UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF FIRST PRINCIPLE APPROACH ON STUDENTS' ACHIEVEMENTS IN THE DETERMINATION OF LIMITING REAGENTS IN REACTIONS

FRANCIS ABBAN-ACQUAH

MASTER OF PHILOSOPHY

2022

UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF FIRST PRINCIPLE APPROACH ON STUDENTS' ACHIEVEMENTS IN THE DETERMINATION OF LIMITING REAGENTS IN REACTIONS

FRANCIS ABBAN-ACQUAH

(202122432)

**A thesis in the Department of Science Education,
Faculty of Science Education, submitted to the School of
Graduate Studies in partial fulfilment of
the requirements for the award of the degree of
Master of Philosophy
(Science Education)
in the University of Education, Winneba**

AUGUST, 2022

DECLARATION

STUDENT'S DECLARATION

I, **FRANCIS ABBAN-ACQUAH**, hereby declare that except for references to other people's work which have been duly cited, this research work is the result of my own work and that it has neither in a whole nor part been presented elsewhere.

Signature: ……………………………………

Date: …………….........…………………….

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this research work was supervised in accordance with the guidelines on the supervision of research work laid down by the University of Education, Winneba

Supervisor's Name: Professor John K Eminah

Signature: ……………………………………

Date: …………….........…………………….

DEDICATION

This research work is dedicated to my beloved spouse Anita Tackey Otoo and my children; Nana Abban, Elizabeth and Michealina for offering both financial and moral support during the entire duration of this studies.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to the Almighty God through our redeemer Jesus Christ my sincerer of knowledge and strength for the love and guidance shown unto me through the present times of age and for sustaining me up to this level. I also want to express my sincere gratitude to my dear supervisor Professor John K. Eminah through whose suggestions, directions and appreciation that helped me to eliminate errors and have made this project work a master piece. To my supervisor, I wish more grease to his elbow.

There is nothing better than encouragement and support from my good friends and that is why I wish to acknowledge my dear friends Joseph Coleman, Justice Edusei Ackah, Robert Acquah and Anthony Boakye.

TABLE OF CONTENTS

Content **Page**

LIST OF TABLES

ABSTRACT

A quasi experiment research was conducted to find out the effect of first principle instructional approach, on students’ achievements in the determination of limiting reagents in chemical reactions. Convenient sampling technique was employed to select 120 Second year science students from Lamp Lighter and Wiawso Colleges of Education all in the Western North region of Ghana. The instruments used to gather data in this study were questionnaire and tests. The internal consistency of the items on the instruments was verified by examining the coefficient alpha of the various items in the instrument using the scores from the pilot-testing to determine the reliability. The overall reliability coefficient alpha for each of the two (2) test instruments constructed was found to be 0.70. Test statistics value of -4.941 which was less than the critical value of 1.980 or probability value, the null hypothesis was rejected. Thus there was a statistically significant difference in the students’ performance. A careful study of the analysis of research questions shows that students appreciated the use of the first principles, in general students ' performance in the test, based on the first principle approach, was better than actual mole ratio and stoichiometric mole ratio. The control group had a mean score of 44.06% whiles the experimental group had a mean score of 58.23%. From the foregoing, it concluded that the first principle approach helped the students to deduce the limiting reactants in chemical reactions better than the other approaches. Among other recommendations, it was suggested that teachers consider the use of first principle approaches during instructions for the benefit of the students. It was also suggested that further research be done on this topic by other researchers in other places of the country.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter deals with the introduction of the study. The areas covered in the introduction include; Background to the Study, Statement of the Problem, The Purpose of the Study, Significance of the Study, Research Objectives, Research Questions, Delimitations and Limitations of the study.

1.1 Background to the Study

The limiting reagent concept in reaction stoichiometry problem solving is an area that often poses problems to students. The difficulties that students experience are related to several conceptual issues evidenced in the wider context of stoichiometry problem solving in general (Schmidt, 1997; Boujaoude & Barakat, 2000). Students' understanding or lack of understanding of science concepts, especially chemical concepts they learn in senior high school has been the subject of most studies by science education researchers (Anderson & Renstrom, 1983; Anamuah-Mensah, 1995; Schmidt, 1997; Boujaoude & Barakat, 2000). The general consensus of these studies has been that, students have misconceptions about chemical concepts. Chandrasegaran, Treagust, Waldrip and Chandrasegaran (2009) conducted a qualitative case study to investigate the understanding of the limiting reagent concept and the strategies used by five students in Year two when solving four reaction stoichiometry problems.

Students' written problem-solving strategies were studied using the think-aloud protocol during problem-solving, and retrospective verbalisations after each activity. The study found that, contrary to several findings reported in the research literature, the two high-achieving students in the study tended to rely on the use of a memorised formula to deduce the limiting reagent, by comparing the actual mole ratio of the reactants with the stoichiometric mole ratio. The other three average-achieving students, however, generally deduced the limiting reagent from first principles, using the stoichiometry of the balanced chemical equation.

According to Chandrasegaran, et al (2009), the average-achieving students in their study have demonstrated a preference for the use of reasoning strategies from first principles making use of the balanced chemical equation when solving limiting reagent problems. This preference for the use of first principles by average-achieving students according to Chandrasegaran, et al (2009) reinforces the need for teachers to consider the use of this strategy during instruction for the benefit of average and lower-achieving students, without totally relying on solving problems in rote fashion. Worth considering therefore, among the scientific approaches to learning is the use of the first principle approach to enable students of Wiawso College of Education deduces the limiting reagents in chemical reactions.

Science education plays a vital role in National Development. The need for a strong scientific and technological base as a prerequisite for national development is known world-wide in contemporary development strategies. In Ghana, this has been recognized since independence, and resources however inadequate, have been directed to education in general and science education in particular. In recent years the Ministry of Education (M.O.E.) has committed large sums of money to help improve the coverage and quality of education, both from Government Budget and from funds granted by the Nation's Development Partners.

Ghana is said to be the first independent sub-Saharan African country outside South Africa to embark on a comprehensive drive to promote science education and the application of science in industrial and social development (Anamuah-Mensah, 1999). According to Anamuah-Mensah (1999), quality teachers and quality teaching are the single most important determinant of a good science education. The success of our students in science education and the progress of the nation will depend on quality science teaching which ensures the development of the innate capacities of all students.

Quality teaching builds a strong foundation in basic sciences and lead also to the acquisition of better research skills. Interventions allow schools to introduce exemplary and transferable programmes that help to develop teachers' and students' knowledge and skills in science and their ability to innovate. Teachers have to bring in interventions during their teaching and learning processes to help improve the lot of their students.

According to Kuhn (1962), "The structure of Scientific Revolutions" offered a radically different way of thinking about scientific methodology and knowledge, and changed the practice of history of science. His philosophy of Science has influenced academia from literary theory to management of science, and he seems single-handedly to have caused the widespread use of the word "paradigm" (p.2)

One of the goals of science education is to develop learners' ability to acquire knowledge in specific subject areas and to improve their conceptual understanding needed for designing instruction that will promote better understanding of scientific concepts which are very crucial to the development of Science education. However, the kind of Science to be taught and how to teach it at different levels has been challenging over the past few decades.

Chemistry is the science that deals with chemical changes involving the mole, molecule, and particle concepts as well as mathematical computations including Stoichiometry and determination limiting reagents.

Nurrenbern and Pickering (1987) employed a visual and iconic method to displace traditional rote "plug and chug" procedures for stoichiometry. The students worked on paper with collections of blocks and circles which represented atoms and molecules in various bonding configurations. Since they could not use rote memorized algorithms to predict molecular formulas or balance equations, they had to "construct" an intuitive understanding of stoichiometry in order to succeed.

In every classroom setting the students who are of different learning abilities always have problems with learning what they have been taught. The teacher during the evaluation of his lesson has to write his test items to cover the aspects of the profile dimension as stipulated in the syllabus. The students' inability to plan their studies well brings a lot of challenges when it comes to classroom teaching and learning.

Chamizo and Padilla (2007) highlighted on historical recurrent teaching models 2: from Stoichiometry to Nanotechnology. For teaching purposes, Historical Recurrent Teaching Models, (HRTM) have recently been introduced. They have to do with an appreciation of the kind of problems that a model was designed to solve, the extent to which it does so, and the reasons why, if it is correct, previous attempts were not successful and therefore had to be altered or abandoned. Here we develop (with a specific document entitled Stoichiometry: from equivalent: atomic models) and test (first with six chemistry high school teachers and later through a semantic differential scale) on HRTM related with Stoichiometry, atomic theory and nanotechnology for undergraduate students in the school of Chemistry in the Autonomous National University of Mexico.

According to Chamizo and Padilla (2007), the identification of hybrid models provides a new insight through which teaching can be discussed. The existence of hybrid models in teaching means that no history of science is possible because it implies that scientific knowledge grows linearly and is context independent. It leads students to have misconceptions in their mental models of the theme being discussed and/ or to have difficulties in understanding the reasons for which hybrid relationships are introduced.

According to Alson (2014), in general chemistry the primary tool used to solve problems is the rote method, which can present some difficulties. Students are often plagued with poor recognition of new problems, and faculty in later courses are often disappointed that the students rave forgotten what they were taught in the freshman year.

Chemical Reaction: Stoichiometry, limiting reagents and Beyond tackles this issue in a new way by teaching students how all problems are solved. This innovative textbook presents a universal format to be used when solving all problems. Instead of memorization, students learn to ask three answerable questions, and by using the format, solve the problem. So, once the student masters how to use the format, they can solve any problem.

According to Felder (1990), students write equation after equation, but never seem to have quite enough information to solve for the quantities they are trying to calculate. Some being to believe that there may be a point, after all, in being systematic about setting up problem solutions, and save themselves; others resist to the bitter end and fail (Felder, 1990)

In order to bring a change depends on the following:

1. There must be dissatisfaction with existing conceptions,
2. New conceptions must be minimally understood,
3. New conceptions must appear initially plausible, and
4. New conceptions should suggest the possibility of a fruitful research programme (Howe, Devine & Tavares, 201l).

According to Fach, de Boer and Parchmann (2007), in recent years many research studies investigated students' misconceptions in limiting reagents, and problem solving strategies. Additionally, alternative approaches for teaching this issue of chemistry developed. However, among students and teachers, this topic is still regarded as being difficult and motivating. Our approach is to combine (qualitative) investigation with the development and evaluation of specific teaching and learning materials. To help students working on Stoichiometric problems, we developed a set of stepped supporting tools (SST), based on the results of an interview study investigating the phases of the solution processes of German secondary school students (grade 9) on these problems.

In research on education in the sciences, there seem to be two main ways of working. Many research groups focus on investigating certain aspects of science education, trying to give a detailed description of for example students' way of thinking or the pros and cons of a certain teaching method. Other research groups try to develop teaching and learning materials to improve on classroom situations.

However, the two aspects of research are seldom linked to each other. Although there are models that try to combine the two sides of the same coin (e.g. "the model of educational reconstruction" (Duit, Gropengie Per & Kattmann, 2005) or the model of "developmental research" (Lijnse, 1995) The investigating researchers often only provide "recommendations for teaching" without building on their results to produce teaching modules. The researcher's approach tries to bridge this gap between investigation, development and evaluation.

Much research has been done on limiting reagents problems in recent years (for reviews see eg. Gabel & Bunce, 1994; Furio, Azcona & Guisasola, 2002). This is probably clue to the fact that Stoichiometry is a very basic and fundamental concept in chemistry. For example, students have to switch from thinking about concrete aspects of matter to more abstract thinking concerning aspects of particles, thus, they may enhance their conceptual understanding (Boujaoude & Barakat, 2003). On the other hand, many authors agree that the concept is very difficult for students to grasp and therefore discouraging (Schmidt & Jigneus, 2003). Therefore, to close the gap between what is and what could be, research results will have to be implemented into school practice, providing teachers with specific teaching materials (worksheets) and thus combining fundamental research with day-to -day practice.

The constructivist model states that: "Knowledge is constructed in the minds of the learner" (Bodner, 1986, p. 873). Describes the two theories of learning which are applied to chemistry instruction, for learning theory (A) "the purpose is to inform, the teaching procedure used can be described as INFORM, VERIFY and PRACTICE". Learning theory (B) "also has the purpose of the mastery of content, but an additional overt purpose is to lead the students to adjust the understanding held about a field and/ or concept"

1.2 Statement of the Problem

The key concepts of chemistry that often pose difficulty to students in colleges of education in the western north region of Ghana are determination of the limiting reagents and chemical stoichiometry problem solving. The limiting reagent concept in reaction stoichiometry problem solving is an area that often poses problems to students. The difficulties that students experience are related to several conceptual issues evidenced in the wider context of stoichiometry problem-solving in general (Schmidt, 1997; BouJaoude & Barakat, 2000).

The Institute of Education (IOE) of University of Cape Coast (UCC) Chief Examiner's report therefore suggested that tutors should arouse the interest of students in science and makes them feel that science is life, and must therefore relate what they study to things around them. He continued that, students' performance in the science examination may be influenced by their misconception or lack of understanding of topics in the Senior High School (SHS) Integrated Science syllabus.

It is in the light of this that it becomes imperative to consider the effect of the first principle approach, in a quasi-experimental research, to enable students of Wiawso College of Education to determine the limiting reagents in chemical reactions.

1.3 **The Purpose of the Study**

The ultimate purpose of this study was to assess the effect of first principle instructional approach on students' achievements in the determination of limiting reagents in chemical reactions

1. 4 Objectives of the Study

The objectives of the study were to:

1. assess difficulties students encounter when asked to determine the limiting reagents in chemical reactions.
2. assess students' views about the concept of limiting reagents in chemical reaction.
3. evaluate the effect of first principle instructional approach on students' achievements in the determination of limiting reagents in chemical reactions.
4. evaluate students' perceptions on the use of first principle instructional approach.

1.5 Research Questions

Four research questions were formulated to direct investigations in the study.

1. What difficulties do students encounter when asked to determine the limiting reagents in chemical reactions?
2. What are the students' view about the concept of limiting reagents in chemical reactions?
3. What is the effect of first principle instructional approach on students' determination of the limiting reagents in chemical reactions?
4. What are the students' perceptions of the use of first principle instructional approach to determine the limiting reagents in chemical reactions?

Null Hypothesis Ho: There is no significant difference in student's performance when asked to determine the limiting reagent using actual mole ratio and Stoichiometric mole ratio (AMR/SMR) or the first principle instructional approach.

1.5 Significance of the Study

It is hoped that the findings of this study would be useful to all teachers of science and textbook writers to employ the right instructional methodologies in their presentation and treatment of the concept of limiting reagent in chemical reaction so as to minimize as far as possible any lack of understanding or misconception of the concept.

The students who are the subject of the study will benefit greatly as it will help them to be able to deduce the limiting reagents in chemical reactions. The findings will also benefit all science students since the suggested approaches will provide them with techniques in deducing the limiting reagents in chemical reactions. The study will be significant to other researchers because it will serve as a documentary reference for future research works.

Finally, the study would be of significance to Stakeholders and Educational Policy Makers because it will provide valuable information that will direct policy, planning and implementation in science educational studies.

1.6 Delimitations of the Study

The sample frame forming the students ' population from which the sample was drawn from second year science students of Wiawso and Lamp Lighter Colleges of Education all in the Western North Region of Ghana. The science students were selected because they had just completed a course in stoichiometry and chemical equation in chemistry which had as one of its sub-topics;" the limiting reactants in chemical reactions" at the end of their study in first year. First year students were not used because they had not treated the topic; "stoichiometry and chemical equation in chemistry". Also, final year students were not used as the subject for the study because they were in their final out segment Programme.

The study took place within a period of two (2) months. It could have gone beyond the two (2) months period but due to the fact that the study was time bond, it had to be done within the two (2) months period.

1.7 Limitation of the Study

According to Anamuah-Mensah (1995) limitation is condition beyond the control of the researcher that place restriction on the validity of the study. The results of the research may be influenced by the following;

Some of the students were absent from lessons during the treatment stage. They were likely not to understand the concepts taught very well. Other students also kept revising their old notes on the topic; hence the study may not be solely responsible for their output in the tests. The findings of this study would provide insights into the efficacy of first principle instructional approach for science lessons.

Also, the study could not detect whether the answers that were given by the students in the bio-data section of the questionnaire were true or otherwise. In view of this the students were encouraged to be as sincere as possible.

1.8 Operational Definitions of Terms

In this section, definitions of terms are provided including explanations where necessary. In doing so, cognizance is taken of the scope and context of the research.

Conceptual Change: Pertaining to teaching and learning, one giving up an idea held in the cognitive structures for another "correct" idea.

Limiting reagent: The limiting reagent is the substance that is in shortage to complete the chemical reaction fully.

First principle: It is one of the procedures which can be used to determine limiting reagents in a chemical reaction.

Actual mole ratio: This is the division or ratio of the number of moles of the reacting species.

1.9 Abbreviation

G.E.S: Ghana Education Service

S.H.S : Senior High School

M.O.E: Ministry of Education

WASSCE: West African Senior School Certificate Examination

U.C.C: University of Cape Coast

IOE Institute of Education

U.E.W: University of Education, Winneba

H.R.T.M: Historical Recurrent Teaching Model SST: Stepped Supporting Tool

IMRS: Item mean response score

OIMRS: Overall item mean response score

10.0 Organization of the Research Reports

This report consists of five chapters. The first chapter is the introduction which entails the background to the study, statement of the problem, purpose of the study, research objectives, research questions, null hypothesis, significance of the study, delimitations of the study, ethical issues limitations of the study, operational definitions of terms and the organization of the work.

The second chapter deals with review of literature. Here the opinions of other researchers and educationists who have studied and written on limiting reagents and stoichiometry are discussed.

The third chapter is methodology. It includes the design used for the study, the population and sample selection, and research instruments as well as data analysis plan.

The fourth chapter dwells on the analysis and discussion of results obtained from the research instruments. The last chapter which is chapter five presents the summary, conclusion and recommendations of the study.

CHAPTER TWO

REVIEW OF THE RELATED LITERATURE

2.0 Overview

This chapter deals with the review of the related literature. Literature on Theoretical Framework, students' understanding of science concepts, Limiting Reagent Concept Difficulties, Mathematical Concepts and Stoichiometry Problem Solving, and Reasoning and Algorithmic Strategies in Stoichiometry Problem Solving are discussed. Also, Understanding the Mole Concept and Interpretation of Chemical Formulae and Equations, The First Principle Approach in Chemistry.

- Theoretical Framework
    - (i) Cognitive load theory of learning
    - (ii) Cognitive load and reaction stoichiometry
    - (iii)Measurement of cognitive load in reaction stoichiometry
    - (iv)Constructivism theory of learning
- Conceptual framework
- Categorization of broad factors that affect students' learning

2.1 The theoretical framework of the study

This study was based on cognitive load theory (Sweller, Ayres & Kalyuga, 2011). This theory primarily focuses on students being the pivot in the learning environment. The theory is to derail any misconception or difficulties which students have on the determination of limiting reagents in chemical reactions.

2.1.1 Cognitive Load and limiting reagents concept

The Cognitive Load Theory attempts associations with instructional design principles on the basis of human cognitive architecture theories. The instructional principles of the theory are based on long-term memory and working memory assumptions about human cognitive architecture (Paas & Sweller, 2014). The Cognitive Load Theory emphasises that all novel information is initially processed by working memory which has capacity and duration limitations; the information is then stored in long-term memory which is unlimited (Anmarkrud, Andresen & Braten, 2019; Sweller, van Merrienboer & Paas, 2019). The aim of instructional design should be to reduce unnecessary working memory loads, and free the capacity for learning-related processing to accommodate the limited capacity of working memory (Sweller, 2010; Sweller, Ayres & Kalyuga, 2011). The Cognitive Load Theory claims there are three categories of cognitive load on working memory in any learning task. These include intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (Paas & Sweller, 2014; Sweller, van Merrienboer & Paas, 2019). The intrinsic cognitive load is determined by the complexity of a learning task and the results from element interactivity. The number of interacting information elements belonging to a learning task is defined as "element interactivity." The learning task becomes more complex as the intrinsic cognitive load becomes higher.

