2 [ ]** **SHS 3 [✓]**
4. Do you have a chemistry teacher; Yes [✓] No [ ]

SECTION B: CHEMICAL REACTION

5. Complete the reaction below:
$4CH_4 + 4Cl_2 \xrightarrow{\text{UV light}} 4CH_3Cl + 4HCl$ ✗
Provide reason
In halogenation reactions of alkanes alkylhalitive and an acid are produced ✗

6. $CH_3CH_2CH_2Br + 2Na \xrightarrow{\text{Dry/ethoxyethane}} CH_3CH_2CH_2Na + HBr$ (2)
provide reason
The reaction is involving sodium metal in the presence of dry ethoxyethane ✓

7. $CH_3CH_2CH_2CH_2CH_3 + 5O_2 \xrightarrow{\text{heat}} CO_{2(g)} + H_2O_{(g)}$ (2)
provide reason
The compound is an alkane (C_5H_{12}) and in combustion of alkanes in excess oxygen, carbondioxide and water ~~are~~ produced.

1

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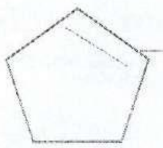
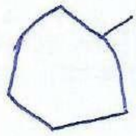
8. $CH_2{=}CH_2 + H_2O \xrightarrow{H_2SO_4}$ CH_3-CH_2-OH
provide reason
It is hydration reaction of the compound.

9. $CH_3CH(Cl)CH{=}CH_2 + HBr \xrightarrow{AlBr_3}$ $CH_3Al(Cl)CH_2CH_3 + Br$
Give reason
It is the reaction of an alkene with hydrogen halide (Br, Cl or I) in the presence of $AlCl_3$ as catalyst

10. $CH_3CH{=}CH_2 + 9/2O_2 \xrightarrow{\text{Excess air}}$ $3CO_{2(g)} + 3H_2O_{(g)}$
Give reason
In the combustion of alkenes in excess oxygen (air) carbon dioxide and water are produced.

11. $CH_2{=}CHCH_3 + H_2 \xrightarrow{Pt}$ $CH_3CH_2CH_3$
Give reaction
In a complete hydrogenation reaction of alkene, a corresponding alkane is formed in catalyst e.g. Ni (Pt)

12. $CH_2{=}CH_2 + NaCN/HCl \longrightarrow$ $C_2H_5CONH_2$ $+ 2H_2/Pt \longrightarrow$ $H_3C \rightarrow CH{=}CH_2$
give reason
the reaction partially reacts with NaCN / HCl

13.  CH_3 + HCl $\longrightarrow$  CH_3Cl + H_2

Provide reason

14. $CH \equiv CH + H_2 \xrightarrow{Pt}$ H_2C
give reasons
In an incomplete hydrogenation of alkynes a corresponding alkene is produced. Alkynes need 2 mols of H_2 to form an alkane

2

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15. $CH_3C \equiv CH + H2O$ $\xrightarrow[60^oC]{HgSO_4}$ $CH_3-CH=CH$

provide reason

It is the dehydration of the compound in the pressence of H_2SO_4 at 60^oC heat

16. $HC\equiv CCH_3 + Br_2$ ⟶ $H_2C=C(Br)CH_2(Br)$

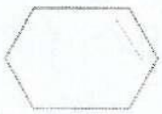
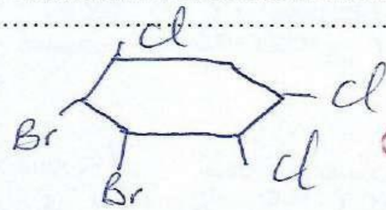
Provide reasons

Because in an incomplete bromination of alkynes, a corresponding 2,3-dibromo propene is formed when alkyne is the above

(2)

17. $C(CH_3)_2\ C\equiv C\text{-}H + 2HCl$ ⟶ H_2C-

Provide reason

18.  $+ Br_2/CCl_4$ ⟶ 

provide reason

19. $CH_3OH + 2Na$ ⟶ $CH_3Na + NaOH$

Provide reason

Because when an alkanol reacts with a metal metalic hydroxide is formed.

(0)

20. $CH_3C(CH_3)_2OH + HCl$ $\xrightarrow[25^oC]{}$ $CH_3C(CH_3)_2Cl + H_2O$

Provide reasons

The product is br because it's the reaction of alkanol with Hcl (hydrogen halide) under heat.

(2)

21. $CH_3CH_2OH + \text{Conc } H_2SO_4$ $\xrightarrow[heat]{}$ CH_3CH_2COOH

Give reason

3

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....

....

....

22. $CH_3CH_2CH_2OH + KMnO_4/H^+ \longrightarrow$ C3H7COOH

Give reason

this is because, the reaction takes place in the presence of acidified potassium permanganate

23. $CH_3COOH + CH_3OH \xrightarrow{H_2SO_4}$ CH3COOCH3 + H2O

provide reason

In esterification reaction, the reaction between alkanoic acid, and alkanol alkyl kanoates or estes and H2O are found

24. $CH_3COOH + NaHCO_3 \longrightarrow$ CH3COONa + H2O + CO2 (g)

Provide reason

When an alkanoic acid reacts with an acidic salt, CH3COONa, H2O and CO2 are produced, CH3COONa because of Na in NaHCO3

SECTION C: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

25. Which of the following compounds reacts with Propan-1-ol ($OHCH_2CH_2CH_3$) in the presence of H_2SO_4 to form ethylpropanoate ($CH_3COOCH_2CH_2CH_3$) and water?
    - A. CH_3CH_3
    - B. CH_3CHO
    - C. CH_3CH_2OH
    - (D.) CH_3COOH

    Provide reason

    because the reaction is esterification so the alkanol is given then the other compound left should be an alkanoic acid

26. Which of the following products is formed when ethanol reacts with excess acidified potassium dichromate($K_2Cr_2O_7/H^+$)?
    - A. $CH_3CHOK_2Cr_2O_7$
    - B. CH_3CHO
    - C. CH_3COOH
    - D. CH_3CO

    Provide reason

4

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....

27. When 2-propanol reacts with acidified potassium permanganate, the product formed is ....

A. $CHCOCH_3$
B. $CHCOOCH_3$
C. CH_3CH_2COOH
D. $CH_3CH=CH_3$

2

Provide reason

Because in this reaction, the corresponding expected product is an alkanoic group

28. The products formed when $CH_3C\equiv C$-H react with $KMnO_4/H^+$ are.....

A. CH_3COOH, CO_2 and H_2O
B. CH_3COOH and HOOCH
C. CH_3COOH and CO_2
D. CH_3COOH and H_2O

0

Provide reason

Because the corresponding product of such reaction must be alkanoic acid and water.

0

29. The product(s) form when $CH_3CH_2CH_2CH=CH_2$ reacts with HBr is ...

A. $CH_3CH_2CH_2CH_2CH_3$
B. $CH_3CH_2CH_2CH_2CH_2Br$
C. $CH_3CH_2CHBrCH_2CH_3$
D. $CH_3CH_2CH_2CH(Br)CH_3$

Provide reason

the hydrogen bromide split and bond to the compound in terms of the mechanism of electrophiles and nucleophiles

SECTION D

Write balanced chemical equations when the following compounds react:

30. Ethane reacts with bromine in the presence of ultra violet light to form bromo ethane and hydrogen ~~bromide~~. bromide

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$C_2H_6 + Br_2 \xrightarrow{U.V\ light} C_2H_5Br + HBr$ (2)

Provide reason

ethane is undergoing bromination reaction in the presence of U.V light and the corresponding products are shown above

31. Propane heated to produce propene and hydrogen gas

$C_3H_8 \xrightarrow{heat} H_3C - CH = CH_2 + H_2$ (2)

Provide reason

When an alkane is heated, a corresponding alkene and hydrogen are produced as shown above.

32. Propan-2-ol is being dehydrated with dilute tetraoxosulphate (vi) acid to produce propene.

$CH_3 - CH(OH) - CH_3 \xrightarrow{dil\ H_2SO_4} H_2C = C(H) - CH_3$ (2)

provide reason

(0)

33. 1,2-dibromoethane reacts with potassium hydroxide in the presence of ethanol to produce ethyne, water and a salt.

$H - C(H)(Br) - CH_2(Br) + KOH \xrightarrow{C_2H_5OH} HC \equiv CH + H_2O\ H_2H_5$

provide reason

(0)

34. Ethyne partially react with hydrogen cyanide to form ethylcyanide (vinyl cyanide) which is fully hydrogenated in the presence of nickel to produce propane.

6

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HC ≡ CH + HCN ⟶ $C_2H_5CONH_2$ + H_2 $\xrightarrow{Ni}$ $H_2C = CHCH_3$

Provide reason

0

35. Ethanol reacts with ethanoic acid in the presence of conc sulphuric acids and heat to produce a sweet scented ethyl ethanoate.

$C_2H_5OH + C_2H_5COOH \xrightarrow[heat]{conc\ H_2SO_4} C_2H_5COOC_2H_5 + H_2O$ 2

Provide reason

the reaction esterification reaction in the presence of conc. Sulphuric acid

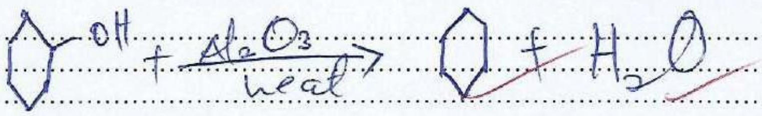
36. Propan-1-ol is reacts with acidified potassium permanganate to produce propanoic acid

$C_3H_7OH + KMnO_4/H^+ \longrightarrow C_3H_2COOH$

provide reason

reaction takes place in an acidified potassium permanganate which acts as a catalyst

37. Cyclohexanol reacts with aluminium oxide in the presence of heat to produce cyclohexene and water



2

Provide reason

0

SECTION E: write the chemical equation and provide the **condition necessary** for the following reaction to proceed

38. Hydrogenation of 2-butene to produce butane

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$H_3C-CH=CHCH_3 + H_2 \longrightarrow CH_3CH_2CH_2CH_3$ (2)

Provide reason

the reaction is hydrogenation of alkenes in the presence of nickel or platinum as the catalysts.