However, as a learner's prior knowledge also plays a role in determining the intrinsic cognitive load, it is not merely a feature of instructional content (Canham & Hegarty, 2010; Park, Korbach & Brunken, 2015). Extraneous cognitive load is a cognitive load that causes an unnecessary increase in interactional elements to be processed by the learner, and it is a result of inappropriate instructional design (Paas & Sweller, 2014). Therefore, the instructional approach (for example, explanation adequacy or instructional material integration) critically affects the extraneous cognitive load. Germane cognitive load is a load that emerges during the formation and regulation of mental structures. The capacity that remains from extraneous and intrinsic loads on working memory capacity is used for the germane cognitive load (Paas & Sweller, 2014). The capacity left for the germane cognitive load is effective in realising learning. In conclusion, according to the Cognitive Learning Theory, the total cognitive loads counted in the learning process should not exceed the learning capacity of the learner. Therefore, designers should analyse content to be taught, and consider the load processed in working memory while using texts, pictures, and graphs.

2.1.2 Cognitive load and limiting reagent

Empirical research on learning and instruction commonly utilizes the Cognitive Load Theory as a theoretical framework (Korbach, Brunken & Park, 2018). The focus of these studies is to identify methods and techniques that might reduce the working memory load of cognitive load types in instructional design. Similarly, this topic is important in multimedia learning studies. Multimedia Learning is defined as the learning realised when constructing mental representations through pictures and words (Mayer, 2014). The Cognitive Theory of first principle approach, which is based on the Cognitive Load Theory, was developed in light of the studies conducted. The theory addresses how individuals process information, and how they learn through limiting reagent (Mayer, 2014). The theory encompasses three fundamental assumptions: (1) people have separate channels for processing visual and audio information, (2) each channel has a limited amount of information per unit of time, and (3) people experience active learning by accessing related information, organising the selected information through mental structures, and integrating them with previous mental structures. According to the theory, limiting reagent is realised (Mayer, 2014a) as follows: Initially, words and pictures are selected by sensory memory which has an unlimited capacity, and it is subsequently transferred to working memory. Knowledge is organised in working memory, which has a limited capacity, and integrated with knowledge in long-term memory. The instructional design should be appropriate for a given individual's cognitive processing, and avoid overloading the memory demand present during learning. Three types of learner processing are realised in information processing according to the Cognitive Theory of Limiting reagent: extraneous processing, essential processing, and generative processing (Mayer, 2014). Essential processing is what is realised in the process of selecting and organising the realised ones from those presented via limiting reagent. Words and pictorial representations related to the material presented as a result of this processing are constructed in working memory.

Several studies have confirmed the influence of alternative conceptions that are held by students in contributing to the difficulties that they experience when solving stoichiometry problems (Mitchell & Gunstone, 1984; Boujaoude & Barakat, 2000; Dahsan & Coll, 2007). Studies associated with reaction stoichiometry estimations by Colleges of Education students, some of which are referred to in this section, have included the limiting reagent concept as part of the studies. In the other hand, only one reactant was tought to have changed completely when a solid was one of the reactants. Students' weaknesses which manifested included, inability to balance chemical equations, inability to write chemical symbols, inability to write IUPAC names,

It resembles the intrinsic cognitive load associated with Cognitive Load Theory (Mayer, 2014). Extraneous processing refers to processing that results from the instructional design and does not serve instructional goals. It resembles the extraneous cognitive load in Cognitive Load Theory (Mayer, 2014). Generative processing encompasses received information organization and its integration with previously related knowledge. It resembles the germane load in Cognitive Load Theory. Limiting reagent studies suggest that various instructional principles contribute to the learning process for every type of cognitive load (Mayer & Pilegard 2014). The principles suggested for minimizing extraneous processing are as follows (Mayer & Fiorella, 2014): coherence principle, signaling principle, redundancy principle, spatial contiguity principle, and temporal contiguity principle. The principles suggested for managing essential processing are (Mayer & Pilegard, 2014): segmenting principle, pre-training principle, and modality principle. The principles suggested for fostering generative processing are: limiting reagent principle (Butcher, 2014), personalization principle, voice principle, embodiment principle (Mayer, 2014 a,b), guided discovery principle (de Jong & Lazonder, 2014), self-explanation principle (Chi & Wylie, 2014), and drawing principle (Leutner & Schmeck, 2014). The three-partite nature of cognitive load: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load are of importance for the generation and design of limiting reagent materials and, therefore, should be seriously considered. A chart on the relationship between limiting reagent and cognitive load is shown in Figure 1.

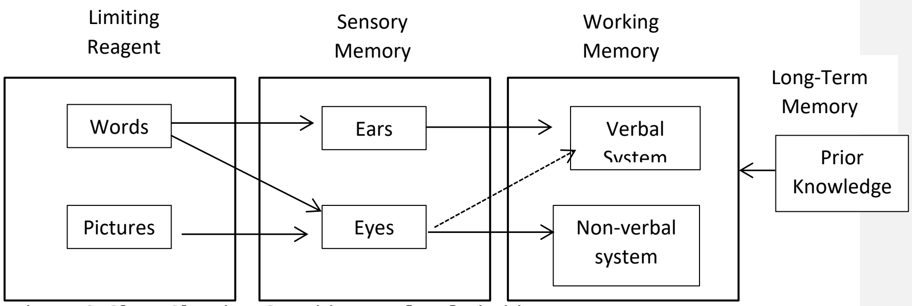

Fig. 1: A Chart Showing Cognitive Load and Limiting Reagent

2.1.3 Measurement of cognitive load in limiting reagent

There are various methods used to measure cognitive load which cannot be observed directly; thus, it is a challenge to assess cognitive load (Brunken, Plass, & Leutner, 2003; De Leeuw & Mayer, 2008). Brunken, Plass & Leutner, (2003) classified cognitive load measurement methods into two dimensions: objectivity and casual relationship. Objectivity refers to using the reader's own, self-reported tools or objective observations, physiological conditions, and performance. Causal relationship is related to whether there is a direct or indirect link between cognitive load and observed phenomenon (Brunken, Plass & Leutner, 2003). Subjective measures are the most common methods used to assess cognitive load. The development of these measures was based on the assumption that individuals can "evaluate their own cognitive processes" and rate the cognitive load they experience during completion of a task (Anmarkrud, Andresen & Braten, 2019). There are both "indirect" types such as self-reported mental effort and "direct" types such as material difficulty ratings of subjective measures (Brunken, Plass & Leutner, 2003). Although subjective measures are commonly employed methods to assess cognitive load, there are methodological limitations: reliability and validity, single item cognitive load measurement, inadequate clarification of the difference between cognitive loads constructs, various and inconsistent constructs to operationalise cognitive loads in subjective measures, and the time of cognitive load assessment (Anmarkrud, Andresen & Braten, 2019; Brunken, Plass & Leutner, 2003).

There are also attempts to measure different types of cognitive load with varying assessment tools (DeLeeuw & Mayer, 2008; Leppink, Paas, Van der Vleuten, Van Gog & Van Merrienboer, 2013). However, subjective measures create concerns in multimedia learning due to "the lack of data and the psychometric properties of subjective measures" (Anmarkrud, Andresen & Braten, 2019 16-30). Objective measures of cognitive load consist of various methodssuch as dual-task methodology and physiological measures (Anmarkrud, Andresen & Braten, 2019 p61-83). Indirect objective measures include analysis of performance outcome, analysis of behavioral patterns or physiological conditions and functions that correlate with the learning process (e.g. time-on-task, lost-in-hyperspace, eye-tracking), and physiological measures such as heart rate and pupil dilation (Brunken, Plass & Leutner, 2003). Eye-tracking helps record eye-movement data while an individual is looking at a screen or another medium such as a book, etc. Various measures from eye-tracking data such as cognitive pupillary responses, fixation duration, fixation count, blink rate, blink duration, and blink latency can be acquired (Kruger & Doherty, 2016). Direct objective measures include functional magnetic resonance imaging (fMRI), positron-emission tomography (PET), functional near-infrared spectroscopy (fNIRS), electroencephalography (EEG), and dual-task-paradigm (Antonenko, Paas, Grabner & van Gog, 2010; Brunken, Plass & Leutner, 2003). The use of fMRI and PET as neuroimaging techniques help collect data related to blood flow during neural activity (Antonenko, Paas, Grabner & van Gog 2010). fNIRS is a compact device compared to fMRI and is used alternatively to measure neural activity for this reason. It helps collect cortical blood flow data (Antonenko, Paas, Grabner & van Gog, 2010). EEG is another neuroimaging technique: it provides data from the brain's electrical activity (Kruger & Doherty, 2016).

2.1.4 Constructivism theory of learning

The basic premise of constructivist theory is that people are said to learn when they have gained experience from what they learn. That is, people create their own meaning through experience. Constructivist thinking is rooted in several aspects of

Piaget and Vygotsky's cognitive theories. From Piaget, we learn actively, create schemes, assimilate and accommodate all forms of science learning. From Vygotsky, we get social constructivism, group work, internships, and so on. Thus, we can say that the "top-down" and" bottom-up" learning methodology is born of constructivism thinking. This means that the teacher will give the main idea then the students will get the details. In this thinking, the teacher does not teach the detail so that students will find it difficult to find an understanding of the details (Aljohani, 2017).

Scientists and philosophers like Dewey, Piaget, and Vygotsky have different perspectives and ideas about constructivism especially around its epistemology and ontology (Giridharan, 2012). In other words, they have interpreted constructivism according to their own experience. In relation to that, the conclusion is that the learners' knowledge is their own life, their style and their life is an experience they get. Therefore, the teaching and learning process must be related to the practical real.

Constructivism views the formation of knowledge as an active subject that creates cognitive structures in their interactions with the environment. Cognitive interaction will occur as far as reality is structured through the cognitive structure created by the subject itself. The cognitive structure must always be altered and adapted according to the demands of the environment and the changing organism. The process of adjustment occurs continuously through the process of reconstruction (Aminah & Davatgari, 2015). The most important thing in constructivism theory is that in the learning process; the learner should get the emphasis. Learners must actively develop their knowledge, not others. Learners must be responsible for their learning outcomes. Their creativity and liveliness will help them to stand alone in their cognitive life. Learning is directed at experimental learning which is a humanitarian adaptation based on concrete experience in the laboratory, discussions with classmates, who then contemplated and made ideas and developing new concepts. Therefore, the accentuation of educating and teaching is not focused on the educators but on the learners (Kothari, 2004).

In the classroom, students are the main body of cognition, the centre of the whole class, and the active constructors of meaning construction which breaks through the limitations of traditional classroom. Before class, students preview the relevant knowledge through some online media to have their autonomous meaning construction. Such a teaching mode of classroom is carried out by the constructivist learning theory which holds the opinion that students are active constructors of meaning, the leader and controller of the learning process while teachers only assist students in developing their autonomous learning.

Defining the Constructivist Learning Theory, (Gordon, 2008; Neo, 2009 & MacMillan, 2014) hold the opinion that constructivism has emerged as a powerful theory for explaining how humans learn about the world around them and how new knowledge is formed. The theory of constructivism is that knowledge is not waiting to be discovered but rather it is constructed by humans by interaction with the world and with each other. Learner collaboration, interaction, and engagement are foundational in the constructivist theory of learning, interactive activities have been touted to be most effective at helping students reach a higher level of understanding. The constructivist learning theory states that through consultation in the community, learning can be the process of construction and cognition of knowledge. The introduction of system of language and text has solved the communicative and objective validity of knowledge and made it possible to achieve the teaching and learning of knowledge. The largest community is mankind. As long as man exists, knowledge can be acquired. And at the meantime, knowledge can only be acquired under the condition of the existence of mankind (Butzler, 2014). Currently, the constructivist learning theory is widely used in the area of education and the activities of teaching. Analysis of and enlightenment from this theory may be expounded as follows: From the perspective of knowledge construction, knowledge is the understanding and hypothesis towards reality of an individual influenced by specific experience and culture. Different persons have different understandings towards the construction of knowledge. Thus, teachers' pay attention to their students' individual characteristics and teach them according to their aptitude, so that each student can construct new knowledge according to their own cognitive level of knowledge. From the perspective of teaching, constructivists believe that learning is the active exploration of the student subject or the learning object so as to construct the process of understanding the object meaning. Therefore, teaching pivots on the meaningful construction of students by inspiring them to construct their own knowledge structure. From the perspective of learners, constructivists confirm that students are active constructors of meaning. So, during the process of teaching, teachers try their best to exert students' initiatives, emphasize the students' autonomy and help them actively discover, analyse and solve the problems in learning.

Constructivist Teaching Mode and Teaching Design The constructivist learning theory emphasizes that students are the centre of teaching and the subject of cognition. Teachers should adopt new teaching mode and carry out new teaching design in teaching process. Therefore, the new teaching mode and teaching design that are suitable to the constructivist learning theory are gradually formed.

Constructivist teaching mode in the constructivist learning environment, compared with the traditional teaching method, the status of teachers and students has changed greatly. The constructivist learning theory emphasizes the opinion of students, taking students as the main body of cognition, and as the active constructors of the knowledge meaning. Teachers only help to promote students' performance.

Obviously, the constructivist learning theory advocates the student-centred learning under the guidance of teachers. Besides, constructivist learning environment includes four elements: situation, cooperation, conversation and meaning construction. To be more specific, the situation in the learning environment must be conducive to the students' construction of the meaning of what they have learned. Collaboration occurs throughout the learning process. It is very important for the collection and analysis of learning materials and the evaluation of learning outcomes and the final construction of meaning. Conversation is an integral part of collaborative learning process which should be discussed by the group members on how to complete the prescribed learning tasks. Meaning construction is the ultimate goal of the whole learning process. In the process of learning, teaching is harnessed to help students construct meaning, digest the content of the current study, and achieve a deep understanding of the inner link between one thing and some other things. In summary, the teaching mode, based on the constructivist learning theory and constructivist learning environment, can be expounded as follows: In the course of the whole learning process, teachers play the role of organizer, mentor, helper and facilitator while students are placed at the centre.

Constructivist teaching design in recent years, experts have made an extensive research and exploration in the field of education technology. They try to establish a new teaching design theory and method system which can adapt to constructivist learning theory and constructivist learning environment. It is a difficult task, and cannot be completed in a short term. But its basic ideas and main principles have become gradually clear and have been applied to the teaching design under the constructivist learning environment with aid of on multimedia and internet. According to (Kim, 2014) the teaching design principles can be summarized as follows:

Firstly, there are three main elements, which are taking student as the centre, externalizing knowledge and realizing self-feedback. Secondly, they emphasize the important role of situation in meaning construction. Through assimilation and adaptation, the construction of new knowledge can be achieved successfully.

Thirdly, they focus on the key role of collaborative learning in meaning construction. Constructivists hold that the interaction between learners and the surrounding environment is very important in the understanding of learning content (i.e. the construction of knowledge).

Fourthly, it emphasizes the design of the learning environment rather than the teaching environment. Constructivists strongly advocate that learning environment is a place where learners can explore freely and learn independently. Under this environment, students can use various tools and information resources, such as text materials, audio, video materials, CAI, multimedia courseware, Internet information to achieve their final learning goals. Teaching means more control and domination, while learning means more initiative and freedom.

Fifthly, they favour the use of many information resources to support the idea that learning rather than teaching is more important and necessary.

2.2 Categorization of Broad Factors that affect Students' Learning

In this era of globalization and technological revolution, education is considered as a first step for every human activity. It plays a vital role in the development of human capital and is linked with an individual's well-being and opportunities for better living (Lewis, 2000). It ensures the acquisition of knowledge and skills that enable individuals to increase their productivity and improve their quality of life. This increase in productivity also leads towards new sources of earning which enhances the economic growth of a country (Saxton, 2000).

Many researchers have discussed the different factors that affect the students' learning in their research. There are two factors that have been identified to affect students' learning. They are internal and external classroom factors. According to Eminah (2009), these internal and external classroom factors can be broadly grouped into the following categories: Background and environmental factors, study habits and examination factors, demographic factors, instructional factors, school management factors, physiological factors, health and nutritional factors, motivational factors, and personality factors.

2.2.1 Background and environmental factors

Karemera (2003) found that students' learning is significantly correlated with satisfaction with academic environment and the facilities such as computer laboratory, library and so no in the institution. With regard to background variables, he found a positive effect of high school performance and school achievement he found no statistical evidence of significant association between family income level and students' learning. The home environment also affects students' learning. Educated parents can provide such an environment that suits best for academic success of their children. The school authorities can provide counselling and guidance to parents for creating positive home environment for improvement in students' quality of work (Marzano, 2003). The students' learning heavily depends upon the parental involvement in their academic activities to attain the higher level of quality in academic success Farooq et al (2011).

2.2.2 Study habits and examination factors

Students face a lot of problems in developing positive study attitudes and study habits. Guidance may be a possible means through which a student can improve his study attitudes, and study habits and is likely to be proportional to academic achievement Karemera (2003). Factor through which a student can improve his study attitudes and study habits is directly proportional to academic achievement (Noble, William, Sawyer & Richard, 2006). Harb & El-Shaaraw, (2006) found that the most important factor with positive effect on students' performance is student's competence in English. If the students have strong communication skills and have strong grip on English, it increases the performance of the students. The performance of the student is affected by communication skills; it is possible to see communication as a variable which may be positively related to performance of the student in open learning.

2.2.3 Demographic factors

Generally, these factors include age, gender, geographical belongingness, ethnicity, marital status, socioeconomic status (SES), parents' education level, parental profession, language, income and religious affiliations. These are usually discussed under the umbrella of demography (Saxton, 2000). In a broader context demography is referred to as a way to explore the nature and effects of demographic variables in the biological and social context. Unfortunately, defining and measuring the quality of education is not a simple issue and the complexity of this process increases due to the changing values of quality attributes associated with the different stakeholders' view point (Blevins, 2009; Parri, 2006).

Socioeconomic status is one of the most researched and debated factor among educational professionals that contribute towards the students' learning. The most prevalent argument is that the socioeconomic status of learners affects the quality of their learning. Most of the experts argue that the low socioeconomic status has negative effect on the students' learning because the basic needs of students remain unfulfilled and hence, they do not perform better academically (Adams, 2006).

2.2.4 Instructional factors

According to Eminah (2009), in spite of that fact that learners are central to the teaching and learning process, the role of teachers is crucial to the amount of learning that can take place. He further explained that, teachers plan lessons, select teaching and learning materials, assign tasks to learners, conduct assessments and provide a variety of learning environments.

The learning of students at whatever level of the educational structure is largely dependent on what the teacher possesses or does before, during and after the teaching learning situations process. Significantly, Rice (2004) noted that teachers' variables are the most important teacher- related factor influencing students' performance. Hence, the common saying that good teachers inspire students to learn and develop positive personality through teachers' teaching traits, attributes and characteristics which might have been imitated and internalized. It should be noted that the total experiences acquired by students are functions of the teacher characteristics including gender, qualification, certification, experience, teachers' use of instructional materials and this disposition; This is what usually reflected by the teacher's effectiveness and by extension, the students' learning (Stronge, 2002; Akbari & Allvar, 2010). On pedagogical skills, people agree that good teachers are caring, supportive, concerned about the welfare of students, knowledgeable about their subject matter and are genuinely excited about the work that they do and able to help students learn (Cruickshank, Jenkins & Metcalf, 2003). Teacher's competence, ability, resourcefulness and ingenuity to efficiently utilize the appropriate language, methodology and available instructional materials to bring out the best from learners in terms of students' learning is what a pedagogical skill supposed to produce in a teacher. Enem (2005) carried out a study on the impact of instructional material utilization and the result shows that students taught with instructional materials performed better than students taught without instructional materials.