39. Partial hydrogenation of but-2-yne produced but-2-ene

$H_3C-C\equiv C-CH_3 + H_2 \longrightarrow H_3C-CH=CHCH_3$ (2)

Provide reason

It is incomplete hydrogenation of but-2-yne (alkyne) in the presence of pt (Ni(pb)...

40. Methane reacts with free radical chlorine to form tetrachloromethane

$CH_4 + CH_3Cl \longrightarrow CCl_4$ (1)

Provide reason

the condition for the reaction is that there are the reaction homolytic bond cleavage

41. Butan-2-ol is being dehydrated to produce But-2-ene

$C_4H_9OH + H_2O \xrightarrow[heat]{H_2SO_4} H_3C-CH=CHCH_3$ (2)

Provide reasons

the condition for the reaction is that sulphuric acid should be present as a catalyst accompanied by heating.

42. Hydrolysis of propancyanide to butanoic acid and ammonia

$C_3H_7CONH_2 + H_2O \longrightarrow C_4H_9COOH + NH_3$

Provide reason

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43. Reaction of ethyne with sodium metal to produce ionic salt and hydrogen gas.

$HC \equiv CH + 2Na \longrightarrow 2CNa^{4+} + H_2$

provide reason
the condition for the reaction is the presence of dotty/ ethoxyethane

44. Cracking of butane to form ethane and ethene

$C_4H_{10} \longrightarrow CH_3CH_3 + H_2C = CH_2$

provide reason
the condition for the reaction is the presence of heat and very high presure on the compound

45. Hydration of 2-methylpropene to produce 2-methylpropan-2-ol.

$H_2C = C(CH_3) - CH_3 + H_2O \xrightarrow[\text{room temp}]{H_2SO_4} H_3C - C(OH)(CH_3) - CH_3$

Provide reasons
the condition is that reaction occurs at room temperature in the presence of H_2SO_4

SECTION F: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

46. Which of the following carbon compounds is capable of reacting to form hydrogen bond
   A. CH_3CH_2OH
   B. $CH_3\text{-}O\text{-}CH_3$
   C. CH_3CHO
   D. CH_3CH_3

Provide reasons

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Because in the compound CH_3CHOH hydrogen bond is found in OH – bond

47. Which of the following compounds has 2 pi-bonds that can react with acidified water to produce diol
   A. $CH_3CH_2CH_3$
   B. CH_3CCH
   C. CH_3CHCH_2
   D. CH_2CCH_2

Provide reasons

In the above answers provided, only alkynes that have 2 pi-bonds but for alkanes is stigma and alkene, one pi-bond

48. The type of breakage which occurs in Chlorine when it reacts with methane in the presence of ultra violet light is...
   A. Homolytic cleavage
   B. Heterolytic cleavage
   C. Catalytic cleavage
   D. thermal cleavage

   Provide reasons

   It is in the homolytic cleavage of alkanes that methane react with chlorine as free radical to form CCl_4

49. During chemical reaction to form a product, the species which is formed between successive reaction step and consumed is termed as
   A. Reaction mechanism
   B. activation energy
   C. intermediate
   D. rate determining step

Provide reasons

It is only in the reaction mechanism of compounds that a successive retention step forms and is consumed on the process

50. Which of the following bonds is/are capable of making some organic compounds very reactive?
   A. covalent bond
   B. hydrogen bond
   C. pi bond
   D. sigma bond

provide reason

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Considering the Pi-bond and sigma bonds
its the Pi-bond that is very reactive
because stigma bonds are stronger than Pi-bonds

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ACHIEVEMENT TEST ITEMS FOR SHS 2 & 3 CHEMISTRY STUDENTS ON CHEMICAL REACTION OF ORGANIC COMPOUNDS

Dear respondent,

This research instrument seeks your understanding of the concept of reactions and equations of organic compounds. The information you will provide is solely for a research purpose; which will be used to improve students' understanding of organic chemistry. It is **Not** any external or internal examination which seeks to grade you. The response that will be provided will be treated **confidentially** and you will also **not** be personalized. You are **not** to write your name or the name of your school.

When you complete this instrument it means you are consenting to be part of the research.

Kindly read through the instructions and respond favorably to all the items according to your understanding.

SECTION A: Tick the appropriate response

1. SEX: Male [ ] Female [✓]
2. Age [18]
3. **Level: SHS 2 [ ]** **SHS 3 [✓]**
4. Do you have a chemistry teacher; Yes [✓] No [ ]

SECTION B: CHEMICAL REACTION

5. Complete the reaction below:
   $CH_4 + 4Cl_2 \xrightarrow{\text{UV light}}$ $CCl_4 + 4HCl$
   Provide reason
   Halogenation of alkanes in the presence of UV light produce acid and a Heterophatic alkane

   2

6. $CH_3CH_2CH_2Br + 2Na \xrightarrow{\text{Dry/ethoxyethane}}$ $CH_3CH_2CH_2Na + NaBr$
   provide reason
   ……………………………………………

7. $CH_3CH_2CH_2CH_2CH_3 + 5O_2 \xrightarrow{\text{heat}}$ $5CO_2 + 6H_2O$
   provide reason
   combustion reaction of hydrocarbons produces CO_2 and H_2O

   3

1

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8. $CH_2{=}CH_2 + H_2O \xrightarrow{H_2SO_4}$ C_2H_5OH
provide reason
The hydration of an alkene produces an alkanol.
Thus ~~H~~ hydration of ethene produces

(2)

9. $CH_3CH(Cl)CH{=}CH_2 + HBr \xrightarrow{AlBr_3}$ $CH_3CH(Cl)CH{=}CHBr + H_2$ ~~$CH_3CH_2CH_2CHBr_2 + HCl$~~
Give reason
Adding an acid to alkene yields H_2 gas.

10. $CH_3CH{=}CH_2 + 9/2O_2 \xrightarrow{\text{Excess air}}$ $3CO_2 + 3H_2O$
Give reason
~~combustion reaction of alkenes/hydro com pou~~
hydrocarbons like alkenes yields CO_2 and H_2O

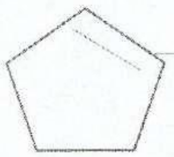
3

11. $CH_2{=}CHCH_3 + H_2 \xrightarrow{Pt}$ $CH_3CH_2CH_3$
Give reaction
Hydrogenation of ~~alke~~ alkenes in the presence of platinum ~~yei~~ yields an alkane

(2)

12. $CH_2{=}CH_2 + NaCN/HCl \longrightarrow$ $CHCl{=}CHCl$ $+ 2H_2/Pt \longrightarrow$ CCl_4
give reason

?

13.  $CH_3 + HCl \longrightarrow$ 

(0)

Provide reason

0

14. $CH \equiv CH + H_2 \xrightarrow{Pt}$ $CH_2{=}CH_2$
give reasons
Hydrogenation of an alkyne in the presence of platinum gives an alkene

(1)

2

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15. $CH_3C \equiv CH + H2O \xrightarrow[60^{o}C]{HgSO_4}$ $CH_3CH = CH_2$ ✗

provide reason

Hydration of an alkyne gives an alkene ✗ (0)

16. $HC \equiv CCH_3 + Br_2 \longrightarrow$ $CHBr = CBrCH_3$ ✗ (0)

Provide reasons

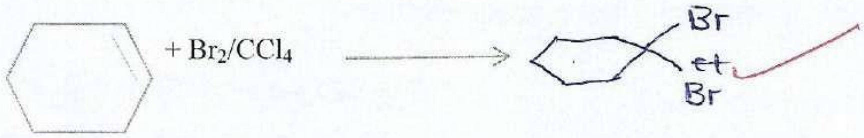
Halogenation of an alkyne gives an alkene ✗

17. $C(CH_3)_2\ C \equiv C\text{-}H + 2HCl \longrightarrow$ ~~$C(CH_3)_2CHCH_2Cl(CH_3)_2CH_2ClCHCl$~~

Provide reason ~~$CH_3CH = CH_3CCl = CHCHClCH_3$~~

Adding an acid to an alkyne gives an alkene ✗

18.



provide reason

Halogenation of an arovnatic compound yield a Heterogenous aromatic compound ✗

19. $CH_3OH + 2Na \longrightarrow$ $CH_2Na_2 + H_2O$ ✓ (1)

Provide reason

Neutralization of a basic hydrocarbon yields salt and water ✗

20. $CH_3C(CH_3)_2OH + HCl \xrightarrow[25^{o}C]{}$ $CH_3C(CH_3)_2Cl + H_2O$ ✗

Provide reasons

Neutralization of a basic hydrocarbon yields salt and water ✗ (0)

21. CH_3CH_2OH + Conc $H_2SO_4 \xrightarrow[heat]{}$ ~~$CH_3CH_2SO_4 + (CH_3CH_2)_2SO_4 + H_2O$~~ ~~$(CH_3CH_2)_2SO_4 + H_2O$~~

Give reason

Neutralization reaction of acid and base ✗

Ans $CH_3CH_2OH_3SO_4$

3

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....
....
....

22. $CH_3CH_2CH_2OH + KMnO_4/H^+$ ⟶ ~~$CH_3CH_2CH_2KMnO_4 + H^+ + KOH$~~ $CH_3CH_2CH_2O$
Give reason
..Neutralization reaction of acid and base...
....
....

23. $CH_3COOH + CH_3OH \xrightarrow{H_2SO_4}$ ~~$CH_3CH_2CH_3 + CH$~~ $CH_3CH_2COOCH_3 + H_2O$ 2
provide reason
..Neutralization reaction ~~in the~~ of two bases in the presence of H_2SO_4 making one of the bases an acid thus yielding salt and water.

24. $CH_3COOH + NaHCO_3$ ⟶ CH_3CO~~HO~~$ONa + CO_2 + H_2O$ 2
Provide reason
..Reaction between ~~a~~ a acidic salt and a base yielding a salt, ~~and~~ water and carbon dioxide.
....

SECTION C: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

25. Which of the following compounds reacts with Propan-1-ol ($OHCH_2CH_2CH_3$) in the presence of H_2SO_4 to form ethylpropanoate ($CH_3COOCH_2CH_2CH_3$) and water?
   A. CH_3CH_3
   B. CH_3CHO
   C. CH_3CH_2OH
   (D) CH_3COOH 1

   Provide reason

..Reaction between two ~~h~~ hydro carbon bases and an acid in the presence of an ac
..Reaction between an acid and a base giving salt and water.