2.2.5 School management factors

Several research studies accentuate the importance of principals and other heads of institutions taking on strong leadership roles in creating efficient and successful schools (Gunter, 2001). Heads of schools usually perform three interchangeable functions at school level. As managers, they focus on managing and controlling human, physical, and financial resources. As leaders, they drive the vision of the institution and focus on organizational development and school improvement, while as administrators, they deal with day-to-day operational matters, and continuously shift between leadership and management functions (Kowalski, 2010). Moreover, the principal's role is one that is in a constant state of transition, moving from being an instructional leader (Abdullah & Kassim, 2011; DeMatthews, 2014; Mestry, 2017) to that of a transactional leader, who at times embraces the notion of a transformational leader (Balyer, 2012; Tingle, Corrales & Peters, 2019). The class schedules, class size, textbooks, environment of the class, are managed by the school management.

Good heads of institutions create successful schools, according to Kelley and Peterson (2007) and the Wallace Foundation (2008), by critically examining innovative ways to improve their schools by aiming to provide exemplary leadership. Shipman, Queen and Peel (2007) agree that effective school leaders understand their ultimate goal, which is to provide students and teachers with continuous learning opportunities. DeMatthews (2014) claims that heads of institutions become effective instructional leaders when they critically analyse existing curricula and the implications thereof for teachers' teaching strategies and student outcomes.

2.2.6 Physiological factors

According to Zaitoon, (2021) the psychological effects of stress can impair the students' ability to think, behaviour and emotions during exams. Also, stress can cause restlessness; lack of motivation and irritability, the research tested the effects of examination anxiety on 200 male and female high school students with effects on cardiac rhythm and vascular regulations with using a Hamilton Anxiety Scale questionnaire. This depression can have a destructive impact on students' professional and personal lives, leaving them anxious, exhaustive and socially isolated at low academic levels, blood pressure. The hazardous factors that can alter the arterial pressure and cardiac frequency include age, gender, ethnicity, family history, obesity, smoking and alcoholism. Anxiety gradually disrupts the quality of life. Historically, numerous definitions of anxiety have been presented. For example, Kazdin (2000) defines anxiety disorder as an emotion characterized by feelings of tension, worried thoughts and physical changes like increased blood pressure (Kazdin, 2000). Similarly, students with advanced anxiety stages incline to get lower marks at the end of examinations and semester assessment report.

Despite, based on some investigations, the connection between sex and anxiety has been explained recurrently: the female students encounter advanced rates of test anxiety in comparison with males. Finally, several researches conducted by Hildrum (2011), confirmed that the high level of feminine test anxiety is characteristically not supplemented by lower activities' marks.

2.2.7 Health and nutritional factors

Existing research on the relationship between malnutrition and academic achievement has primarily focused on early childhood (Perez-Escamilla & Pinheiro, 2012). Malnutrition has been prospectively associated with lower mental proficiency in toddlers (Zaslow, Bronte- Tinkew & Capps, 2009), as well as impaired reading and mathematical performance (Zaslow, Bronte-Tinkew & Capps, 2009) and inadequate standardized test scores (Faught, Williams, & Willows, 2017) among school-aged children. The psychological and emotional stress that often results from the experience of inadequate food for students (Jyoti, Frongillo & Jones, 2005)

Although few studies have explicitly tested this hypothesis, psychosocial factors have been found to mediate the association between inadequate feeding and various health outcomes including weight status, sleep quality and child cognitive development (Zaslow, Bronte- Tinkew & Capps, 2009)

Associated with numerous poor health (Gundersen & Ziliak 2015) and academic outcomes. Food insecurity in schools may hinder student achievement and undermine the potential for increased educational access to reduce health disparities (Laraia, 2013).

2.2.8 Motivational factors

Motivation is a fundamental recipe for academic success. It involves internal and external factors that stimulate desire and energy in people to be continually interested and committed to job, role, or subject, or to make an effort to attain a goal (Slavin, 2006). Dornyei (2001) argued that motivation explains why people decide to do something, how hard they are going to pursue it, and how long they are willing to sustain the activity. In order words, "motivation is what gets you going, keeps you going, and determines where you're trying to go" (Slavin, 2006).

Also, Alderman (2004), indicated that those students who have optimum motivation have an edge because they have adaptive attitudes and strategies, such as maintaining intrinsic interest, goal setting, and self-monitoring. Besides, motivational variables interact with cognitive, behavioral, and contextual factors to upset self-regulation (Dornyei, 2001).

Furthermore, motivational beliefs are very essential to the academic achievement of students because they help to determine the extent to which students will consider, value, put in effort, and show interest in the task (Mousoulides & Philippou, 2005) For example, self-efficacy influences how learners feel, think, motivate themselves, and behave (Alderman, 2004).

2.2.9 Personality factors

Personality may be considered a theoretical construct aimed at describing, explaining, and predicting the way human beings' function in various aspects of life (South, Jarnecke & Vize, 2018).

According to Komarraju (2009) the various psychological paradigms, the Big Five model of personality is the most frequently used to assess dimensions such as neuroticism (emotional stability), extroversion, agreeableness, conscientiousness, and openness to experience (intellect). The personality traits are determined biologically and environmentally (Komarraju, 2009). Again, Veresova (2015) and Komarraju, (2009) showed that Big-Five personality factors contribute to academic success, including exam performance and grading of students. Research indicates that of the five personality traits, only conscientiousness was consistently the strongest predictor of students' learning (Rosander, Backstrom & Stenberg, 2011; Veresova, 2015). In particular, academic success is related to a proactive aspect of conscientiousness, such as being hard-working and persistent (South, Jarnecke & Vize, 2018).

Gender differences in personality were found in many studies but results of the research were inconsistent (Lippa, 2010). For example, Mac Giolla and Kajonius, (2019) showed that women scored higher than men on all of the Big Five traits of personality and that these differences were larger in more gender-equal countries. However, in other studies, no gender differences were found in openness (Weisberg, Deyoung & Hirsh, 2011) conscientiousness or extroversion (South, Jarnecke, & Vize, 2018).

2.3 Students' Understanding of Science Concepts

In recent years, students ' understanding or lack of understanding of science concepts, especially chemical concepts, they lean in senior high school has been the subject of most studies by science education researchers (Anderson & Renstrom, 1983; Anamuah Mensah, 1995; Schmidt, 1997; Boujaoude & Barakat, 2000; Murdoch, 2000). The general consensus of these studies has been that, students have misconceptions about chemical concepts. A few studies attempted to provide a list of topics which may be difficult for students at certain levels. Pereira and Pestana (1991) used qualitative analysis of students' model to discern the nature of students' representations and the presence of any misconception and came out with a list of some topics which pose potential difficult to students at different grade levels. These topics include: the concept of particulate nature of matter, melting, dissolving, cooling, chemical reactions and vaporization.

Rosalind (1981) using the work of Jean Piaget and others on the development of children's thinking, has indicated that far from being ' tabula rasa' of repute, pupils bring to their school learning in science ideas, expectations and beliefs concerning natural phenomena which they have developed to make sense of their own past experiences. The alternate frameworks, in some cases strongly held and resistant to change and in others flexible and with many internal inconsistencies, have their influence on the effectiveness of formal school science programmes.

A similar investigation done by Osbome and Feyberg (1985) on the nature of children's ideas, showed that from young age and prior to any teaching and learning of formal science, children develop meanings for many words used in science teaching and views of the world, which relate to ideas taught in science. The study revealed that these children's ideas are usually strongly held, even if not well known to teachers and are often significantly different from the views of scientists. The ideas are sensible and coherent views from the children's point of view and they often remain uninfluenced or can be influenced in unanticipated ways by science teaching.

Studies indicate that a similar problem exist with older students. Students' and teachers' understanding of chemical equilibrium was assessed by Banerjee (1991). The sample consisted of 120 college chemistry students enrolled in the third semester of a four-year teacher education course, 42 students in a content methodology course with a one-year teacher education programme, 4 college chemistry teachers. A 21 item test on chemical equilibrium (containing closed and open response items) was developed and administered to all the participants. The data indicated widespread misconceptions among both teachers and students relating to Le Chatelier's principle, rate and equilibrium, application of equilibrium principles to acid-base and ionic solutions. Group comparisons showed misconceptions to be equally high in both teachers and students. It was speculated that the teachers may have developed their misconceptions during their educational experiences and retained the misconceptions despite their teaching and professional experiences.

Again, how students develop their understanding of the concept of diffusion was the focus of a cross-age study conducted by Westbrook and Marek (1991). The sample consisted of 100 randomly selected students from each of the three grade levels: 7th, 10th and college students enrolled in freshman zoology. All subjects completed a biographical questionnaire, two Piagetian tasks assessing combinational logic and proportional reasoning, and a concept evaluation statement. Understanding diffusion at the concrete, observable level was considered to be a "sound" understanding and an understanding at the molecular, abstract level was considered to be a "complete" understanding. At the end of the study, the researchers found out that none of the 300 students possessed a " complete" or " sound" understanding and there was no apparent relationship between understanding and Piagetian developmental level. Interestingly, 55 % of the 7th graders were found to possess misconceptions and over 60 % of both 10th graders and college students exhibited misconception as well. The researchers concluded that certain misconceptions about diffusion prevail across grade levels, at the molecular perspective of diffusion and as one proceeds through school does not lead to greater understanding, and students used errant vocabulary when describing diffusion.

In another study of undergraduate students ' conceptions of phenomena, Sexena (1991) investigated 181 Indian undergraduate students' conception of light. The students were administered an eight-item questionnaire, with each item based on at least one of six identified major concepts associated with light (eg. reflection, refraction, shadow). The questions were multiple choices, but students were required to explain the reason for their selected responses. A sample of 5 % of the students were interviewed to clarify written responses. Analysis of the questionnaire response and interviews indicated that students had difficulty understanding the process of visibility of an object, shadow formation by an opaque object, action of a filter, and action of a lens in image formation. The study also noted that even many of the students who arrived at correct response were not able to support their responses with acceptable logical reasoning.

Ministry of Education therefore suggested that tutors should arouse the interest of students in science and makes them feel that science is life, and must therefore relate what they study to things around them. The report continued that, students ' performance in the science examination may be influenced by their misconception or lack of understanding of topics in the College Science Course outline. The increasing poor performance by Colleges of Education Science Students Integrated Science examination/ papers may point to a general lack of understanding of science concepts in the Senior High Schools. Anamuah-Mensah (1995) in his study on what students found difficult in' O ' level chemistry has shown that it is possible to identify topics in chemistry which students have difficulty with. He also contended that students' understanding of the topics in the syllabus strongly reflects their actual performance in those topics as indicated by the grades obtained at the WASCE examination.

2.4 Limiting Reagents Concept Difficulties

The limiting reagent concept in reaction stoichiometry problem-solving is an area that often poses problems to students. The difficulties that student’s experiences are related to several conceptual issues evidenced in the wider context of stoichiometry problem solving in general (Schmidt, 1997; Boujaoude & Barakat, 2000). Several studies have confirmed the influence of alternative conceptions that are held by students in contributing to the difficulties that they experience when solving stoichiometry problems (Mitchell & Gunstone, 1984; Boujaoude & Barakat, 2000; Dahsan & Coll, 2007). Studies associated with reaction stoichiometry computations by high school students, some of which are referred to in this section, have included the limiting reagent concept as part of the studies. A study by Gauchon and Méheut (2007) investigated the effect of Grade 10 students' preconceptions about the concept of limiting reagent on their understanding of stoichiometry. Depending on the physical state of the reactants, students believed that both reactants in a chemical reaction were completely used up when the reactants were in the same state. On the other hand, only one reactant was thought to have changed completely when a solid was one of the reactants.

2.5 Conceptual Framework

Mathematical Concepts and Stoichiometry Problem-Solving

One major contributory factor to facilitating stoichiometry problem-solving is the tendency for students to treat exercises on limiting reagents like any other problem in mathematics (as they often do in all chemistry problem solving exercises) with little display of their knowledge and understanding of the chemical principles involved. Students' limited proficiency in the use of the mathematical concepts of proportions, ratios and percentages in reaction stoichiometry is another contributory factor (Bucat & Fensham, 1995). Bucat and Fensham (1995) noted that;

"Even the simplest computations in chemistry" involve a more complex set of ratios and proportions than most students would have encountered in their mathematical studies of these concepts", and "simple though it seems to an experienced chemistry teacher, (a limiting reagents problem) is a minefield far beyond what was regarded as a mastery of these ideas (of ratios and proportions) in mathematics classes ". (p. 135).

The importance of these mathematical concepts was echoed by Koch (1995) who reiterated that" the ability to understand and use proportional reasoning is at the heart of stoichiometry " (p. 39). In his study on finding ways of simplifying stoichiometry problems for first year university chemistry students, he noted that for students to be able to solve a variety of stoichiometry problems, they need to have mastery of important concepts such as the mole, molar mass and mole ratio.

These findings are supported by a study that investigated the reasoning strategies used by twenty-seven Venezuelan college freshmen during stoichiometry problem-solving (de Astudillo & Niaz, 1996). The students' understandings were found to improve when they conceptualized stoichiometric relations in terms of ratios. The reasoning strategies of the successful students indicated an attempt by them to establish a mass-mole relationship in the solution process.

Findings about issues associated with the use of mathematics in the chemistry classroom are further confirmed by the views of chemistry teachers concerning the difficulties that beginning students of chemistry face in relation to the use of the mole in stoichiometry computations (Dierks, 1985; Furió, Azcona, Guisasola & Ratcliffe, 2000). Added to this difficulty is the lack of mathematical reasoning among students. One cause of this difficulty is the confusion between equations in mathematics and those used in chemistry. While mathematics is concerned mainly with operation on numbers, in chemistry the emphasis is on operating on quantities of substances. Although students ' problems with handling mathematical relationships are widely acknowledged by chemistry teachers, there is limited reference to research in this area.

A direct consequence of such confusion is the general inability of students to translate textual statements in chemistry into mathematical statements. Dierks (1985) illustrated how a statement like; "for a given amount of sodium carbonate, twice the amount of hydrochloric acid is needed", is often misrepresented mathematically. Instead of stating n (HCI) = 2 x n (Na_2CO_3), students incorrectly state 2 x n (HCI) = n (Na_2CO_3). A misrepresentation of this nature is analogous to the reversed equation phenomenon' in algebra involving the translation of expressions in everyday language to algebraic equations using letters, and vice versa (Nickerson, 1985). For example, in a study cited by Nickerson (1985), students expressed the statement; " There are six times as many students (S) as professors (P)' algebraically by the equation 6S = P (instead of S = 6P).

An extensive study (in terms of students' participation) involving reaction on limiting reagents problem-solving strategies of senior high school students, Schmidt (1984) identified five problem-solving strategies that students used when solving the test items. Two of these strategies used by 50-60 % of successful students were not illustrated by their teachers during instruction, nor were they found in German textbooks. In these two strategies, students used their own words, like' twice as much ' and' same proportion ', thereby avoiding mathematical expressions to describe ratios between masses, molar masses and moles of substances. The other three strategies that were less frequently used had been introduced by their teachers during instruction. These strategies involved the use of mathematical relationships, like n(CuS) = n(Cu), m(Cu) = n(Cu) x M (Cu), etc. The results of this study indicated that success in stoichiometry problem-solving was associated with use of comprehensible reasoning strategies. Comparing his studies with others, Schmidt (1984) concluded that students are more likely to use algorithmic strategies when solving more difficult problems, but tended to use reasoning strategies with easier problems.

2.4 Reasoning and Algorithmic Strategies in Stoichiometry Problem-Solving

The common practice of using algorithms when students perform stoichiometric computations is well documented in the science education research literature (Schmidt, 1997; Fach, de Boer & Parchmann, 2007). The over-dependence on the use of algorithmic strategies, without attempts at reasoning out the solution process, was evident in the problem-solving behaviour of 266 high school students in a study using the think-aloud procedure while they were solving problems in reaction stoichiometry (Gabel & Sherwood, 1984).

In a study conducted by Boujaoude and Barakat (2000), forty Year 11 students were required to provide explanations when solving eight stoichiometry problems. These students successfully solved traditional problems using algorithmic strategies, but lacked conceptual understanding when solving unfamiliar problems. Similar findings have also been documented with introductory college chemistry students (Nurrenbern, 1979; Lythcott, 1990; Nakhleh, 1993; Mason & Crawley, 1994; Niaz, 1995; Cracoline, Deming & Ehlert, 2008). One reason for the over-reliance on algorithmic procedures suggested by researchers was lack of understanding of the chemical concepts that was further supported by their inability to solve transfer problems involving situations different from the ones that were used using instruction (BouJaoude & Barakat, 2000; Bodner & Herron, 2012). In an investigation of Grade 12 Swedish students' algorithmic stoichiometry problem-solving strategies that they used when solving four stiohiometry problems. The students were required to calculate the mass of an element in a given mass of a binary compound. All the students were found to use non-mathematical strategies to solve the easy problems. When solving more difficult problems, however, most of the students calculated the mass fraction or the percentage of an element in each compound.

2.5 Understanding the Mole Concept and Interpretation of Chemical Formulae and Equations

The idea of the mole as the unit of the amount of a substance is an integral part of stoichiometric computations. However, there is widespread confusion over the meaning of the mole among students and teachers (Novick & Menis, 1976; Gabel & Sherwood, 1984; De Jong, Veal & Van Driel, 2002; Furió, Azcona & Guisasola, 2002). One reason for this confusion is the different definitions that are used in textbooks and the chemistry curriculum in several countries (Dorin, 1987; Smoot, Price & Smith, 1987; Burton, Holman, Pilling & Waddington, 1994). Students' difficulties with "the mole concept" has been known for a long period (Lazonby, Morris & Waddington, 1982). Given that particle ideas are often poor or inconsistent among teenage chemists, difficulties are unsurprising. Dierks (1981) noted that the mole has only been adopted as a unit in chemistry in relatively recent years. He says that discussion of "the mole problem" began in 1953 (p. 146) and that thereafter chemists spent a number of years agreeing on a definition. The word "mole" acquired three meanings: "an individual unit of mass; a portion of substance; and a number" (p. 150). Chemistry teachers frequently adopt the simplistic standpoint of the mole as a" counting unit". Nelson (1991) disagreed with this approach on the grounds that in fact the mole is not strictly defined as a number, but rather as:" ... the amount of substance corresponding to the number of atoms in 0.012 kg of carbon-12. " (p. 103). Dierks (1981) suggested that problems also arise when the mole concept is introduced to students who are not being prepared to become professional chemists. He reported that early work on students' difficulties centered on the vital connection between chemical formulae/ equations and mathematical expressions representing amounts of substance.

Dierks (1981) states: "It is generally argued that pupils need a clear conception of what is meant by amount of substance if they are to work successfully with this concept. This concept can apparently only be developed when amount of substance is interpreted as a numerical quantity" (p. 152). Adopting the Ausubelian argument that "meaningful learning occurs when new information is linked with existing concepts" (p. 153), Dierks (1981) advocated beginning to teach the mole as a "number". This contrasts directly with Nelson (1991) who suggested strongly that the mole should be taught as an " amount", suggesting use of the term " chemical amount" rather than " amount of substance". This difference may be at the centre of problems associated with the mole-in teaching this concept, we may use "amount of substance and number of particles" synonymously, contributing unwittingly to students' difficulties by never really explaining what we mean in either case.