26. Which of the following products is formed when ethanol reacts with excess acidified potassium dichromate($K_2Cr_2O_7/H^+$)?
   A. $CH_3CHOK_2Cr_2O_7$
   ~~(B)~~ CH_3CHO
   (C) CH_3COOH
   D. CH_3CO
   Provide reason

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Neutralization reaction between an alkanol and acid yields ~~and alkoxide~~ an alkanoic acid

27. When 2-propanol reacts with acidified potassium permanganate, the product formed is …….
    - A. $CHCOCH_3$
    - B. $CHCOOCH_3$
    - (C) CH_3CH_2COOH
    - D. $CH_3CH{=}CH_3$

Provide reason

Reaction between an alkanol and an acid ~~yeid~~ yields and alkanoic acid.

28. The products formed when $CH_3C{\equiv}C\text{-}H$ react with $KMnO_4/H^+$ are…..
    - A. CH_3COOH, CO_2 and H_2O
    - B. CH_3COOH and HOOCH
    - (C) CH_3COOH and CO_2
    - D. CH_3COOH and H_2O

    Provide reason

Reaction between an alkyne and an acid yields and alkanoic acid and carbondioxide

29. The product(s) form when $CH_3CH_2CH_2CH{=}CH_2$ reacts with HBr is …
    - A. $CH_3CH_2CH_2CH_2CH_3$
    - (B) $CH_3CH_2CH_2CH_2CH_2Br$
    - C. $CH_3CH_2CHBrCH_2CH_3$
    - D. $CH_3CH_2CH_2CH(Br)CH_3$

    Provide reason

Reaction between a alkene and acid gives ~~an~~ a halo alkane.

SECTION D

Write balanced chemical equations when the following compounds react:

30. Ethane reacts with bromine in the presence of ultra violet light to form bromo ethane and hydrogen bromide.

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$CH_3CH_3 + Br_2 \xrightarrow{UV} CH_2BrCH_2Br + HCl$

Provide reason

$C_3H_8 \xrightarrow{heat} CH_3CH = CH_2 + H_2$

31. Propane heated to produce propene and hydrogen gas

Provide reason

~~$CH_3COHCH_3 + H_2SO_4 \rightarrow CH_3CH = CH_2$~~

$CH_3CH(OH)CH_3 + H_2SO_4 \rightarrow CH_3CH = CH_2$

32. Propan-2-ol is being dehydrated with dilute tetraoxosulphate (vi) acid to produce propene.

provide reason

33. 1,2-dibromoethane reacts with potassium hydroxide in the presence of ethanol to produce ethyne, water and a salt.

$CH_2(Br)CH_2(Br) + KOH \xrightarrow{ethanol} CH \equiv CH + H_2O + salt$ ~~KCH~~

provide reason

34. Ethyne partially react with hydrogen cyanide to form ethylcyanide (vinyl cyanide) which is fully hydrogenated in the presence of nickel to produce propane.

6

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$CH \equiv CH + HCN \rightarrow CCN \equiv CCN \xrightarrow{Ni} + H_2 \xrightarrow{Ni} CH_3CH_2CH_3$

Provide reason

35. Ethanol reacts with ethanoic acid in the presence of conc sulphuric acids and heat to produce a sweet scented ethyl ethanoate.

$CH_3CH(OH)CH_3 + CH_3COOH \xrightarrow{H_2SO_4} CH_3CH_2COOCH_3CH_2$

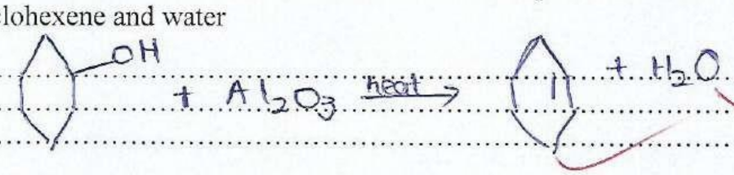
Provide reason

36. Propan-1-ol is reacts with acidified potassium permanganate to produce propanoic acid

$CH_3CH(OH)CH_3 + KMnO_4/H^+ \rightarrow CH_3CH_2COOH$

provide reason

37. Cyclohexanol reacts with aluminium oxide in the presence of heat to produce cyclohexene and water



Provide reason

SECTION E: write the chemical equation and provide the **condition necessary** for the following reaction to proceed

38. Hydrogenation of 2-butene to produce butane

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$CH_3CH_2=CH_2CH_3 + H_2 \xrightarrow{UV\ light} CH_3CH_2CH_2CH_3$ (1)

Provide reason

?

39. Partial hydrogenation of but-2-yne produced but-2-ene

$CH_3C\equiv C-C$ $CH_3C\equiv CCH_3 + H_2 \xrightarrow{Ni} CH_3CH=CHCH_3$ (1)

Provide reason

?

40. Methane reacts with free radical chlorine to form tetrachloromethane

$CH_4 + 4Cl_2 \xrightarrow{UV\ light} CCl_4 + HCl$ 4HCl ✗

Provide reason

?

41. Butan-2-ol is being dehydrated to produce But-2-ene

$CH_3CH(OH)CH_2CH_3 + H_2SO_4 \longrightarrow CH_3CH=CHCH_3$ (1)

Provide reasons

?

42. Hydrolysis of propancyanide to butanoic acid and ammonia

$CH_3CH_2CH_2$ $CH_2CN + H_2 \xrightarrow{Dt} CH_3CH_2CH_2COOH + NH_3$ (2)

Provide reason

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………………………………………………………………………………

43. Reaction of ethyne with sodium metal to produce ionic salt and hydrogen gas.

CH₃C CH ≡ CH + Na —Pt→ CNa ≡ CNa + H₂ ✗

provide reason

………………………………………………………………………………

44. Cracking of butane to form ethane and ethene

CH₃CH₂CH₂CH₃ —60°C→ CH₃CH₃ + CH₂ = CH₂ (1)

provide reason

………………………………………………………………………………

45. Hydration of 2-methylpropene to produce 2-methylpropan-2-ol.

~~CH₃ CH(CH₃) = CH₂ C(CH₃) = CH CH₃ —NaSO₄→ +~~

CH₃ C(CH₃) = CH₂ + H₂O ⟶ CH₃ CH(OH)(CH₃) CH₃ (1)

Provide reasons

………………………………………………………………………………

SECTION F: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

46. Which of the following carbon compounds is capable of reacting to form hydrogen bond
   - A. CH_3CH_2OH ✓
   - B. CH_3-O-CH_3
   - C. CH_3CHO
   - D. CH_3CH_3

Provide reasons

9

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Reactio Hydration of an alkanol gives an alkane, which has a hydrogen bond

47. Which of the following compounds has 2 pi-bonds that can react with acidified water to produce diol
A. $CH_3CH_2CH_3$
B. CH_3CCH
(C) CH_3CHCH_2
D. CH_2CCH_2

Provide reasons

The second and third carbon atoms still need an electron each to become stable, So they form two pi bonds, which can react with water to produce diol.

48. The type of breakage which occurs in Chlorine when it reacts with methane in the presence of ultra violet light is…
(A) Homolytic cleavage
B. Heterolytic cleavage
C. Catalytic cleavage
D. thermal cleavage

Provide reasons

Both bonding electron are equally shared between the chlorine atoms

49. During chemical reaction to form a product, the species which is formed between successive reaction step and consumed is termed as
(A) Reaction mechanism
B. activation energy
C. intermediate
D. rate determining step

Provide reasons

it is the species that leads to the formation of a product

50. Which of the following bonds is/are capable of making some organic compounds very reactive?
A. covalent bond
B. hydrogen bond
C. pi bond
(D) sigma bond

provide reason

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The bonds are usually ~~ust~~ unstable, thus making them unreactive.

11

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11.3a.

ACHIEVEMENT TEST ITEMS FOR SHS 2 & 3 CHEMISTRY STUDENTS ON CHEMICAL REACTION OF ORGANIC COMPOUNDS

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When you complete this instrument it means you are consenting to be part of the research.

Kindly read through the instructions and respond favorably to all the items according to your understanding.

SECTION A: Tick the appropriate response

1. SEX: Male [✓] Female [ ]
2. Age [19]
3. **Level: SHS 2 [ ]** **SHS 3 [✓]**
4. Do you have a chemistry teacher; Yes [✓] No [ ]

SECTION B: CHEMICAL REACTION

5. Complete the reaction below:
   $CH_4 + 4Cl_2$ $\xrightarrow{\text{UV light}}$ $CCl_4 + 2H_2(g)$ ✗
   Provide reason
   Methene reacts with Chlorine by Substitution reaction to give tetrachloromethene.

   (2)

6. $CH_3CH_2CH_2Br + 2Na$ $\xrightarrow{\text{Dry/ethoxyethane}}$ $CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_3 + 2NaBr$ ✗
   provide reason
   halogenated alkanes react with alkalimetal to give an alkane which is twice its length.

7. $CH_3CH_2CH_2CH_2CH_3 + 5O_2$ $\xrightarrow{\text{heat}}$ $5CO_2 + 6H_2O$ ✓
   provide reason
   Alkanes undergo Combustion in excess oxygen to Produce CO_2 and H_2O.

   (3)

1

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8. $CH_2{=}CH_2 + H_2O \xrightarrow{H_2SO_4}$ CH_3CH_2OH
provide reason 3

Alkenes ract with Water in the Presence Of H_2SO_4 to give an alkanol.

9. $CH_3CH(Cl)CH{=}CH_2 + HBr \xrightarrow{AlBr_3}$ $CH_3CH(Br)CH_2CH_3 + C$
Give reason

10. $CH_3CH{=}CH_2 + 9/2O_2 \xrightarrow{\text{Excess air}}$ $3CO_2 + 6H_2O$
Give reason 3

Alkanes undergo Combustion in excess air to Produce CO_2 and H_2O

11. $CH_2{=}CHCH_3 + H_2 \xrightarrow{Pt}$ $CH_3CH_2CH_3$
Give reaction 2

Alkenes undergo addition reaction With H_2 to form a Corresponding alkane in the Presence of Platinum (Pt)

12. $CH_2{=}CH_2 + NaCN/HCl \longrightarrow$ CH_3CH_2CN $+ 2H_2/Pt \longrightarrow$ $CH_3CH_2CH_3$ 2
give reason

13.  CH_3 + HCl ⟶

Provide reason

14. $CH \equiv CH + H_2 \xrightarrow{Pt}$ CH_3CH_3
give reasons 0

Alkynes undergo addition reaction With $H_2(g)$ to give a Corresponding alkane

2

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15. $CH_3C \equiv CH + H2O \xrightarrow[60^oC]{HgSO_4}$?

provide reason

?