Boujaoude and Barakat (2000) made three suggestions about teaching the mole. They developed a stoichiometry test and carried out unstructured interviews with forty 16 - 17 year olds revealing misunderstandings about molar quantities, limiting reagent, conservation of matter, molar volume of gases at STP and coefficients in a chemical equation. The authors suggest that teachers should help students develop clear relationships between these ideas before numerical problems are presented. They point out that teachers should also analyse students ' approaches to problem solving, suggesting that this will prevent students from continuing to use incorrect strategies. A third suggestion points to use of problems which stimulate thinking, rather than application of an algorithm. In this study, these authors found this helped to build students' problem-solving abilities.

Also, several studies have documented inadequacies in high school students ' understanding and interpretation of the significance of chemical formulae and equations. In particular, students appear to have limited understanding of the significance of coefficients and subscripts in chemical equations, as well as about the conservation of mass in relation to chemical formulae (Duncan & Johnstone, 1973; Schmidt, 1984; Mulford & Robinson, 2002; Sanger, 2005).

A chemical equation is a shorthand description of the chemical change that occurs during a chemical reaction. Once chemical equations have been introduced in a course of study, it is often assumed that students understand this representational system. The chemical equation is a language of chemistry, one that chemists and chemical educators use constantly. Many of the difficulties in learning chemistry for students may well relate to this problem (Mulfold, 1996). After its introduction, and often a brief one that is focused on the balancing of equations and not usually on what they represent, educators use chemical equations to explain much of the rest of chemistry. This can be seen in everything from phase changes and thermodynamics to chemical equilibrium. If students do not understand the language used by the instructor, how can they be expected to understand what is said? (Mulfold, 1996)

An equation, which represents equal number of atoms of all similar elements on both sides of a chemical equation, is called a balanced equation. In balancing equations, it is important to understand the difference between a coefficient of a formula and a subscript in a formula. The coefficients in a balanced chemical equation can be interpreted both as the relative number of molecules, moles or formula units involved in the reaction. And subscripts on the other hand indicate the relative number of atoms in a chemical formula. Subscripts should never be changed in balancing an equation, because changing subscript changes the identity of the substance. In contrast, changing a coefficient in a formula change only the amount and not the identity of the substance and hence can be manipulated in balancing chemical equations. Balancing equation go further than word equation. It gives the formula of the reactants and products and shows the relative number of particles of each of the reactant and the products. Notice that the atoms have been reorganized. It is also important to recognize that in a chemical reaction; atoms are neither created nor destroyed.

In other words, there must be the same number of each type of atom on the product side and on the reactant side of the arrow. Thus, a chemical equation should obey the law of conservation of mass. That means a chemical equation should be balanced. The study of the quantitative nature of chemical formulas and chemical reactions is called stoichiometry. Equations and stoichiometry are essential tools in chemistry, and they deserve critical study of how students conceive these concepts.

Eylon et al (1982) as cited in Gabel, Samuel and Hunn, (1987) found that when students are given a chemical formula for a relatively simple molecule, 35 percent of the high school chemistry students were unable to represent it correctly using circles. A representing atoms. These students had an additive view of chemical reactions rather than interactive one. Eylon et al (1982), as cited in Gabel et al (1987) also found that many students perceive a chemical formula as representing one unit of a substance rather than a collection of molecules. In a similar research, Yarroch (1985) found that of the 14 high school students whom he interviewed, only half were able to represent the correct linkages of atoms in molecules successfully. Although the unsuccessful students were able to draw diagrams with the correct number of particles, they seemed unable to use the information contained in the coefficients and subscripts to construct the individual molecules. For example, in the equation, $N_2 + 3H_2 \rightarrow 2NH_3$, students represented $3H_2$ as 0000000 rather than 00 00 00.

Students were able to use formulas in equations and even balance equations correctly without understanding the meaning of the formula in terms of particles that the symbols represent.

Another researcher (Nakhleh, 1992) concluded that many students perceive the balancing of equations as a strictly algorithmic (plug-and-chug). Further, Yarroch (1985) illustrated students ' lack of understanding of the purpose of coefficients and subscripts in formulas and balanced equations of the reaction between nitrogen and hydrogen as follows:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Ben-Zvi, Eylon and Silberstein (1987) concluded that balancing and interpreting equations for students is a difficult task. As an example, they performed a task analysis on the combustion of hydrogen, as represented by the equation $2H_{2\,(g)} + O_{2(g)}$ $2H_2O_{\,(g)}$

Ben-Zvi et al (1987) argued that in order to appropriately interpret such equation the learner should understand many things such as, the structure and physical state of the reactants and products, the dynamic nature of the particle interactions, the quantitative relationships among the particles, and the large numbers of particles involved. Further they also note that some students seem to have an additive model of reaction: compounds are viewed as being formed by simply sticking fragments together, rather than as being created by the breaking and reforming of bond. Still on a similar research conducted by Sawery (1990) on stoichiometry revealed that only about 10 percent out of 323 students could answer conceptual questions.

Understanding the mole, chemical equations and formulae has a significant bearing on students ' ability to perform stoichiometric computations in chemistry.

2.6 The First Principle Approach in Chemistry

One method that can be used in deducing the limiting reagent in a chemical reaction is by the use of the first principle approach using the stoichiometry of the balanced chemical equation. For example, if 1 mol of A reacted with 2 mol of B, x mol of A would require 2x mol of B. If 2x mol of B were not available in the question, then B was the limiting reagent and A was the reagent in excess. However, if say, 3x mol of B was available, this was more than sufficient; then A was the limiting reagent. This method does not involve computing the actual mole ratio (AMR) and the stoichiometric mole ratio (SMR). For example;

Consider the following reaction:

$$Pb^{2+}\,(aq) \quad + \quad 21^{-}_{(aq)} \quad \rightarrow \quad PbI_{2(s)}$$

If a solution containing 0.03 mol of Pb^{2+} is added to a solution containing 0.05 mol of I^- to produce the precipitate of lead (II) iodide, $Pb1_2$ (s), deduce the limiting reagent.

In using the first principle approach to deduce the limiting reagent in the problem above, consider the balanced chemical equation. From the balanced chemical equation in the problem above, it may be deduced that 1 mol of Pb^{2+} ions react with 2 mol of I ions.

Therefore, the 0.03 mol of Pb-ions present will require 0.06 mol of I ions, which is more than the 0.05 mol that is available. Hence, the iodide ion, I is the limiting reagent in this case, the first principle approach might be applied.

2.7 Empirical Framework of the Study

A search in Science literature shows that several researches have been conducted on the concepts of limiting reagents and stoichiometry. Chemistry in the high school today is often taught passively and abstractly. By passively is meant that the students are fed masses of descriptive symbols, facts and theories for memorization. The theories are presented as gospel. No attempt is made to show or involve the students in the intellectual processes which resulted in the theories. Whether the periodic table, gas laws, stoichiometric relationships, quantum orbitals whatever, the students are taught "rules" or "formulas to plug numbers into". The laboratories generally contain dull or repetitions mixings of solutions with "fill in the blanks" type questions. Little correlation occurs between lecture and laboratory exercises (MacMillan, 2014).

Sawrey (1990), demonstrated that students trained to work with gas laws equations via traditional plug in procedures, performed miserably when confronted with problems presenting gas molecules. The same problems presented in traditional numerical formats were solved several times more successfully. While the author thus showed the failure of traditional methods to promote deeper understanding of molecular relationships, no data was presented to show increased achievement via this approach (Sawrey, 1990).

Pickering (1987) decried the rote "cook book" procedures found in most student laboratory note books. In order to force the students to construct their own algorithms for efficiently performing laboratory tasks, they are not allowed to bring their lab text to the laboratory. They are allowed to bring notes or "step out" to the hallway for text referral. Comparison of the student with time for lab completion showed strong correlation of concise condensed notes with efficient lab practice. Students who could construct procedures to filter out the extraneous textual -material were more successful.

This approach was successful in forcing students to displace from memory textual concepts or information of less than immediate utility. For example, the "solubility product constant of barium sulphate, a very small number, is always presented in the text of an analysis experiment. Student need not concern himself or herself with this concept, however of immediate need is a lower level practical knowledge that, because of the very low value for this constant, he or she may wash his or her precipitate repeatedly with water without measurable weight loss (Pickering, 1987).

In another study conducted by Frazer and Servant (1986, 1987) on titration calculations, the authors investigated which one of four possible expert methods was used by students solving two titration calculation problems. Three of the four methods were similar to those reported by Schmidt (1994) if one transfers the methods to this kind of problem:

1. A method of determining limiting reagents from a balanced chemical equation and using direct, calculation of amounts of substance.
2. A method avoiding calculation of amounts of substance and instead using a proportion equation.
3. A method immediately converting the reaction stiochiometry into the quantities given in the text and continuing by using the "unitary method" Wickstrom et al (1980).

According to Fach, de Boer and Parchmann (2006), at a second sight, one can see that all strategies contain up to six steps, which were sometimes combined with each other. These are;

(i) extracting the problem from the text given;

(ii) formulating the chemical equation;

(iii) calculating (the necessary) molar masses;

(iv) calculating the amount of substance;

(v) considering the ratio of amount of substance and

(vi) calculating the mass. (Fach, de Boer, & Parchmann, 2006)

According to Ladyman (2008), a disciplinary matrix is a set of answers to such questions that are earned by scientists in the course of the education that prepares them for research, and that provide the framework within which the scientist operates. It is important that different aspects of the disciplinary matrix may be more or less explicit, and some parts are constituted by the shared values of scientists, in that they prefer certain types of explanation over others and so on. It is also important that some aspects of it will consist of practical skills and methods that are not necessarily expressible in words. This is partly what makes a paradigm different from a theory, because the disciplinary matrix includes skills that enable scientists to make technological devices work, such as how to focus a telescope and experimental skills, like how to crystallise a salt from a chemical reaction, which have to be learnt by practical experience (such skills are sometimes called tacit knowledge) (Ladyman, 2008).

According to Ladyman (2008), exemplars, on the other hand, are those successful parts of science that all beginning scientists learn, and that provide them with a model for the future development of their subject. Anyone familiar with a modern scientific discipline will recognise that teaching by example plays an important role in the training of Scientists.

Textbooks are full of standard problems and their solutions, and students are set exercises that require them to adapt the techniques used in the example to new situations. The idea is that, by repeating this process, eventually, if they have the aptitude for it, students will learn how to apply these techniques to new kinds of problems that nobody has yet managed to solve.

Philosophy of science has a history. Francis Bacon was one of the first to attempt to articulate what the method of modern science is. In the early 17th century he proposed that the aim of science is the improvement of man's lot on earth, and for him that aim was to be achieved collecting facts. (Ladyman, 2008)

2.8 Conceptual Change Idea

Initially the idea of conceptual change was used in education as a way of thinking about the learning of disciplinary content such as physics (Posner, Strike, Hewson & Gertzog, 1982) and biology (Carey, 1985). Its use, however, has expanded in two ways.

First, from the outset the notion of teaching for conceptual change has gone hand in hand with considerations of learning as conceptual change. Second, conceptual change has been considered in other domains of disciplinary content such as chemistry, earth science, mathematics, writing, reading and teacher education.

To understand conceptual change what it is and how it might influence science teaching, it is necessary, in my view, to consider its links to two other ideas that are currently popular. These are constructivism (as a view of how people learn) and students' conceptions (tenacious ideas different from those generally accepted and held by students of all ages in all countries, called among other things alternative conceptions or misconceptions).

The interpretation of student responses as driven by alternative conceptions suggest that learning may involve changing a person's conceptions in addition to adding new knowledge to what is already there. This view was developed into a model of learning as conceptual change (or CCM) by Posmer, Strike, Hewson and Gertzog (1982) and expanded by Hewson (1982, 1992). From this point of view, learning involves an interaction between new and existing conceptions with the outcome being dependent on the nature of the interaction. There are two major components to the CCM. The first of these components is the conditions that need to be met (or no longer met) in order for a person to experience conceptual change.

The extent to which the conception meets these three conditions is termed the status of a person's conception. The more conditions that a conception meets, the higher is its status.

The second component is the person's conceptual ecology that provides the context in which the conceptual change occurs, that influences the change, and gives it meaning. The conceptual ecology consists of many different kinds of knowledge, the most important of which may be epistemological commitments (e.g. to consistency or generalizability) metaphysical beliefs about the world (eg, the nature of time) and analogies and metaphors that might serve to structure new information.

Learners use their existing knowledge (i.e. their conceptual ecology), to determine whether different conditions are met, that is whether a new conception is intelligible (knowing what it means), plausible (believing it to be true), and fruitful (finding it useful). If the new conception is all three, learning proceeds without difficulty.

According to Ozdemir and Clark (2007), conceptual change researchers have made significant progress on two prominent but competing theoretical perspectives regarding knowledge structure coherence. These perspectives can be broadly characterized as (1) knowledge as theory perspectives and (2) knowledge as elements perspectives.

Piagetian learning theory has influenced many researchers of knowledge as theory perspectives.

From the knowledge as theory perspectives and knowledge as elements perspectives, these agreements were arrived at:

i. Learners acquire knowledge from their daily experiences.
ii. Learners' naive knowledge influences their formal learning.
iii. Much naive knowledge is highly resistant to change. Thus, conceptual change is a time consuming process. (Ozdemir & Clark, 2007)

It is important to understand that conceptual change research is performed by people who are heavily involved in the science education system, and who are searching for solutions for its crucial problems and inadequacies (Anderson, 1987). As such, the futile endeavour of altering the plethora of individual ideas is rejected. Instead, conceptual change researchers focus their attention on those concepts that are at the "core" of a system of concepts. It is more analogous to what Piaget, calls an accommodation, or to what Kuhn calls a paradigm shift (Posner & Strike, 1992).

It can be concluded that pedagogical content knowledge (PCK) is a very personal domain of knowledge based on the sources from which it is generated. As carefully noticed by Bindernagel and Eilks (2009), it is developed step-by-step and constantly influenced by beliefs. The beliefs that are capable of influencing PCK are epistemological beliefs, general educational beliefs, content-related beliefs, beliefs about curriculum orientation and much more. In their contributions toward the manner through which PCK is nurtured, Clermont, Krajcik and Borko (1994) observed that PCK growth among beginning teachers is generally slow and incremental, and is related to the time required for these teachers to plan, gather resources, teach, reflect, and reteach specific topics with increased effectiveness and fluency.

According to Bindernagel and Eilks (2009), growth of chemistry teachers' PCK also appears to be dependent on the motivation, creativity, and pedagogical reasoning skills of the teacher (Bindernagel & Eilks, 2009).

According to Okanlawon (2010), the objectives may be derived from a course syllabus, stated in a textbook, taken from a curriculum guide, or developed by the teacher. He further on stated the objectives as follows:

1. define limiting reagents and distinguish between composition and reaction stoichiometry;
2. identify the major types of instructional approaches use to determine limiting reagents in stoichiometry problems;
3. predict the products of chemical reactions given the reactants;
4. describe chemical reaction types and classify them;
5. write balanced chemical equations for simple reactions;

6. interpret balanced chemical equations in terms of interacting moles, representative particles, masses aid gas volume at STP;
7. distinguish between products and reactants in a chemical equation;

2.9 Review of the College Chemistry Course Outline

2.9.1 Rationale for teaching chemistry

Chemistry is concerned with the study of matter and its changes. As such, it is about us humans and everything around us. Chemistry keeps living things alive through the numerous changes that take place in their bodies. Around us for example, there is chemistry in food, clothing, medicine, shelter and in our transportation system. There is chemistry in outer space. Household items like soap, plastics, books, radio, TV, video and computers would not exist without chemistry. Chemistry enables us to understand, explain, control and prevent phenomena like bush fires, industrial pollution, corrosion of metals and the depletion of the ozone layer. Chemistry is therefore a subject of vital importance.

2.9.2 General aims of studying chemistry

The 2018 Chemistry Course outline is intended to:

i. Create awareness of the interrelationship between chemistry and the other disciplines or careers.
ii. Help students with provide knowledge, understanding and appreciation of the scientific methods, their potential and limitations.
iii. Create awareness in students that chemical reactions and their applications have significant implications for society and the environment.
iv. Develop students ' ability to relate chemistry in school to the chemistry in modern and traditional industries or real world situations.

v. Help students use facts, patterns, concepts and principles to solve personal, social and environmental problems.

vi. Help students use appropriate numeric, symbolic, nomenclature and graphic modes of representation and appropriate units of measurement (eg. SI units).

vii. Help students produce, analyse, interpret and evaluate qualitative data; solve problems involving quantitative data; identify sources of error and suggest improvements to reduce the likelihood of error.

viii. Help students apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting hazard symbols;

ix. By using appropriate techniques for handling, maintaining and storing laboratory materials and by using appropriate personal protection equipment.

x. Develop the ability of students to communicate ideas, plans, procedures, results, and conclusions of investigations orally, in writing, and/ or in electronic presentations, using appropriate language and a variety of formats (eg. data, tables, laboratory reports, presentations, debates, models).

xi. Make the subject interesting and motivating through designing hand-on activities for students to enhance their understanding of the subject.

xii. Train students to use their theoretical ideas to design experiments to solve practical chemistry problems.

xiii. Encourage investigative approach to the teaching and learning of chemistry and make chemistry lessons, problem solving in nature.

2.9.3 Scope of content

The 2018 chemistry teaching course outline builds upon the science learnt at the Senior High School level, and is designed to offer at the Senior High School level, the chemistry required to promote an understanding of the chemical processes taking place all around us. The Course outline is also designed to provide enough chemistry to students who:

i. Will end their study of chemistry at the tertiary level,
ii. Require knowledge of chemistry in their vocational studies

In providing a course based on this syllabus, a wide range of activities including projects have been suggested, in the syllabus, to bring out the initiative and creativity of both the teacher and the student.

2.9.4 Pre-requisite skills

According to chemistry teaching course outline, the learning of the Colleges of Education chemistry requires of students:

(A). Proficiency in English language and a high level of achievement in SHS Integrated Science.

(B). Mathematical Knowledge in the following areas, is also required to facilitate the learning of the subject.

i. arithmetical and algebraic addition, subtraction, multiplication, division, including fraction.
ii. Indices, reciprocals, standard forms, decimals, significant figures and approximations.

iii. Variations, simple proportions and ratios
iv. Squares, square roots and other roots.
v. Logarithms and antilogarithms to base 10.
vi. Averages including weighted averages.
vii. Algebraic equations: linear, quadratic, simultaneous linear equations and their solutions.
viii. Graph drawing and their interpretations.
ix. Equation of a straight line, slopes and intercepts.
x. familiarization with the following shapes: triangles, squares, rectangles, circles, cubes, spheres, pyramids and other two and three-dimensional structures.
xi. Basic calculus.
xii. use of the internet and search engines.
xiii. Knowledge in food and nutrition such as carbohydrates, fats and oils and proteins.

2.9.5 Organization of the Syllabus

The syllabus has been structured to cover the three years of the SHS programme. Each year's work consists of a number of sections with each section comprising a number of units.

2.9.6 The topic: "Limiting reagent" in the syllabus

The 2010 GES chemistry course outline suggests that the topic. "Limiting reagent" is taught in SHS 1 under section 4 of the broad topic: "Conservation of matter and stoichiometry". Specifically, the limiting reagent concept is treated under unit 3 of the section 4 of SHS 1 with the heading: "Stoichiometry and Chemical Equations".

According to the syllabus, at the end of the lesson on stoichiometry and chemical equations, students should be able to determine limiting and excess reagents in a chemical reaction. Under the teaching and learning activities column of the syllabus, it is recommended that teachers help students to determine the limiting and excess reagents in chemical reactions by comparing the available moles of each reactant (“actual mole ratio', AMR) to the moles required for complete reaction ('stoichiometric mole ratio', SMR) using the mole ratio. No mention is made in the syllabus about the use of first principle approach in deducing the limiting reagent in chemical reactions. Meanwhile, according to Chandrasegaran et al (2009), the average-achieving students in their study demonstrated a preference for the use of reasoning strategies from first principles making use of the balanced chemical equation when solving limiting reagent problems. This preference for the use of first principles by average achieving students, according to Chandrasegaran, et al. (2009), reinforced the need for teachers to consider the use of this strategy during instruction for the benefit of average and lower-achieving students, without totally relying on solving problems in rote fashion. It is in the light of this that the researcher focused on the topic: “The effect of first principle approach on students’ achievements in the determination of limiting reagents in chemical reactions”

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter deals primarily with the method used in carrying out the study. It has been divided into ten distinct sections under the following sub-headings: Research Design, Population, Sample and Sampling Procedure, Research Instruments, Pilot Testing of Instrument, Reliability of the Instrument, Validity of the Instrument, Data Collection Procedure, Implementation of treatment Design and Data Analysis.

3.1 Research Design

The design of this study was a quasi-experimental research (Johnson & Christensen, 2008). This design involves manipulation of factors on intact groups while at the same time controlling any other factors or phenomena that may affect the subjects' behavoiur by confounding the results. Among the ideas that are included in a design are the strategy, who and what will be studied, and the tools and procedures to be used for collecting and analyzing empirical materials (Punch, 2006).

The research procedure for this stud comprises of five phases. The first phase addressed the design of the instruments. In implementing the first phase, a questionnaire and sets of test items were constructed for students. The tests were pilot-tested and feedbacks obtained from the pilot-test were used to refine the test items and the refined tests administered to the subjects of the study later. The second phase of the study was the treatment of the control group using actual mole ratio (AMR) and stoichiometric mole ratio (SMR) approach. This involved the interaction of the researcher with the students who formed the subject of the study to explain to them what the study was about. It also included the administration of the pre-treatment test and the marking of the tests.

The third phase was the implementation of the treatment to the experimental group using the first principle approach. This involved defining and explaining the term “limiting reactants" as it occurs in chemical reactions to the subject of the study. After this, the students who formed the subject of the study took part in exercise by using the first principle approach to deduce limiting reactants in chemical reactions. The tests were collected and marked at the end of its administration. The third and the final phase of the study involved the data analysis.

3.2 Population

Johnson and Christensen (2008) defined a population as the set of all elements, objects, persons, individuals and institutions about which information is needed. They continue that, “it is the large group to which a researcher wants to generalize his or her sample results" (p.224). In other words, it is the total group the researcher is interested in learning more about. This group is sometimes referred to as the target population.

The sample frame forming the student’s population from which the sample was drawn from Wiawso College of Education second year science students in the Western North Region of Ghana. The second year science students were selected because they had just completed a course in stoichiometry and chemical equation in chemistry which had as one of its sub-topics; “determining the limiting reactants in chemical reactions" at the end of their study in their first year.

3.3 Sample and Sampling Procedure

A sample is a representation taken from a larger population according to certain rules (Johnson & Christensen, 2008). According to Johnson and Christensen (2008), sampling is the process of drawing a sample from a population. This implies that, when we sample, we study the characteristics of a subset (the sample) selected from a larger group (the population) in order to understand the characteristics of the larger group (the population). A sample is always smaller than a population, and it is often much smaller.

Convenient sampling technique was employed in this study. This technique was used because the participants needed to be of certain characteristics. In this case, students who had just completed a course in stoichiometry and chemical equations in chemistry were needed. second year science students offering chemistry were the people who had these characteristics. One science class from each college was used each made up of sixty making a total sample of 120 students. The experimental group consist of 50 males and 10 females. The control group also made up of 50 males and 10 females all making up 60 students for each group. The study was quasi experimental and only one intact group was needed for the study. The second-year science class was chosen and the purpose and the benefits of the study was explained to them. The Table 1 shows sex distribution of both the experimental and control group.

Table 1: Sex of participants

Sample size	Male	Female	Total
Experimental group	50	10	60
Control group	50	10	60
Grand total			**120**

3.4 Research Instruments

The instruments used to gather data in this study were questionnaire and tests. A questionnaire according to Patton (2002) is a self-report data-collection instrument that each research participant fills out as part of a research study. In this study, questionnaire was used to gather the bio-data of the participants. This data included the name of the school, age, form and sex. A five point Likert scale questionnaire was constructed to determine students' perception on the use of first principle instructional approach to determine the limiting reagents in chemical reaction See Appendix B for the questionnaire. Questionnaires were also used for the bio-data collection because of its convenience of enabling respondents' consistency and uniformity to questions they answer. Again, with questionnaire, less time is required to collect data and confidentiality is also assured.

Cohen, Swerdlik and Philips (1996) defined testing as "the process of measuring variables by means of devices or procedures designed to obtain a sample of behavior" (p.6). Ten test items were constructed for this study during the treatment stage. The test items were specifically on "Determining limiting reagent in chemical reaction". The question items as seen in Appendix C was used to gather information about the understanding of students on the concept of limiting reagent in chemical reaction. The treatment test also consisted of ten (10) sets of items on stoichiometry and chemical equations as it occurs in the teaching chemistry course outline for Colleges of Education. The same treatment test items were used for both control and experimental groups. The test items as seen in Appendix C were used to find out about the effectiveness of using the approach of first principle in determining the limiting reagents in chemical reactions.

3.5 Trial-Testing the Instrument

Trial testing is a small scale test administered before conducting an actual study. Its purpose is to reveal defects in the research instrument (Cohen et al, 1996). According to Patton (2002), it is highly desirable to trial-test an instrument in order to revise the items based on the results of the pilot test. This enables the researcher to determine whether the instrument items possess the desired qualities of measurement and discriminability. This is emphasized by Johnson and Christensen (2008) who stated that a pilot-testing of instrument can reveal ambiguities, poorly worded questions, questions that are not understood, and to check how long it takes participants to complete the test under circumstances similar to those of the actual research study. Johnson and Christensen (2008) add that pilot-testing should be conducted with a minimum of five (5) to ten (10) people. The pilot-testing of the instrument for this study was conducted using ten (10) third year science students of Wiawso College of Education. The ten (10) third year science students were used for the pilot-testing because they had similar features with the main participant of the study. The students for the pilot-testing had completed a course in stoichiometry and chemical equation in chemistry just as the participants in the main study and they were taught by the same teacher who taught the participants in the main study. Through the pilot-testing, it was revealed that one and half hours initially allocated to complete the ten (10) test items each in the treatment test and was not enough to complete the questions. The duration for completing the tests was adjusted to 2 hours. The researcher administered the pilot-testing himself. Ambiguous and poorly worded questions were refined using the results from the pilot-test to ensure reliability.

3.6 Reliability of the main Instrument

Reliability refers to the consistency or stability of a set of scores. It is often defined as the degree of stability or consistency of a measure (Aron, Aron & Coups, 2004). That means that, the reliability of a score is how much you would get the same results if you were to give the same score again to the same person under the same circumstances. According to Johnson and Christensen (2008), reliability is determined by the methods of repeated forms (test-retest), internal consistency, inter-scorer and equivalent forms.

After obtaining the scores from the pilot-testing of the instrument, the internal consistency of the items on the instrument was verified by examining the coefficient alpha of the various items in the instrument. Coefficient alpha provides an estimate of the reliability of a homogeneous test or an estimate of the reliability of each dimension in a multidimensional test (Aron, et al, 2004). The Statistical Package for Social Sciences (SPSS, version 16.0) computer software was used for the analysis of the items on the instruments. The overall reliability coefficient alpha for each of the two (2) test instruments was found to be 0.70. This results showed that the items in the instruments had a good internal consistency and therefore capable of measuring what they were purported to measure. This is so, because according to Johnson and Christensen (2008), as a popular rule. The size of coefficient alpha should generally be, at a minimum, greater than or equal to 0.70 ($\geq$ 0.70) for research purposes and somewhat greater than that value (e.g.> 0.90) for clinical testing purposes.

3.7 Validity of the main Instruments

Validity is the extent to which a test measures what is needed for a particular purpose. Validity is defined by Johnson and Christensen (2008) as "the accuracy of inferences, interpretations, or actions made on the basis of test scores” (p. 150). Patton (2002) also refers to validity as the appropriateness, correctness, meaningfulness, and usefulness of the specific references researchers made based on the data they collect. In short, it can be said that, a valid instrument is one that measures what it was designed to measures. Therefore, what is important in validity is to make sure that a test is measuring what it is intended to measure for the particular people in a particular context and that the interpretations made on the basis of the test scores are correct. According to Patton (2002), validity is the most important idea to consider when preparing or selecting an instrument for use.

According to Johson and Christensen (2008) one method for obtaining validity evidence of an instrument is to study the construct to measure, examine the test content, and make a decision whether the test content adequately represents the construct. This is usually done by experts according to Johnson and Christensen (2008). Another method for obtaining validity evidence of an instrument according to Johnson and Christensen (2008) is to relate the test scores to a known criterion by collecting concurrent and/ or predictive evidence.

Great effort was made to ensure that the questionnaire and the test items covered all the research questions posed in this study. This was done by cross checking to see whether the test items can really answer the research questions. Also the supervisor, two chemistry teachers at Wiawso College of Education were served with copies of the questionnaire and the test items to examine and determine whether the items covered all the research questions adequately. Suggestions received from them were used to refine and sharpen the content of the questionnaire and the test items, making them more relevant and valid for the purpose of the study.

3.8 Data Collection Procedure

The researcher sought permission from the College authorities to carry out a research using the second-year science classes of the two colleges. Lamplighter College of Education was labeled as control group whiles Wiawso College of Education was labeled as the experimental group since the researcher is a chemistry tutor at Wiawso College of Education, there was no need for an introductory letter to the school authorities. The researcher met one group of sixty (60) science students and was thought separately using AMR and the SMR and the other class using first principle approach. The researcher gave them orientation on the purpose and benefits of the study. The researcher again briefed the students on how the various items were to be responded. The students' questions and concerns were clarified to enable them understand issues and provide the appropriate responses.

The researcher personally administered the questionnaire (see Appendix A for the questionnaire) and the test items to each of the class. In the administering the items, the questionnaire, gathering information about their bio-data, was given to the students first. Five (5) minutes was allowed for the students to complete the questionnaire. After collecting the questionnaire on the bio-data, the students were administered the treatment test. They were given two (2) hours to complete the test items. Once again, they were not rushed. Those who could not complete within the two (2) hours were allowed extra time. All the questionnaires and the treatment test items were administered and collected by the researcher on the same day in the classroom. None of the questionnaires and the test items were missing. The responses of the students on the tests were marked over 100 and the scores recorded. See Appendix D for marking scheme of the treatment test.

The researcher met the groups of sixty (60) each, science students who formed the subjects of the study in two weeks' time to carry out the treatment activity. All the sixty (60) students were present for the treatment activity. The treatment activity consisted of four parts and was carried out in four consecutive days. After the treatment activity, the students were discharged to re-appear in two (2) weeks' time for the treatment test to be administered. The researcher and all the sixty (60) students met after two (2) weeks of the treatment activity, in the classroom. The researcher, once again, personally administered the test items to the students. They were allowed two (2) hours to answer the test items. However, students who could not answer all the test items within two (2) hours were allowed extra time to complete the task. The treatment test items were administered and collected by the researcher the same day and none was found missing. The responses of the students on the treatment tests were marked over 100 and the scores recorded. See Appendix D for the marking scheme of the treatment test.

3.9 Implementation of the Treatment

This aspect of the research outlines the various practical activities that were carried out to achieve the aims and objectives of the research work. This include orientation, explaining the concept of limiting reagent, using the first principle approach to teach the concept of deducing the limiting reagent and using class exercise to build up students' confidence. The four aspects of the treatment activity were carried out in four consecutive days.

3.10 Orientation

The researcher met the two groups of sixty each (60) science students who formed the subjects of the study on day one of the treatment activity and gave them orientation on the purpose and the benefits of the study. They were also told what the study entails, how long the study will take and the need for them to remain in the study to the end. They were also briefed on the difficulties students find in deducing the limiting reagent in chemical reactions and how the use of the first principle approach will help them and students in general in overcoming these difficulties.

3.11 Explaining the concept of limiting reagent

Students were taken through the discussion of the concept of limiting reagent as it occurs in chemical reactions on the second day of the treatment activity. The concept of limiting reagent in chemical reactions was explained to students as occurring in a situation when we carry out reactions with limited amount of one reactant and an excess amount of the other. In this case, the reactant, that is completely consumed in the chemical reaction limits the amount of product (s) formed and is called the limiting reactant or limiting reagent. The combustion of octane (C_8H_{18}) in excess amount of oxygen gas (O_2) was used as an illustrative example to help students understand the concept of limiting reagent in chemical reactions. (See Appendix E for details on explaining the concept of limiting reagent.)

3.12 Using the first principle approach to determine limiting reagent in a chemical reaction

The researcher illustrated the use of the first principle approach to the experimental group to determine the limiting reagent in a chemical reaction to the students after explaining the concept of limiting reagent on the second day of the treatment activity.

A reaction involving 0.150 mol of LiOH and 0.080 mol of CO_2 to produce Li_2CO_3 and H_2O was used as the first illustrative example. This illustrative example demanded indicating which of the two (2) reactants, LiOH and CO_2, is the limiting reactant and also calculating the moles of Li_2CO_3: that can be produced. This approach required the writing of a balanced chemical equation for the reaction and making the assumption that; "all of one of the reactants is used up in the reaction".

This assumption is made on the basis that, reactions whose reactants are not in stoichiometric proportions would always have one reactant being used up and another being in excess. With this assumption, one then finds how much of the other reactant (s) would be needed if all of the other reactant is used up. If the moles of this reactant needed is more than the moles available, then this reactant is the limiting reactant and if less than the actual moles available, then this reactant is the reactant in excess. Also the amount of products produced is/ are always dependent on the limiting reactant. The researcher went through a second illustrative example with students on how to use the first principle approach to deduce the limiting reactant in chemical reaction. See Appendix E for details on how to use the first principle approach to deduce the limiting reactant in a chemical reaction.

3.13 Use of class exercise to build up students' confidence

At the end of the lesson on how to use the first principle approach to determine limiting reactants in chemical reactions, the researcher met the subject of the study on the third day of the treatment activity and class exercise was given to the students to use the knowledge gained to determine the limiting reactants in some chemical reactions. The researcher went round to inspect the students doing the class exercise. The exercises were marked and corrections made for the students. The researcher went through the class exercise with students. This helped build up their confidence in the use of the first principle approach to deduce limiting reactants in chemical reactions. See Appendix C for the details on the class exercise.

3.14 Data Analysis

Data analysis is the process of simplifying data in order to make it comprehensible (Cohen et al, 1996). Therefore, in data analysis, any statistical techniques, both descriptive and inferential used should be described. This study, being a qualitative study required a descriptive statistic for analysis of the data. After recording the scores from the AMR approach and the first principle approach, the SPSS version 16.0 computer programming for analysing data was used to analysed the scores. The descriptive statistics was used to describe the data in terms of mean, standard deviation, frequency and percentage. The results were then summarized as the major findings of the study. The discussions were done according to the major findings identified in the study and were used to answer the research questions.

3.15 Ethical consideration

The consent of the students was sought before the study was initiated. This apart from the identities of the research subjects were never revealed at any point in the studies. The researcher needed to protect the identity of the students and the institution, develop a trust with them and promote the integrity of the research. During the process of data collection all the student in the class and the two groups benefit first principle instructional approach. The students who were interviewed were assured of confidentiality. The researcher respected the research site by not allowing the treatments to interfere with the institution’s programmes and disturb them after the study. For data analysis and interpretation, the researcher ensured the anonymity of individual students by the use of aliases and pseudonyms for individuals. The researcher also provided accurate account of the information from the data collected.

CHAPTER FOUR

RESULTS, FINDINGS AND DISCUSSIONS

4.0 Overview

In this chapter, the results of the study and the analysis done on them to answer the research questions are presented. The presentations of the results and the analysis were done according to the research questions.

4.1 Research Question One

1. **What difficulties do students encounter when asked to determine limiting reagent in a chemical reaction?**

The findings from the study did reveal number of factors which do cause students' difficulties in determining limiting reagent. These results were determined in relationship with the type of instructional approach used to teach limiting reagent. Table 2 shows students' difficulties when they were asked to determine the limiting reagents in chemical reactions.

Table 2: Summary of students' difficulties involving determination of limiting reagents

S/N	Students' difficulties
1	Inability to balance chemical equations
2	Inability to write chemical formula of compounds
3	Inability to write IUPAC names.
4	Inability to apply chemical principles.
5	Lack of arithmetic operational skills
6	Lack of ability to draw correct inferences even when they had described the correct test and expected observations
7	Inability to determine mole ratio
8	Lack of the ability to identify relative atomic masses of the elements
9	Assigning wrong units to quantities
10	Inability to write chemical symbols of elements

4.2 Research Question Two:

What are the students' views about the concept of limiting reagents in chemical reactions?

This research question attempted to find out about the general understanding of the students on the concept of limiting reagents in chemical reactions. The question 2 is on the students' view about the concept of limiting reagents, in their own words, the term limiting reagent as it occurs in a chemical reaction. A student was deemed to have an understanding of the concept of limiting reagent if he or she was able to give correct explanation to the concept of limiting reagent as it occurs in a chemical reaction. Students' responses to this question 2 in the test was marked and grouped into" correct explanation" and" wrong explanation". Students with" correct explanations" are those who have understanding of the concept of limiting reagent as it occurs in a chemical reaction and those with" wrong explanations" are those who lack understanding of the concept. The result, as analyzed by the descriptive statistics as shown in Table 3.

Table 3: Students' views/explanation on "Limiting reagent"

Responses	Number of Students	Percentage
Correct explanation	100	83.33
Wrong explanation	20	16.67
Total	**120**	**100**

The results from Table 3 shows that 100 (83.33 %) of the students had a good understanding of the concept of limiting reagent as it occurs in a chemical reaction. It can also be seen from Table 3 that 16.67 % of the total students gave wrong explanations to the term limiting reagent. These students lacked the understanding of the concept of limiting reagent. These students are in the minority as compared to the 83.33% who had understood the concept of limiting reagent. Some of the students' correct explanations, picked at random, are summarized below.

Student 1: The limiting reagent is the substance that is in shortage to complete the chemical reaction fully

Student 2: The limiting reagent is the substance that is in short supply. It is the reactant which is fully used up in a reaction.

Student 3: The limiting reagent is the substance that is used to completion and limits the reaction from producing more of the product.

Student 4: Not enough of one (reactant) is available to react with all of the other (reactant).

Student 5: The limiting reagent.is one reactant that does not have enough mass to fully react with all of another reactant.

As evidenced from the above statements, these students conveyed at least a satisfactory understanding of what the concept meant. Phrases such as 'short supply' and 'used to completion' conveyed the perception of the limiting reagent as a reactant that was completely used up during a chemical reaction. This result shows that lots of the students understood the concept of limiting reagent when it was taught by their class teacher. This finding is in sharp contrast with a study by Gauchon and Méheut (2007) who investigated the effect of students' preconceptions about the concept of limiting reagent on their understanding of stoichiometry. According to Gauchon and Méheut (2007), depending on the physical state of the reactants, students believed that both reactants in a chemical reaction were completely used up when the reactants were in the same state. On the other hand, only one reactant was thought to have changed completely when a solid was one of the reactants.

4.3 Research Question Three:

What is the effect of first principle instructional approach on students' determination of limiting reagents in chemical reactions?