16. $HC\equiv CCH_3 + Br_2 \longrightarrow$ CHBrBrCBrBrCH3 ✗

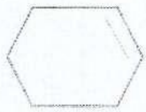
Provide reasons

Alkynes react with Bromine to give 1,1,2,2-tetrabromo alkane. the above compound is 1,1,2,2-tetrabromopropane ✗

17. $C(CH_3)_2\ C\equiv C\text{-}H + 2HCl \longrightarrow$?

Provide reason

?

18.  $+ Br_2/CCl_4 \longrightarrow$?

provide reason

?

19. $CH_3OH + 2Na \longrightarrow$?

Provide reason

?

20. $CH_3C(CH_3)_2OH + HCl \xrightarrow[25^oC]{}$ $CH_3-C(CH_3)_2-Cl + H_2O$ ✗

Provide reasons

?

21. $CH_3CH_2OH + \text{Conc } H_2SO_4 \xrightarrow[\text{heat}]{}$ $CH_2=CH_2 + H_2O$ ✓

Give reason

2

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.... ? ....
....
....

22. $CH_3CH_2CH_2OH + KMnO_4/H^+ \longrightarrow$?
Give reason
.... ? ....
....
....

23. $CH_3COOH + CH_3OH \xrightarrow{H_2SO_4}$ $CH_3COOCH_3 + H_2O$ (3)
provide reason
....
ethanoic acid react with Methanol to give an esther
CCH_3COOCH_3 and H_2O in the Presence of H_2SO_4

24. $CH_3COOH + NaHCO_3 \longrightarrow$?
Provide reason
....
.... ? ....
....

SECTION C: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

25. Which of the following compounds reacts with Propan-1-ol ($OHCH_2CH_2CH_3$) in the presence of H_2SO_4 to form ethylpropanoate ($CH_3COOCH_2CH_2CH_3$) and water?
   A. CH_3CH_3
   B. CH_3CHO
   C. CH_3CH_2OH
   ✓D. CH_3COOH (1)

   Provide reason
Alkanols react with alkanoic acids in ē Presence of H_2SO_4 to form alkylalkanoates
....

26. Which of the following products is formed when ethanol reacts with excess acidified potassium dichromate($K_2Cr_2O_7/H^+$)?
   ✓A. $CH_3CHOK_2Cr_2O_7$
   B. CH_3CHO
   C. CH_3COOH
   D. CH_3CO
   Provide reason

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....
....
....

27. When 2-propanol reacts with acidified potassium permanganate, the product formed is ......

    A. $CHCOCH_3$
    B. $CHCOOCH_3$
    C. CH_3CH_2COOH
    D. $CH_3CH{=}CH_3$

Provide reason

....
....
....

28. The products formed when $CH_3C\equiv C\text{-}H$ react with $KMnO_4/H^+$ are.....

    A. CH_3COOH, CO_2 and H_2O
    B. CH_3COOH and HOOCH
    C. CH_3COOH and CO_2
    D. CH_3COOH and H_2O

    Provide reason

....
....
....

29. The product(s) form when $CH_3CH_2CH_2CH{=}CH_2$ reacts with HBr is ...

    A. $CH_3CH_2CH_2CH_2CH_3$
    B. $CH_3CH_2CH_2CH_2CH_2Br$
    C. $CH_3CH_2CHBrCH_2CH_3$
    D. $CH_3CH_2CH_2CH(Br)CH_3$

    Provide reason

Alkenes react with HBr to give a 1-bromo alkane.
....
....

SECTION D

Write balanced chemical equations when the following compounds react:

30. Ethane reacts with bromine in the presence of ultra violet light to form bromo ethane and hydrogen bromide.

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$CH_4 + Br_2 \xrightarrow{UV} CH_3Br + HBr$

Provide reason

reaction of alkanes with halogens to form a haloalkane and a corresponding Hydrogen halogen.

31. Propane heated to produce propene and hydrogen gas

$CH_3CH_2CH_3 \xrightarrow{heat} CH_3CH{=}CH_2 + H_2$

Provide reason

Cracking of alkanes to give other hydrocarbons and hydrogen gas

4

32. Propan-2-ol is being dehydrated with dilute tetraoxosulphate (vi) acid to produce propene.

$CH_3CH(OH)CH_3 \xrightarrow{H_2SO_4} CH_3CH{=}CH_2$
an

2

provide reason

alkenes react with water to form corresponding alkanols. So if an alkanol is dehydrated with H_2SO_4, it gives a corresponding alkene.

33. 1,2-dibromoethane reacts with potassium hydroxide in the presence of ethanol to produce ethyne, water and a salt.