Table 4: t-Test: Two-Sample Assuming Equal Variances

	Control group scores	Experimental group scores
Mean	44.05	58.23333
Variance	288.8957627	205.3345
Observations	60	60
Pooled Variance	247.115113	
Hypothesized Mean Difference	0	
df	118	
t Stat	-4.941846866	
P(T<=t) one-tail	1.29105E-06	
t Critical one-tail	1.657869522	
P(T<=t) two-tail	2.58209E-06	
t Critical two-tail	1.980272249	

This research question attempts to find out the effect of the first principle instructional used by students in determining the limiting reagents in chemical reactions. This was determined by analyzing or comparing the mean score/marks for both experimental and the control group. From the analysis of the students' score the mean mark for the experimental group was 58.23%. whiles that of the control group was 44.05%. the shows that the first principle instructional approach was better than the actual and stoichiometric mole ratio

4.4 Research Question 4

What are the students' perceptions on the use of first principle instructional approach to determine limiting reagents?

To ease the analysis procedure, the strongly agree and agree options were collapsed into single category – agree while the strongly disagree and disagree options were also collapsed into single category disagree, this is shown in Table 5 below.

Table 5: Students' Perception on the use of first Principle

S/N	Statement	Responses in percentages (%)		
		Agree	**Not Sure**	**Disagree**
1	First principle approach made me understand the concept better	70	4	26
2	First principle approach is rather abstract	12	5	83
3	First principle approach is confusing	6	2	92
4	First principle approach makes me more enlightened	84	4	2
5	The teachers' use of first principle approach made the calculations easier for me	75	6	19
6	I prefer other approaches to the first principle approach	16	5	79
7	I would always opt for the use of first principle approach in all my chemistry calculations	70	15	15
8	If I had my way, I will not use the first principle approach	16	3	81
9	The first principle approach is more learner friendly	80	5	15
10	The first principle approach is too demanding	12	3	85

As seen in Table 5, 70% of the experimental group agreed that first principle instructional approach made them understood the concept better. This finding is also in support of the finding by Chandrasegaran, et al (2009), who conducted a qualitative case study to investigate the understanding of the limiting reagent concept and the strategies used by five students in Year 2 when solving four reaction stoichiometry problems. Students' written problem-solving strategies were studied using the think-aloud protocol during problem-solving, and retrospective verbalizations after each activity. The study found that, contrary to several findings reported in the research literature, the two high-achieving students in the study tended to rely on the use of a memorized formula to deduce the limiting reagent, by comparing the actual mole ratio of the reactants with the stoichiometric mole ratio.

Only few students, about (5% - 15%) were not in support of the use of first principle instructional approach' in the determination of limiting reagents in chemical reaction problems presented to them.

Research Hypothesis Ho: There is no significance difference in student's performance in the use of Actual mole ratio and Stoichiometric mole ratio (AMR/SMR) and the first principle approach.

Table 6: t-Test: Two-Sample Assuming Equal Variances

	Control Group Scores	Experimental Group Scores
Mean	44.05	58.23333
Variance	288.8957627	205.3345
Observations	60	60
Pooled Variance	247.115113	
Hypothesized Mean Difference	0	
df	118	
t Stat	-4.941846866	
P(T<=t) one-tail	1.29105E-06	
t Critical one-tail	1.657869522	
P(T<=t) two-tail	2.58209E-06	
t Critical two-tail	1.980272249	

This research question sought to find out whether the first principle approach was more effective than the Actual more ratio (AMR) and the stoichiometric mole ratio (SMR) in determining the limiting reagents in chemical reactions or otherwise. In other words, this research question sought to determine whether students are able to determine limiting reagents in chemical reactions better after they have been introduced to the approach of first principle. This was done by comparing the scores of students in the two tests. In the treatment test students determine the limiting reagent in chemical reaction from the first principle approach using the stoichiometry of the balanced chemical equation. The result, as analysed by the SPSS version 16.0 computer programming for analysing data, is shown in Table 6

From Table 6, test statistics value of -4.941 which was less than the critical value of 1.980 or probability value, the null hypothesis is rejected. There is significance difference in the student performance

A careful study of Table 6 shows that, in general students ' performance in the test, based on the first principle approach, was better than their performance in the use AMR and (SMR). The control group show a mean score of 44.06% whiles the experimental group had a mean score of 58.233%.

From Table 6, it can be concluded that the first principle approach helped the students to deduce the limiting reactants in chemical reactions better than the other approaches. This finding is in support of the finding by Chandrasegaran, et al (2009) that, the average-achieving students in their study demonstrated a preference for the use of reasoning strategies from first principles making use of the balanced chemical equation when solving limiting reagent problems. This preference for the use of first principles by average-achieving students according to Chandrasegaran, et al (2009) reinforces the need for teachers to consider the use of this strategy during instruction for the benefit of average and lower-achieving students, without totally relying on solving problems in rote fashion.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter summarizes the findings that has been established in this study on “effect of first principle approach on students’ achievement to determine limiting reagent in chemical reactions", conclusions drawn, recommendations and suggestions given by the researcher for future research in this area.

5.1 Summary of the Major Findings

The findings from the study indicated that students were able to state correctly that the limiting reagent is the reactant that is completely used up in a chemical reaction. This was an indication that the students had a good understanding of the concept of limiting reagent as it occurs in a chemical reaction. This is evident by the fact that 82 % of the students in the study were able to give correct explanations to the meaning of the concept of limiting reagent in the treatment test. Phrases such as 'short supply' and 'used to completion' used by the students in the explanations conveyed the perception of the limiting reagent as a reactant that was completely used up during a chemical reaction. The results showed that lots of the students understood the concept of limiting reagent when it was taught by the teacher.

Again, from the analysis of the students' in the control group and experimental group test responses, two strategies were identified to be used by the students in deducing the limiting reagent in chemical reactions. These were the strategies of; "deducing limiting reagent by comparing 'actual mole ratio' (AMR) and 'stoichiometric mole ratio' (SMR) “and "deducing limiting reagent from first principle approach”.

The first strategy involved comparing the actual mole ratio (AMR) with the stoichiometric mole ratio (SMR). In order to determine the limiting reagents, students had to reason how the numerator or the denominator of the AMR had to change so that is was equal to the SMR, and from there deduce the limiting reagent (which was the reagent that was in short supply). The second method also involved deducing the limiting reagent from first principles using the stoichiometry of the balanced chemical equation. This method does not involve computing the actual mole ratio (AMR) and the stoichiometric mole ratio (SMR).

The findings of the study indicate that 46 students representing 92% used the approach of comparing AMR and SMR' as against only four (4) students representing eight percent (8%) who used the 'first principle approach' in their deduction of limiting reagent in chemical reaction problems presented to them in the treatment test. This finding from this study is not unexpected because the approach of comparing AMR and SMR is the strategy that has been described in the GES (2010) SHS chemistry syllabus to be used by teachers in helping students deduce limiting reagents in chemical reactions.

Finally, it can be concluded that the alternative method, first principle approach, helped the students to deduce the limiting reactants in chemical reactions better than the other approaches. This is evident by the fact that 58.233% was the students' mean score in the experimental group test, after they have been introduced to the first principle approach, as against 44.05% of students' mean score in the control group test, when they used the approach of' comparing AMR and SMR. This finding is in support of the finding by Chandrasegaran, et al (2009) that, the average-achieving students in their study demonstrated a preference for the use of reasoning strategies from first principles making use of the balanced chemical equation when solving limiting reagent problems.

5.2 Conclusion

This study was meant to assess the effect of first principle approach on students' achievement in the determination of the limiting reagent in a chemical reaction at Wiawso College of Education. Students' performance in the test on determining limiting reagents in chemical reactions, using the approach of comparing AMR and SMR, was found to be very low. The experimental group was taught by using the first principle approach to deduce the limiting reagents in chemical reactions. Students' performance in the test on deducing limiting reagent in chemical reactions was better after they have been introduced to the first principle approach. It can therefore be concluded that the first principle approach helped the students to deduce the limiting reactants in chemical reactions better than the approach of comparing AMR and SMR.

5.3 Recommendations

In the light of the foregoing discussion, the following recommendations are worth considering;

1. The students in this study have demonstrated a preference for the use of reasoning strategies from first principles making use of the balanced chemical equations when solving limiting reagent problems, as they performed better when they were introduced to the first principle approach. This preference for the use of first principles by the students reinforces the need for teachers in the study area to consider the use of this strategy during instruction for the benefit of all students, without totally relying on solving problems in rote fashion. If

they feel more confident with the use of algorithmic strategies or memorised formulae, students should be made aware of the reasons for doing so.

2. It is also necessary for tutor at Wiawso College of Education to engage students in a variety of approaches; for example, considering changes at the submicroscopic level using particle diagrams, so that students' conceptual understanding of limiting reagent concepts can be further enhanced.
3. In addition, textbook writers should also consider including this alternative strategy when explaining the determination of limiting reagents in chemical reactions. National Council for Curriculum and Assessment (NaCCA) of the Ministry of Education should also consider including the first principle approach as one of the approaches to be used to help students deduce the limiting reagents in chemical reactions.
4. It is also suggested that further research be done on this topic by other researchers in other Colleges of Education in the country. This is because only Wiawso College of Education in the Western North Region of Ghana was used and this may not be the true reflection in the entire country.
5. More effective and innovative teaching methods need to be developed to help students refrain from rote learning in favour of meaningful learning. Teachers should be informed about the usage and importance of conceptual change texts, and they can plan the instructional activities accordingly.
6. Chemistry teachers should be encouraged to use real life examples and analogies in teaching abstract chemical concepts. Conceptual change text can help improve students' attitude towards learning and help the learner to conceptualize whatever is being taught better.

7. Students should be empowered by their teachers to become responsible for their own learning.
8. Ministry of Education, in collaboration with Ghana Education Service, University of Education and other related bodies in education should regularly and periodically be organizing workshops and in-service training (INSET) for teachers teaching chemistry at the Colleges of Education on the methods of teaching the stoichiometry concept.
9. Researchers and the curriculum developers should focus more on the students' prior knowledge and misconceptions since it is well known that most students are unable to effectively learn all of the materials in their classes.

5.4 Suggestions for Further Studies

The findings of the current study raise other questions for researchers and teacher educators to consider and investigate about the teaching and learning of the concept stoichiometry and determination of limiting reagents. The following research directives have been listed for consideration by other researchers:

1. This study should be replicated in other institutions to test its efficacy and effectiveness.
2. Other researchers should investigate the effect of gender on the first principle approach on students’ ability to determine limiting reagents in chemical reactions
3. The effectiveness of first principle approach to the solution calculations involving other chemistry topics (for example electrochemistry) should be investigated by other researchers.

4. A survey of the approach utilized by chemistry teachers and tutors during lessons on limiting reagents should be conducted to provide insights into the difficulties encounter during such lessons.
5. This study should be replicated in other Colleges of Education in Ghana using larger samples. This would provide a basis for more generalizations of conclusions to be arrived at, about the effect of first principle approach in teaching limiting reagents. This would eventually increase the external validity of the findings of the present study.
6. This study used third year chemistry students as the main sample for the study. The study should also be replicated in other Colleges of Education in Ghana using the first year students.
7. Last but not the least, it is suggested that more developmental researches could be undertaken, by devising teaching methods especially in the area of technology where software can be used to help teach the stoichiometry concept and other concepts be designed and developed to improve the development of science and technology in this country, Ghana.

REFERENCES

Abdullah, J. B., & Kassim, J. M. (2011). Instructional leadership and attitude towards organizational change among secondary schools' principals in Pahang, Malaysia. *Procedia-Social and Behavioral Sciences*, *15*, 3304-3309.

Akbari, R., & Allvar, N. K. (2010). L2 Teacher characteristics as predictors of students' academic achievement. *Tesl-Ej*, *13*(4).

Alderman, M. K. (2013). *Motivation for achievement: Possibilities for teaching and learning*. London: Routledge.

Aljohani, M. (2017). Principles of "constructivism" in foreign language teaching. *Journal of Literature and Art Studies*, *7*(1), 97-107.

Alson, J.A. (2014). *Chemical reactions: Stoichiometry and beyond.* San Diego, CA: Cognella Inc. Academic Publishing,

Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9 16.

Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9-16.

Anamuah-Mensah, J. (1995). Some O ' level chemistry topic: What students find difficult. *The Oguaa Education*, 11(2), 8-18.

Anamuah-Mensah, J. (1999). Science and technology education in Ghana: *A paper delivered at the National education forum on the theme: Towards sustaining an effective national education system*, held at the Accra International Conference Centre, Accra, 17-19th November.

Anderson, B. & Renstrom, I. (1983). *How Swedish pupils, age 12-15, explain the exhaust" problem*. Sweden: University of Goteborg, Department of Education.

Anderson, C. W. (1987). "*Three perspectives on Cognition and their Implications for Science Teaching",* A Paper Presented at the Annual Meeting of the American Educational Research Association in Washington D. C. April 1987.

Anmarkrud, Ø., Andresen, A., & Bråten, I. (2019). Cognitive load and working memory in multimedia learning: Conceptual and measurement issues. *Educational Psychologist*, *54*(2), 61-83.

Annoh, K. (1988). *Educational psychology and guidance and counselling*. Kumasi: Cita Printing Press Ltd.

Antonenko, P., Paas, F., Grabner, R., & Van Gog, T. (2010). Using electroencephalography to measure cognitive load. *Educational psychology review*, *22*(4), 425-438.

Aron, A., Aron, E. N., & Coups, E. J. (2004). *Statistics for the behavioral and social sciences: A brief course* (3rd ed.). Upper Saddle River, New Jersey: Pearson Prentice Hall.

Bacon, S. L., Campbell, T. S., Arsenault, A., & Lavoie, K. L. (2014). The impact of mood and anxiety disorders on incident hypertension at one year. *International Journal of Hypertension*, *2014*.

Balyer, A. (2012). Transformational leadership behaviours of school principals: A qualitative research based on teachers' perceptions. *International Online Journal of Educational Sciences, 4*(3), 581-591. Available at http://www. acarindex.com/dosyalar/makale/acarindex-1423904284.pdf

Banerjee, A. C. (1991). Misconceptions of students and teachers in chemical equilibrium. *International Journal of Science Education*, *13*(4), 487-494.

Barnard, W. M. (2004). Parent involvement in elementary school and educational attainment. *Children and Youth Services Review*, *26*(1), 39-62.

Eylon, B. S., Ben-Zvi, R., & Silberstein, J. (1987). Hierarchical task analysis-An approach for diagnosing students' conceptual difficulties. *International Journal of Science Education*, *9*(2), 187-196.

Bindernagel, J. A., & Eilks, I. (2009). Evaluating roadmaps to portray and develop chemistry teachers' PCK about curricular structures concerning sub-microscopic models. *Chemistry Education Research and Practice*, *10*(2), 77-85.

Blevins, B. M. (2009). *Effects of socioeconomic status on academic performance in Missouri public schools.* Retrieved from http://gradworks.umi.com/33 72318.pdf.

Bodner, G. M., & Herron, J. D. (2002). Problem-solving in chemistry. In *Chemical education: Towards research-based practice* (pp. 235-266). Springer, Dordrecht.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education*, *63*(10), 873-880.

Boujaoude, S., & Barakat, H. (2000). Secondary school students' difficulties with stoichiometry. *School Science Review, 81*(296), 91-98.

Brunken, R., Plass, J. L., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational psychologist*, *38*(1), 53-61.

Bucat, B., & Fensham, P. (1995). Teaching and learning about chemical equilibrium. *Selected Papers in Chemical Education Research*, 167-171.

Burton, G., Holman, J., Pilling, G. & Waddington, D. (1994). *Salters advanced chemistry chemical storylines.* Oxford: Heinemann.

Butcher, K. R., Leary, H., Foster, J., & Devaul, H. (2014). Facilitating teachers' thinking about pedagogy and technology with an online curriculum planning tool. *Journal of Technology and Teacher Education*, *22*(4), 423-447.

Butzler, K. B. (2014). *The effects of motivation on achievement and satisfaction in a flipped classroom learning environment*. Northcentral University.

Canham, M., & Hegarty, M. (2010). Effects of knowledge and display design on comprehension of complex graphics. *Learning and Instruction*, *20*(2), 155-166.

Carey, S. (1985). *Conceptual change in childhood.* Cambridge, MA: MIT Press.

Chamizo, J. A., & Padilla, K. (2007). *Historical Recurrent Teaching Models* 2: From Stoichiometry to Nanotechnology, 9th International History and Philosophy of Science Teaching Group International Conference Calgar. Chief Examiners' report (2008; 2009;2010; 2011). WEAC, W.A.S.S.C.E. Chemistry. Ghana.

Chandrasegaran, A. L., Treagust, D. F., Waldrip, B. G., & Chandrasegaran, A. (2009). Students' dilemmas in reaction stoichiometry problem solving: deducing the limiting reagent in chemical reactions. *Chemistry Education Research and Practice*, *10*(1), 14-23.

Chi, M. T., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, *49*(4), 219-243.

Clermont, C. P., Borko, H., & Krajcik, J. S. (1994). Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators. *Journal of Research in Science Teaching*, *31*(4), 419-441.

Cohen, R. J., Swerdlik, M. E., & Philips, S. M. (1996). *Pyschological testing and assessment*: An introduce on to test and measurement. (3rd Ed) Mountain View, CA: Mayfield

Cracoline, M. S., Deming, J. C., & Ehlert, B. (2008). Concept learning versus problem solving: A cognitive difference. *Journal of Chemical Education*, *85*, 873-878.

Cruickshank, D. R., Jenkins, D. B., & Metcalf, K. K. (2003). *The Act of Teaching*. New York, NY: McGraw-Hill.

Dahsan, C., & Coll, R. K. (2007). Thai Grade 10 and 11 students' understanding of stoichiometry and related concepts. *International Journal of Science and Mathematics Education*, DOI: 10.1007/ s10763-007-9072-0. Retrieved 7 July 2011 from: http://www.springerlink.com/content/35281870u068w20k/

de Leeuw, K. E., & Mayer, R. E. (2008). A comparison of three measures of cognitive load : Evidence for separable measures of intrinsic, extraneous, and germaine load. *Journal of Educational Psychology, 100*(1), 223-227

de Astudillo, L. R., & Niaz, M. (1996). Reasoning strategies used by students to solve stoichiometric problems and its relationship to alternative conceptions, prior Ga knowledge and cognitive variables. *Journal of Science Education & Technology, 5*,131-40.

Jong, O. D., Veal, W. R., & Driel, J. H. V. (2002). Exploring chemistry teachers' knowledge base. In *Chemical education: Towards research-based practice* (pp. 369-390). Dordrecht: Springer.

De Jong, T., & Lazonder, A. W. (2014). 15 – The guided discovery learning principle in multimedia learning. *The Cambridge handbook of multimedia learning* (pp. 371-390). Cambridge, England: Cambridge University Press.

DeMatthews, D. E. (2014). How to improve curriculum leadership: Integrating leadership theory and management strategies. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 87*(5), 192-196. https://doi. org/10.1080/00098655,2014.911141.

Dierks, W. (1985). Teaching the mole. *European Journal of Science Education, 3*, 145-158.

Dorin, H. (1987). *Chemistry-the study of matter*. Newton, MA: Allyn and Bacon.

Dornyei, Z. (2001). *Motivational strategies in the language classroom.* New York, NY: Cambridge University Press.

Duit, R., Gropengießer, H., & Kattmann, U. (2005). Towards science education research that is relevant for improving practice: The model of educational reconstruction. *Developing Standards in Research on Science education*, 1-9.

Duncan, I. M., & Johnstone, A. H. (1973). The mole concept, *Education Chemistry*, *10*, 213-214.

Eminah, J. K. (2009). Science classroom climates in selected Ghanaian primary schools. *A Journal of Education, Umaru Musa Yar'adua University, Katsina*, *1*(1), 1-8.

Enem, F. O. (2005). The importance of instructional materials to the successful implementation of Social Studies curriculum at junior secondary school level. *Journal of Curriculum and Media Technology Research, 1*(11), 48-56.

Fach, M., de Boer, T., & Parchmann, I. (2006). *Results of an interview study as basis for the development of stepped supporting tools for stoichiometric problems.* University of Oldenburg, Germany.

Fach, M., de Boer, T. & Parchmann, I. (2007). Results of an interview study as basis for the development of stepped supporting tools for stoichiometric problems. *Chemistry Education Research and Practice, 8,* 13-31.

Farooq, M. S., Chaudhry, A. H., Shafiq, M., & Berhanu, G. (2011). Factors affecting students' quality of academic performance: A case of secondary school level. *Journal of Quality and Technology Management, 7*(2), 1-14.

Faught, E. L., Williams, P. L., & Willows, N. D. (2017). The association between food insecurity and academic achievement in Canadian school-aged children. *Public Health Nutrition, 20,* 2778-2785.

Felder, R. M. (1990). Stoichiometry without tears. *Chemical Engineering Education, 24*(4), 188-196.

Frankfort-Nachmias, C., & Nachmias, D. (1992). *Research methods in the social sciences* (4th ed.). London: Edward Arnold.

Frazer, M. J., & Servant, D. (1987). Aspect of Stoichiometry- where do students go wrong? *Education in Chemistry, 24*, 73-75.

Furió C., Azcona, R., & Guisasola, J. (2002). The learning and teaching of the concepts ' amount of substance' and 'mole': A review of the literature, *Chemistry Education Research and Practice, 3*, 277-292.

Furió, C., Azcona, R., Guisasola, J., & Ratcliffe, M. (2000). Difficulties in teaching the concepts of ' amount of substance' and ' mole'. *International Journal of Science Education, 22,* 1285-1304.

Gabel, D. L., & Bunce, D. M. (1994). Research problem solving: Chemistry, In D. L., Gabel (Ed.), *Hand book of research on science teaching and learning*. New York: MacMillan.

Gabel, D. L., & Sherwood, R. D. (1984). Analysing difficulties with mole-concept tasks by using familiar analogue tasks. *Journal of Research in Science Teaching, 21*, 843-841.

Gabel, D.L., Samuel, K.V., & Hunn, D. (1987). Understanding the particulate nature of matter. *Journal of Chemical Education, 64 (8),* 695-697.

Gauchon, L., & Méheut M. (2007). Learning about stoichiometry: From students' preconceptions to the concept of limiting reactant. *Chemistry Education Research and Practice, 8*, 362-375.

Gordon, M. (2008). Between constructivism and connectedness. *Journal of Teacher Education*, *59*(4), 322-331.

Gundersen, C., & Ziliak, J. P. (2015). Food insecurity and health outcomes. *Health Affairs*, *34*(11), 1830-1839.

Gunter, H. M. (2001). *Leaders and leadership in education.* London, England: Paul Chapman Publishing.

Harb, N., & El-Shaarawi, A. (2006). Factors affecting Students' Performance. *Journal of Business Education*, *5*(82), 56-70.

Hewson, P. W. (1992, June). Conceptual change in science teaching and teacher education. In *a meeting on "Research and Curriculum Development in Science Teaching," under the auspices of the National Center for Educational Research, Documentation, and Assessment, Ministry for Education and Science, Madrid, Spain* (pp. 329-342).

Hewson, P. W. (1982). A case study of conceptual change in special relativity: The influence of prior knowledge in learning. *European Journal of Science Education*, *4*(1), 61-78.

Hildrum, B., Romild, U., & Holmen, J. (2011). Anxiety and depression lowers blood pressure: 22-year follow-up of the population based HUNT study, Norway. *BMC Public Health*, *11*(1), 1-8.

Howe, C., Devine, A., & Taylor Tavares, J. (2013). Supporting conceptual change in school science: A possible role for tacit understanding. *International Journal of Science Education*, *35*(5), 864-883.

Johnson, R. B., & Christensen, L. B. (2008). *Educational research: Quantitative, qualitative, and mixed approaches* (3rd ed.). Los Angeles: Sage Publications, Inc.

Jyoti, D. F., Frongillo, E. A., & Jones, S. J. (2005). Food insecurity affects school children's academic performance, weight gain, and social skills. *Journal of Nutrition*, *135*, 2831-2839.

Karemera, D. (2003). The effects of academic environment and background characteristics on students' satisfaction and performance: The case of South Carolina State University's School of Business. *College Students Journal*, *37*(2), 298-311.

Kazdin, A. E. (2000). *Encyclopedia of psychology* (Vol. 8, p. 4128). American Psychological Association (Ed.). Washington, DC: American Psychological Association.

Kelley, C., & Peterson, K. D. (2007). The work of principals and their preparation: Addressing critical needs for the twenty-first century. In M. Fullan (Ed.), *The Jossey-Bass reader on educational leadership (2nd ed.).* San Francisco, CA: Jossey-Bass.

Kim, S. H., Lu, Y., Constantinou, G., Shahabi, C., Wang, G., & Zimmermann, R. (2014, March). Mediaq: Mobile multimedia management system. In *Proceedings of the 5th ACM Multimedia Systems Conference* (pp. 224-235). Retrieved from: https://doi.org/10.1145/2557642.2578223

Koch, H. (1995). Simplifying stoichiometry: students react with confidence to a new approach to quantitative chemistry problems. *Science Teaching, 62* (8), 36-39.

Komarraju, M., Karau, S. J., Schmeck, R. R. (2009). Role of the big five personality traits in predicting college students' academic motivation and achievement. *Learn Individual, 19,* 47-52.

Komarraju, M., Karau, S. J., & Schmeck, R. R. (2009). Role of the Big Five personality traits in predicting college students' academic motivation and achievement. *Learning and Individual Differences*, *19*(1), 47-52.

Korbach, A., Brünken, R., & Park, B. (2018). Differentiating different types of cognitive load: A comparison of different measures. *Educational Psychology Review*, *30*(2), 503-529.

Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Delhi: New Age International.

Kowalski, T. J. (2010. *The school principal- Visionary leadership and competent management.* New York, NY: Taylor and Francis.

Kruger, J. L., & Doherty, S. (2016). Measuring cognitive load in the presence of educational video: Towards a multimodal methodology. *Australasian Journal of Educational Technology*, *32*(6).

Kuhn, T. S. (1962). Historical Structure of Scientific Discovery: To the historian discovery is seldom a unit event attributable to some particular man, time, and place. *Science*, *136*(3518), 760-764.

Ladyman, J. (2008). Structural realism and the relationship between the special sciences and physics. *Philosophy of Science*, *75*(5), 744-755.

Laraia, B. A. (2013). Food insecurity and chronic disease. *Advances in Nutrition*, *4*(2), 203-212.

Lazonby, J. N., Morris, J. E., & Waddington, D. J. (1982). The muddle some mole. *Education in Chemistry, 19,* 109-111.

Leppink, J., Paas, F., Van der Vleuten, C. P., Van Gog, T., & Van Merriënboer, J. J. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods*, *45*(4), 1058-1072.

Leutner, D., & Schmeck, A. (2014). 18 The Generative Drawing Principle in Multimedia Learning. *The Cambridge Handbook of Multimedia Learning*, 433.

Lewis, M. A. (2000). Lean production and sustainable competitive advantage *International Journal of Operations & Production Management, 20*(8), 959-978.

Lijnse, P. L. (1995). "Developmental research" as a way to an empirically based "didactical structure" of science. *Science Education*, *79*(2), 189-199.

Lippa, R. A. (2010). Sex differences in personality traits and gender-related occupational preferences across 53 nations: Testing evolutionary and social-environmental theories. *Archives of Sexual Behavior*, *39*(3), 619-636.

Lythcott, J. J. (1990). Problem solving and requisite knowledge in chemistry, *Journal of Chemical Education, 67,* 248-252.

Mac Giolla, E., & Kajonius, P. J. (2019). Sex differences in personality are larger in gender equal countries: Replicating and extending a surprising finding. *International Journal of Psychology*, *54*(6), 705-711.

MacMillan, J. H. (2014). Is a totally constructivist approach to the teaching of high school chemistry possible in practice? *Journal of Chemical Education.* Retrieved 26/3/2014.

Marzano, R. J. (2003). *What works in schools: Translating research into action?* Retrieved from http://pdonline.ascd.org/pd_ online/whatworks/ marzano2003_ ch13.html.

Mason, D., & Crawley, F. E. (1994). Differences between algorithmic and conceptual problem solving by non-science majors in introductory chemistry. *Paper presented at the 67th annual meeting of the National Association for Research in Science Teaching, Anaheim, CA.*

Mayer, R. E., & Pilegard, C. (2014). Principles for managing essential processing in multimedia learning: Segmenting, pre-training, and modality principles. In R. E. E. Mayer (Eds.). *The Cambridge Handbook of Multimedia Learning* (pp. 316-344).

Mayer, R. E. (2014). Incorporating motivation into multimedia learning. *Learning and Instruction*, *29*, 171-173.

Mayer, R. E., & Fiorella, L. (2014). 12 principles for reducing extraneous processing in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. In *The Cambridge handbook of multimedia learning* (Vol. 279). New York, NY: Cambridge University Press.

Mestry, R. (2017). Empowering principals to lead and manage public schools effectively in the 21st century. *South African Journal of Education*, *37*(1), 1-11.

Mitchell, I., & Gunstone, R. (1984). Some student conceptions brought to the study of stoichiometry, *Research in Science Education, 14,* 78-88.

Mousoulides, N., & Philippou, G. (2005). Students' motivational beliefs, self-regulation and mathematics achievement. *The Psychology of Mathematics Education, 3,* 321-328.

Mulford, D. R., & Robinson, W. R., (2002). An inventory of alternate conceptions among first semester general chemistry students, *Journal of Chemical Education, 79,* 739 744.

Mulford, D. R. (1996). *An inventory for measuring college students' level of misconceptions in first semester chemistry.* MPhil thesis submitted to Purdue University.

Murdoch, J. (2000). And investigation into the understanding of elements, compounds and mixtures through descriptions in words or diagrammatic representations, with learners aged 13 to 16. *School Science Review, 18 (286),* 47-51.

Nakhleh, B. M. (1992). Why some students don't learn chemistry. *Journal of Chemical Education, 69*(3), 191-196.

Nelson, P. G. (1991). The elusive mole. *Education in Chemistry*, *28*(4), 103-104

Neo, M., & Neo, T. K. (2009). Engaging students in multimedia-mediated Constructivist learning–Students' perceptions. *Journal of Educational Technology & Society*, *12*(2), 254-266.

Niaz, M. (1995). Cognitive conflict as a teaching strategy in solving chemistry problems. A dialectic-constructivist perspective. *Journal of Research in Science Teaching, 32,* 959-70.

Nickerson, R. S. (1985). Understanding understanding. *American Journal of Education*, *93*, 201-239.

Noble, J. P., Roberts, W. L., & Sawyer, R. L. (2006). Student achievement, behavior, perceptions, and other factors affecting act scores. *ACT Research Report Series*, 2006-1. ACT, Inc.

Novick, S., & Menis, J. (1976). A study of student perceptions of the mole concept. *Journal of Chemical Education*, *53*(11), 720.

Nurrenbern, S. C. & Pickering, M. (1987). 'Concept learning vs. problem solving: Is there a difference?', *Journal of Chemical Education*, 64(6) 508 - 510.

NURRENBERN, S. C. (1979). *Problem solving behaviors of concrete and formal operational high school chemistry students when solving chemistry problems requiring Piagetian formal reasoning skills*. Doctoral dissertation submitted to Purdue University.

Okanlawon, A. E. (2010). Teaching reaction stoichiometry: exploring and acknowledging Nigerian chemistry teachers pedagogical content knowledge. *Cypriot Journal of Educational Sciences*, *5*(2), 107-129.

Osborne, R., & Freyberg, P. (1985). *Learning in science. The implications of children's science*. Portsmouth, NH: Heinemann Educational Books, Inc.

Özdemir, G., & Clark, D. B. (2007). An overview of conceptual change theories. *Eurasia Journal of Mathematics, Science and Technology Education*, *3*(4), 351-361.

Paas, F., & Ayres, P. (2014). Cognitive load theory: A broader view on the role of memory in learning and education. *Educational Psychology Review*, *26*(2), 191-195.

Park, B., Knorzer, L., Plass, J. L., & Brunken, R. (2015). Emotional design and positive emotions in multimedia learning: An eye-tracking study on the use of anthropomorphisms. *Computers & Education*, *86*, 30-42.

Parri, J. (2006). Quality in higher education. *Vadyba/Management*, *2*(11), 107-111.

Patton, M. Q. (2002). *Qualitative research and evaluation methods.* Thousand Oaks, CA: Sage.

Pereira, M. P., & Pestana, M. E. M. (1991). Pupils' representations of models of water. *International Journal of Science Education*, *13*(3), 313-319.

de Toledo Vianna, R. P., Hromi-Fiedler, A. J., Segall-Correa, A. M., & Pérez-Escamilla, R. (2012). Household food insecurity in small municipalities in Northeastern Brazil: a validation study. *Food Security*, *4*(2), 295-303.

Pickering, M. (1987). What goes on in students' heads in lab? *Symposium on Algorithms and Problem Solving, 64*(6), 521-523.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Toward a theory of conceptual change. *Science Education*, *66*(2), 211-227.

Proctor, B. E., Prevatt, F. F., Adams, K. S., Reaser, A., & Petscher, Y. (2006). Study skills profiles of normal-achieving and academically-struggling college students. *Journal of College Student Development*, *47*(1), 37-51.

Punch, K. F. (2006). *Developing effective research proposal.* Los Angeles: Sage Publications Ltd.

Rice, J. K. (2004). Equity and efficiency in school finance reform: Competing or complementary goods?. *Peabody Journal of Education*, *79*(3), 134-151.

Rosalind, D. (1981). Pupils' alternative framework in science. *European Journal of Science Education, 13* (1), 93-101.

Rosander, P., Bäckström, M., & Stenberg, G. (2011). Personality traits and general intelligence as predictors of academic performance: A structural equation modelling approach. *Learning and Individual Differences*, *21*(5), 590-596.

Sanger, M. J. (2005). Evaluating students' conceptual understanding of balanced chemical equations and stoichiometric ratios using a particulate drawing. *Journal of Chemical Education, 82,* 131-134.

Sawrey, B. A. (1990). Concept learning versus problem solving: Revisited. *Journal of Chemical Education*, *67*(3), 253.

Saxton, J. (2000). *Investment in education: Private and public returns.* Retrieved from http://www.house.gov/jec/edu.pdf.

Schmidt, H. J., & Jignéus, C. (2003). Students strategies in solving algorithmic stoichiometry problems. *Chemistry Education Research and Practice*, *4*(3), 305-317.

Schmidt, H. J. (1997). An alternate path to stoichiometric problem solving. *Research in Science Education*, *27*(2), 237-249.

Schmidt, H. J. (1984). How pupils think: Empirical studies on pupils' understanding of simple quantitative relationships in chemistry. *School Science Review, 66* (234), 156-162.

Saxena, A. B. (1991). The understanding of the properties of light by students in India. *International Journal of Science Education*, *13*(3), 283-289.

Shipman, N. J. Queen, JA & Peel, HA (2007). *Transforming school leadership with ISLLC and ELCC. Jonesborough, TN: Eye on Education*.

Slavin, R. E. (2006). Educational psychology theory and practice (8th ed.). USA: Library of Congress Cataloging in Publication Data.

Smoot, R. C., Price, J., & Smith, R. G. (1987). *Chemistry: A modern course*. Columbus, OH: Merril.

South, S. C., Jarnecke, A. M., & Vize, C. E. (2018). Sex differences in the Big Five model personality traits: A behavior genetics exploration. *Journal of Research in Personality*, *74*, 158-165.

Stronge, J. H. (2002). *Qualities of effective teachers*. Retrieved from http://www.zawodny.net/orientation%2006%20Theteacherasaperson.pdf

Sweller, J. (2010). Elementary interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review*, *22*(2), 123-138.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. Retreived from http://linkspringer.com/10.1007/978-1-4419-8126-4.

Sweller, J., van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, *31*(2), 261-292.

Tingle, E., Corrales, A., & Peters, M. L. (2019). Leadership development programs: Investing in school principals. *Educational Studies*, *45*(1), 1-16.

Veresova, M. (2015). Learning strategy, personality traits and academic achievement of university students. *Procedia-Social and Behavioral Sciences*, *174*, 3473-3478.

Wallace Foundation (2008). *Becoming a leader: Preparing school principals for today's schools*. New York.

West African Examination Council (2003). Chief examiner's report. Accra: WAEC.

Wickstrom, E., Tyson, R. W., Newton, G., Obert, R., & Williams, E. E. (1980). Stoichiometry of homopolynucleotide binding to Escherichia coli translational initiation factor 3. *Archives of Biochemistry and Biophysics*, *200*(1), 296-300.

Weisberg, Y. J., Deyoung, C. G., & Hirsh, J. B. (2011). Gender differences in personality across the ten aspects of the big five. *Frontiers in Psychology*, *2*, 178.

Westbrook, S. L., & Marek, E.A. (1991). A cross-age study of student understanding of the concept of diffusion. *Journal of Research in Science Teaching*, *28*(8), 649-660.

Yarroch, W. L. (1985). Student understanding of chemical equation balancing, *Journal of Research in Science Teaching, 22* (5), 449-459.

Zaitoon, H., Sharkansky, L., Ganaim, L., Chistyakov, I., Srugo, I., & Bamberger, E. (2021). Evaluation of Israeli healthcare worker's knowledge and attitudes toward the COVID-19 vaccine. *Public Health Nursing, 2*(5), 44-45.

Zaslow, M., Bronte-Tinkew, J., & Capps, R. (2009). Food security during infancy: Implications for attachment and mental proficiency in toddlerhood. *Maternal and Child Health Journal, 13,* 66-80.

APPENDICES

APPENDIX A

THESIS ON THE EFFECTS OF FIRST PRINCIPLE INSTRUCTIONAL APPROACH ON STUDENTS' DETERMINATION OF LIMITING REAGENT IN A CHEMICAL REACTION

BIO DATA

This test is to collect information on "the effect of first principle instructional approach to determine the limiting reagents in chemical reactions" It will be appreciated if you answer the following questions. You must note that this study is only a research and the marks you obtain will not be recorded by your teachers. However, you must note that you will benefit greatly for taking part in this exercise as it will provide you with an approach in deducing the limiting reagents in chemical reactions. Thank you for accepting to take part in this exercise. All answers will be treated confidential.

BIO DATA

INSTRUCTION: Please fill where necessary and tick were necessary

College……………………………………………

Age: …………………………………

Form 1st year ☐ 2nd year☐ 3rd year ☐

Sex : Male ☐ Female ☐

APPENDIX B

STUDENT'S PERCEPTION ABOUT THE EFFECTS OF FIRST PRINCIPLE

S/N	Statement	Responses				
		Strongly agreed	Agree	Not Sure	Disagree	Strongly disagree
1	First principle approach made me understand the concept better					
2	First principle approach is rather abstract					
3	First principle approach is confusing					
4	First principle approach makes me more enlightened					
5	The teachers' use of first principle approach made the calculations easier for me					
6	I prefer other approaches to the first principle approach					
7	I would always opt for the use of first principle approach in all my chemistry calculations					
8	If I had my way, I will not use the first principle approach					
9	The first principle approach is more learner friendly					
10	The first principle approach is too demanding					

APPENDIX C

TEST ITEMS ON LIMITING REAGENTS

DURATION: 90 minutes

INSTRUCTION: Answer all questions

1. Explain the term **limiting reagent** as it occurs in a chemical reaction.
2. Zinc and sulphur react to form zinc sulphide according to the equation:

   $Zn + S \longrightarrow ZnS$

   If 25.0 g of zinc and 30.0 g of sulphur are reacted,

   a) Which chemical is the limiting reactant?

   b) How many grams of ZnS will be formed?

   c) How many grams of the excess reactant will remain after the reaction is over?