1,2-diabromo ethane react with Caustic KOH, which is basic to produce an ethyne water and a salt with the cation of KOH thus (K^+)

provide reason

$CH_2Br-CH_2Br + 2KOH \xrightarrow{C_2H_5OH} CH{\equiv}CH + 2H_2O + 2KBr$

2

34. Ethyne partially react with hydrogen cyanide to form ethylcyanide (vinyl cyanide) which is fully hydrogenated in the presence of nickel to produce propane.

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$CH \equiv CH + HCN \longrightarrow CH_3CH_2CN \xrightarrow{Nickel} CH_3CH_2CH_3$ (1)

Provide reason

35. Ethanol reacts with ethanoic acid in the presence of conc sulphuric acids and heat to produce a sweet scented ethyl ethanoate.

$C_2H_5OH + CH_3COOH \xrightarrow{conc. H_2SO_4} CH_3CH_2OOCH_2CH_3$ (1)

Provide reason

36. Propan-1-ol is reacts with acidified potassium permanganate to produce propanoic acid

$CH_3CH_2CH_2OH + KMnO_4/H^+ \longrightarrow CH_3CH_2COOH$ (1)

provide reason

37. Cyclohexanol reacts with aluminium oxide in the presence of heat to produce cyclohexene and water

Provide reason

SECTION E: write the chemical equation and provide the **condition necessary** for the following reaction to proceed

38. Hydrogenation of 2-butene to produce butane

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$CH_3CH_2=CHCH_3 + H_2 \xrightarrow{H_2SO_4} CH_2CH_2CH_2CH_3$ 1

Provide reason

Alkenes react with hydrogen gas in an addition reaction to Produce a Corresponding alkane in the Presence of H_2SO_4.

39. Partial hydrogenation of but-2-yne produced but-2-ene

Provide reason

40. Methane reacts with free radical chlorine to form tetrachloromethane

$CH_4 + 2Cl_2 \xrightarrow{U.V\ light} CCl_4 + 2H_2$

Condition is ultraviolent light.

2

Provide reason

methane reacts with Chlorine in the Presence of U.V light to for tetrachloronethane.

41. Butan-2-ol is being dehydrated to produce But-2-ene

$CH_3CH(OH)-CH_2CH_3 \xrightarrow{Conc.\ H_2SO_4} CH_3CH=CHCH_3 + H_2O$

Provide reasons

Butan 2 of thiaus a Molecule of water will give a Corresponding alkene (Butan-2-ene).

42. Hydrolysis of propancyanide to butanoic acid and ammonia

Provide reason

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43. Reaction of ethyne with sodium metal to produce ionic salt and hydrogen gas.

provide reason

44. Cracking of butane to form ethane and ethene

$CH_3.CH_2.CH_2.CH_3$ —heating at high temperature and pressure→ $CH_3CH_3 + CH_2=CH_2$

provide reason

Cracking of a larger molecule (Butane) to produce two smaller molecules (CH_3CH_3) and ($CH_2=CH_2$).

4

45. Hydration of 2-methylpropene to produce 2-methylpropan-2-ol.

Provide reasons

SECTION F: SELECT BY TICKING THE RIGHT ANSWER FROM THE LETTER A-D AND INDICATE THE REASON FOR THE CHOICE

46. Which of the following carbon compounds is capable of reacting to form hydrogen bond
   A. CH_3CH_2OH ✓
   B. CH_3-O-CH_3
   C. CH_3CHO
   D. CH_3CH_3

Provide reasons

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dehydration of ethanol to form ethene and Water CH_3CH_2OH $- H_2O$ $CH_2 = CH_2 + H_2O$
H_2O has π-bonds in its molecules.

47. Which of the following compounds has 2 pi-bonds that can react with acidified water to produce diol
A. $CH_3CH_2CH_3$
B. CH_3CCH
C. CH_3CHCH_2
D. CH_2CCH_2

1

Provide reasons
Propyne (CH_3CCH) has 2 Pi bonds since it has a C≡C bond in its structure.

48. The type of breakage which occurs in Chlorine when it reacts with methane in the presence of ultra violet light is…
A. Homolytic cleavage
B. Heterolytic cleavage
C. Catalytic cleavage
D. thermal cleavage
Provide reasons
Chlorine Under goes homolytic Cleavage to Produce Chloride molecules with equal electrons. thus $Cl^{\circ} Cl^{\circ} + CH_3^{\circ} H^{\circ} \rightarrow CH_3^{\circ} Cl^{\circ} + H^{\circ}Cl^{\circ}$

3

49. During chemical reaction to form a product, the species which is formed between successive reaction step and consumed is termed as
A. Reaction mechanism
B. activation energy
C. intermediate
D. rate determining step

5

Provide reasons
In the formation of CCl_4, CH_3Cl is consumed to form CH_2Cl_2 and CH_2Cl_2 is further consumed to form $CHCl_3$ and hence $CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$. Therefore, CH_3Cl, CH_2Cl_2, $CHCl$ are intermediate products.

50. Which of the following bonds is/are capable of making some organic compounds very reactive?
A. covalent bond
B. hydrogen bond
C. pi bond
D. sigma bond

provide reason

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Pi bonds have delocalize electrons it hence are very reactive and are broken first before Stronger bonds like Signabonds.

3

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