   [Zn = 65.74, S= 32.065]

3. If 2.35 moles of H_2 gas react with 5.33 mol of N_2 gas to ammonia gas (NH_3) according to the equation, $3H_{2(g)} + N_{2}(g) \longrightarrow 2NH_{3(g)}$.

   a. Which chemical is the limiting reactant?

   b. How many moles of the excess reactant will remain after the reaction is over?

   c. How many grams of NH_3 can you make? [M (NH_3) = 17.04 g/mol^{-1}

4. Consider the reaction: $2Al + 3\ I_2 \longrightarrow 2AlI_3$

   Determine the limiting reagent if one starts with:

   a. 1.20moll Al and 2.40 mol iodine.

   b. 1.20 g Al and 2.40 g iodine [Al = 26.98 g mol^{-1}, I_2 = 253.8 $gmol^{-1}$]

5. 15.00 aluminum sulphide and 10.00 g water react until the limiting reagent is used up.

Here is the balance equation for the reaction: $Al_2S_3 + 6H_2O \longrightarrow 2Al(OH)_3 + 3H_2S$

a. Which is the limiting reagent?

b. What is the maximum mass of H_2S which can be formed from these reagents?

c. How much excess reagent remains after the reaction is complete?

[M (Al_2S_3) = 150 mol^{-1} , M(H_2O) = 18 g mol^{-1}, M(H_2S) = 34 g mol^{-1}]

6. If there is 35.0 grams of CH_{10} and 45.0 grams of O_2, how many grams of the excess

reagent will remain after the reaction ceases? $2C_6H_{10} + 17O_2 \longrightarrow 12CO_2 + 10H_2O$

[M (C_6H_{10}) = 82.145 g/ mol, M(O_2) = 31.998 g/ mol]

7. Based on the balanced equation: $C_4H_8 + 6O_2 \longrightarrow 4CO_2 + 4H_2O$;

a. Determine the limiting reactant and

b. Calculate the number of excess reagent units remaining when $28C_4H_8$ molecules and $228O_2$ molecules react?

8. For the combustion of sucrose: $C_{12}H_{22}O_{11} + 12O_2 \longrightarrow 12CO_2 + 11H_2O$ there are 10.0 g of

Sucrose and 10.0g of oxygen reacting.

a) Which is the limiting reagent?

[M($C_{12}H_{22}O_{11}$) = 342.2948g/mol, M(O_2) = 31.9988 g/mol]

9. The reaction of 4.25 g of Cl_2 with 2.20 g of P_4 produces 4.28 g of PCl_5.

What is the percent yield? Equation: $10Cl_2 + P_4 \longrightarrow 4PCl_5$

[M (Cl_2) = 70.906 g/ mol, M (P) = 123.896 g/mol, M (PCl_5.) = 208.239 g/mol]

10. How many grams of PF_5 can be formed from 9.46g of PF_3 and 9.42g of XeF_4 in the

following reaction? $2PF_3 + XeF_4 \longrightarrow 2PF_5 + Xe$

[M (PF_3) = 87.968 g/mol, M (XeF_4) = 207.282 g/mol, M (PF_5) = 125.964 g/mol]

APPENDIX D

MARKING SCHEME FOR THE TEST ITEMS

1. Limiting reagent is the reactant that is completely used up in a chemical reaction. [10marks]
2. Calculate the moles of Zn and S from their given masses.

Moles, n = m/ M

Mass of Zn, m = 25.0 g

Molar mass of Zn, M = 65.74 $gmol^{-1}$

Mass of S, m = 30.0 g

Molar mass of S, M = 32.065 $gmol^{-1}$.

∴Moles of Zn, n = 25.0 g/ 65.74 $gmol^{-1}$ = **0.380 mol**

Moles of S, n = 30.0g/ 32.065 $gmol^{-1}$ = **0.936 mol**

Balanced equation:	Zn	+	S	$\rightarrow$	ZnS
Mole ratio:	1	:	1	:	1
✓ If all Zn reacts:	0.38 mol	+	0.38 mol	$\rightarrow$	0.38 mol

a) The limiting reagent is Zn (because it was completely used up).

b) Moles of ZnS formed, n = 0.38 mol

Molar mass of ZnS, M = 65.74 + 32.065 = 97.805 $gmol^{-1}$

Mass of ZnS formed, m = 0.38 mol x 97.805 $gmol^{-1}$ = 37.1659 g

c) S is the reactant in excess.

Moles of S in excess = (0.936 - 0.38) = 0,556 mol

Mass, m = n x M

∴Mass of NH_3 formed, m = 1.57 mol x 17.04 $gmol^{-1}$ = 26.75g [10 marks]

3. Balanced equation: $3H_2 + N_2 \longrightarrow 2NH_3$

Mole ratio: 3 : 1 : 2

✓ If all H_2 reacts: 2.25 mol + 1/3 x 2.35 = 2/3 x 2.35

= 0.783 mol = 1.57 mol

a) The limiting reagent is H_2 (because it was completely used up).

b) N_2 is the reactant in excess.

Moles of N_2 that remain after the reaction is over = (5.33 - 0.783) = 4.547 mol

c) Moles of NH_3 produced, n = 1.57 mol

Molar mass of NH_3, M = 17.04 $gmol^{-1}$

Mass, m = nx M

.: Mass of NH_3 formed, m = 1.57 mol x 17.04$gmol^{-1}$ = 26.75g [10 marks]

4. Balanced equation: $2A1 + 3I_2 \longrightarrow 2A1I_3$

Mole ratio: 2 : 3 : 2

✓ If all Al reacts: 1.20 mol + $^3/_2$ x 1.20 $\longrightarrow$ 1.20 mol

= 1.80 mol

a) The limiting reagent is Al (because it was completely used up).

b) Calculate the moles of Al and I_2 from their given masses.

Moles, n = m/ M

Mass of Al, m = 1.20 g

Molar mass of AI, M = 26.98 $gmol^{-1}$

Mass of I_2, m = 2.40g

Molar mass of I_2, M = 253.8 $gmol^{-1}$

∴Moles of Al, n = 1.20g /26.98 $gmol^{-1}$ = 0.0445 mol

Moles of I_2, n = 2.40 g/ 253.8 $gmol^{-1}$ = 9.46 mol

Balanced equation: $2Al + 3I_2 \longrightarrow 2A1I_3$

Mole ratio: 2 : 3 : 2

If all Al reacts: 0.0445 mol + $^3/_2$ x 0.0445

= 0.0668 mol

The limiting reagent is Al (because it was completely used up). [10 marks]

5. Calculate the moles of Al_2S_3 and H_2O from their given masses.

Moles, n = m/ M

Mass of Al_2 S_3 M = 15.00 g

Molar mass of Al, S_3, M = 150 $gmol^{-1}$

Mass of H_2O, m = 10.00 g

Molar mass of H_2O, M = 18 $gmol^{-1}$

∴ Moles of Al_2S_3, n = 15.00 g/150 $gmol^{-1}$ = 0.100 mol

Moles of H_2O, n = 10.00 g/18 $gmol^{-1}$ = 0.556 mol

Balanced equation: Al_2S_3; + 6H2O $\longrightarrow$ 2Al $(OH)_3$ + $3H_2S$

Mole ratio: 1 : 6 : 2 : 3

x If all Al_2,S_3 reacts: 0.100 mol+ 6 x 0.100

= 0.600 mol

✓ If all H_2O reacts: $^1/_6$ x 0.556 + 0.556 mol $\longrightarrow$ $^2/_6$ x 0.556 + $^3/_6$ x 0.556

= 0.0927mol = 0.185 mol = 0.278mol

a) The limiting reagent is H_20 (because it was completely used up).

b) Moles of H_2S formed, n = 0.278 mol

Molar mass of H_2 S, M = 34 $gmol^{-1}$

Mass, m = nxM

.: Mass of H_2S which can be formed, m = 0.278 mol x 34 $gmol^{-1}$= 9.452 g

c) Al_2 S_3 is the reactant in excess.

Moles of Al_2 S_3 in excess = (0.100-0.0927) mol = 0.0073 mol [10 marks]

6. Calculate the moles of C_6 H_{10} and O_2 from their given masses.

.Moles, n = m/ M

Mass of $C_6H_{10,}$ m = 35.00 g

Molar mass of C_6H_{10}, M = 82.145 gmol $^{-1}$

Mass of O_2, m = 45.0 g

Molar mass of O_2, M = 31.998 $gmol^{-1}$

∴ Moles of $C_{10}H_{10}$, n = 35.0 g/ 82.145 $gmol^{-1}$ = 0.426 mol

Moles of O_2, n = 45.0 g/ 31.998 $gmol^{-1}$ = 1.406 mol

Balanced equation: $2C_6H_{10}$ + 170_2 $\longrightarrow$ $12CO_2$ + $10H_2O$

Mole ratio: 2 17 $\longrightarrow$ 12 + 10

If all $C6H_{10}$ reacts: 0.426mol + $^{17}/_2$ x 0.426

= 3.621 mol

✓ If all O_2 reacts: $^2/_{17}$ x 1.406 + 1.406 mol

= 0.164 mol

∴O_2 is the limiting reagent and C_6H_{10} is the reagent in excess.

Moles of C_6H_{10} in excess, n = (0.426 -0.164) mol = 0.262 mol

Mass, m = n x M

.. Mass of C_6H_{10} in excess, m = 0.262 mol x 82.145 $gmol^{-1}$ = 21.52 g (4 sig. fig.)

[10 marks]

7. Number of entities is proportional to moles since N = nx L.

Balanced equation: $C_4H_8 + 6O_2 \longrightarrow 4CO_2 + 4H_2O$

Mole ratio: 1 : 6 : 4 : 4

✓ If all C4H8

Molecules reacts: 28 molecules + 6 x 28 = 168 molecules

a) The limiting reagent is C4H8 since all the molecules are used up.

b) O_2 is the reactant in excess.

Molecules of O_2 remaining at the end of the reaction: = (228 - 168) molecules= 60 molecules

[10 marks]

8. Calculate the moles of $C_{12}H_{22}O_{11}$ and O_2 from their given masses.

Moles, n = m/ M

Mass of sucrose (C12H22011), m = 10.0 g

Molar mass of $C_{12}H_{22}O_{11}$, M = 342.2948 $gmol^{-1}$

Mass of O_2, m = 10.0 g

Molar mass of O_2, M = 31.9988 $gmol^{-1}$

∴ Moles of $C_2H_{22}11$, n = 10.0 g/ 342.2948 $gmol^{-1}$ = 0.0292 mol

Moles of O_2, n = 10.0 g/ 31.9988 $gmol^{-1}$ = 0.313 mol

Balanced equation: $C_{12}H_{22}O_{11} + 12H_2O \longrightarrow 12CO_2 + 11H_2O$

Mole ratio: 1 : 12 : 12 11

If all $C_{12}H_{22}O_{11}$ reacts: 0.0292mol + 12 x 0.0292

= 0.3504 mol

∴ O_2 is the limiting reagent because it was completely used up in the reaction. [10 marks]

9. Calculate the moles of Cl_2, and P_4 from their given masses.

Moles, n = m/ M

Mass of Cl_2, m = 4.25 g

Molar mass of Cl_2, M = 70.906 $gmol^{-1}$

Mass of P_4, m = 2.20 g

Molar mass of P_4, M = 123.896 $gmol^{-1}$

∴Moles of Cl_2, n = 4.25 g/ 70.906 $gmol^{-1}$ = 0.0599 mol

Moles of P_4, n = 2.20 g/ 123.896 $gmol^{-1}$ = 0.01776 mol

Balanced equation: $10C1_2 + P_4 \longrightarrow 4PCI_5$

Mole ratio: 10 : 1 : 4

✓ If all Cl_2 reacts: 0.0599mol + 10 x 0.0599 → 4/10 X 0.0599

= 0.00599 mol = 0.02396 mol

∴ Cl_2 is the limiting reagent since it is completely used up and the amount of PCl_5 produced is dependent on the limiting reagent.

Mass, m = n x M

∴Mass of theoretical yield of PCl_5, m = 0.02396 mol x 208.239 $gmol^{-1}$

= 4.99 g (3 sig. fig.)

Actual yield of $PC1_5$ = 4.28 g

% yield $= \frac{actual\ yield}{theoritical\ yield}$x 100 = 4.28 g/ 4.99 g x 100 = 85.8 %[10 marks]

10. Calculate the moles of PF_3 and XeF_4 from their given masses.

Moles, n = m/ M

Mass of PF_3, m = 9.46 g

Molar mass of PF3, M = 87.968 $gmol^{-1}$

Mass of XeF_4, m = 9.42 g

Molar mass of XeF_4, M = 207.282 $gmol^{-1}$

∴Moles of PF_3, n = 9.46 g/ 87.968 $gmol^{-1}$ = 0.108 mol

Moles of XeF_4, n = 9.42 g/ 207.282 $gmol^{-1}$ = 0.0454 mol

Balanced equation: $2PF_3 + XeF_4 \rightarrow 2PF_5 + Xe$

Mole ratio: 2 : 1 : 2 : 1

x If all PF_3 reacts: 0.108mol + ½ x 0.108

= 0.054 mol

✓ If all XeF_4 reacts: 2 x 0.0454 + 0.0454 mol $\longrightarrow$ 2 x 0.0454 + 0.0454mol

= 0.0908 mol = 0.0908 mol

∴XeF_4 is the limiting reactant and the amount of PFs formed is dependent on the

limiting reactant

Moles of PF_5 formed, n = 0.0908 mol

Molar mass of PF_5, M = 125.964 $gmol^{-1}$

Mass, m = nx M

∴Mass of PF_5 formed, m = 0.0908 mol x 125.964 $gmol^{-1}$ 11.44 g (4 sig. fig.)

APPENDIX E

TREATMENT ACTIVITIES

1. Explaining the term "limiting reactants".

Suppose we carry out a reaction by using numbers of moles of reactants that are in the same ratio as the stoichiometric coefficients in the balanced equation. In this case, we say that the reactants are in **stoichiometric proportions**, and we find that if the reaction goes to completion, the initial reactants are fully consumed. In practice, however, we often carry out reactions with a **limited** amount of one reactant and plentiful amounts of others.

The reactant that is completely consumed in a chemical reaction limits the amount of products formed and is called the **limiting reactant or limiting reagent.** (Reagent is a general term for a chemical). Illustration example:

In the combustion of octane in oxygen shown as;

$$2C_8H_{18\,(1)} \quad + \quad 25O_{2(g)} \rightarrow 16CO_{2\,(g)} \quad + \quad 18H_2O_{(l)}$$

If we allow 2 moles C_8H_{18} to react with 25 moles O_2, the reactants are in stoichiometric proportions. On the other hand, if we allow the 2 moles C_8H_{18} to burn in a plentiful supply of O_2 gas-more than 25 moles-then the C_8H_{18} is the **limiting reactant.**

The octane is completely consumed and some unreacted O_2 remains; the O_2 is a reactant present in excess.

3. Using the first principle reaction. Illustration examples approach: to deduce the limiting reactant in a chemical

a) Lithium hydroxide absorbs carbon dioxide to form lithium carbonate and water as shown below:

$$2LiOH + CO_2 \longrightarrow Li_2CO_3 + H_2O$$

If a reaction vessel contains 0.150 mol LiOH and 0.080 mol CO_2,

i. which compound is the limiting reactant?

ii. How many moles of Li_2CO_3 can be produced?

<u>Solution</u>

i. Balanced equation: $2LiOH + CO_2 \longrightarrow Li_2CO_3 + H_2O$

Mole ratio: 2 : 1 : 1 : 1

To identify the limiting reactant, we make an assumption that;

Assuming that all the LiOH reacts:

$\rightarrow$ 0.150mol LiOH + $^1/_2$ x 0.150mol CO_2 $\rightarrow$ 2 x 0.150mol $LiCO_3$ + $^1/_2$ x 0.150mol H_2O

0.150mol LiOH + 0.075 mol CO_2 $\rightarrow$ 0.075 mol $LiCO_3$ + 0.075 mol H_2O

Since the 0.075 mol of CO_2 required if all LiOH reacts is less than the 0.080 mol of CO_2 available, the LiOH is the limiting reactant and the CO_2 is the reactant in excess.

ii. The amount of product produced is always dependent on the limiting reactant.

Therefore, 0.075 mol of Li_2CO_3 is produced in this reaction.

b) Boron trifluoride and (BF_3) reacts with water to produce boric acid (H_3BO_3) fluoroboric acid (HBF_4) according to the equation:

$4BF_3 + 3H_2O \rightarrow HBO_3 + 3HBF_4$

If a reaction vessel contains 0.496 mol BF; and 0.313 mol H_20,

i. Which compound is the limiting reactant?

ii. For the reactant in excess, how many moles are left over at the end of the reaction?

iii. How many moles of HBF_4 can be produced?

Solution

Balanced equation: $4BF_3 + 3H_20 \rightarrow H_3BO_3 + 3HBF_4$.

Mole ratio: 4 : 3 : 1 + 3

x If all BF_3 reacts: 0.496mol + 4 x 0.496

0.3/2 moi

This is not possible because the 0.372 mol of H_2O required if all BF_3 reacts is not available.

✓ If all H20 reacts: $^4/_3$ x 0.313 + 0.313 mol $\rightarrow$ $^1/_3$ x 0.313 + 0.313nol

= 0.417 mol = 0.104 mol

i. H_2O is the limiting reactant because it was completely used up in the reaction and limited the amounts of products formed.

ii. BF_3 is the reactant in excess.

Moles of BF_3 left at the end of the reaction = (0.496 - 0.419) mol = 0.077 mol

iii. Moles of HBF_4 produced = 0.313 mol

3. Exercise

a) Magnesium nitride metal (Mg_3N_2) can be formed by the reaction of magnesium (Mg) with nitrogen gas (N_2) according to the equation:

$$3Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_2\,(s)$$

i. If 35.0 g of magnesium reacted with 15.0 g of nitrogen, what is the limiting reactant?

ii. How many moles of the excess reactant remain after the reaction?

iii. How many grams of magnesium nitride is formed at the end of the reaction?

[Mr (Mg) = 24.305, Mr (N_2) = 28.013, Mr (Mg_3N_2) = 100.93]

<u>Solution</u>

Calculate the moles of Mg and N_2 from their given masses.

Moles, n = m/ M

Mass of Mg, m = 35.0 g

Molar mass of Mg, M = 24.305 $gmol^{-1}$

Mass of N_2, m = 15.0 g

Molar mass of N_2, M = 28.013 $gmol^{-1}$

... Moles of Mg, n = 35.0 g/ 24.013 $gmol^{-1}$ = 1.44 mol

Moles of N_2, n = 15.0 g/28.013 $gmol^{-1}$ = 0.535 mol

Balanced equation: $3Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_{2(s)}$

Mole ratio: 3 + 1 : 1

✓ If all Mg reacts: 1.44 mol + 1/3 x 1.44 → $^1/_3$ x 1.44

= 0.48 mol = 0.48 mol

i. Mg is the limiting reactant because it was completely used up in the reaction.

ii. N_2 is the reactant in excess because the 0.535 mol available is more than the 0.48 mol

required if all the Mg reacts.

Moles of N_2 that remain after the reaction: (0.535 - 0.48) mol = 0.055 mol

Molar mass of N_2, M = 28.013 $gmol^{-1}$

Mass, m = nx M

∴ Mass of N_2 that remain after the reaction = 0.055 mol x 28.013 gmol

= 1.541 g

iii. Mol of Mg_3N_2 produced, n = 0.48 mol

Molar mass of Mg_3N_2, M = 100.93 $gmol^{-1}$

Mass, m = n x M

∴Mass of Mg_3N_2 produced, m = 0.48 mol x 100.93 $gmol^{-1}$ = 48.45g