STUDENTS' ALGEBRAIC SKILLS IN CALCULATING REACTING MASSES IN CHEMICAL EQUATIONS: A CASE OF PUBLIC SECONDARY SCHOOLS IN NYANDARUA COUNTY, KENYA

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E55/CE/21915/2012

A THESIS SUBMITTED TO THE SCHOOL OF EDUCATION IN PARTIAL FULFIMENT FOR THE AWARD OF THE DEGREE OF MASTER OF EDUCATION OF KENYATTA UNIVERSITY
DECLARATION

I declare that this thesis is my original work and has not been presented in any other university for consideration of any certification. This thesis has been complemented by referenced sources duly acknowledged. Where text, data (including spoken words), graphics, pictures or tables have been borrowed from other sources, including the internet, these are specifically accredited and references cited using current APA system and in accordance with anti-plagiarism regulations.

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Signature........................................ Date..............................

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DEDICATION

This thesis is dedicated to my family for their support, love, care, concern, encouragement and enthusiasm which inspired me to achieve the goal of this study.
ACKNOWLEDGEMENT

First, I thank God for good health and for helping me accomplish this study. I extend my gratitude to my supervisors, Dr. Waweru Gichuhi and Dr. Khatete, David for their encouragement, patience, guidance and technical advice in the process of writing this thesis. I recognize the support, care and encouragement from my family members, classmates and friends.

God bless you abundantly.
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>CAT</td>
<td>Chemistry Achievement Test</td>
</tr>
<tr>
<td>DEO</td>
<td>District Education Officer</td>
</tr>
<tr>
<td>HAHC</td>
<td>High performance on Algorithmic problems, High performance on Conceptual questions</td>
</tr>
<tr>
<td>INSET</td>
<td>In - Service Education and Training</td>
</tr>
<tr>
<td>JICA</td>
<td>Japan International Cooperation Agency</td>
</tr>
<tr>
<td>KCSE</td>
<td>Kenya Certificate of Secondary Education</td>
</tr>
<tr>
<td>KNEC</td>
<td>Kenya National Examinations Council</td>
</tr>
<tr>
<td>MAT</td>
<td>Mathematics Achievement Test</td>
</tr>
<tr>
<td>MOEST</td>
<td>Ministry of Education Science and Technology</td>
</tr>
<tr>
<td>NPE</td>
<td>National Policy on Education</td>
</tr>
<tr>
<td>SSCE</td>
<td>Senior School Certificate Examination</td>
</tr>
<tr>
<td>SMASSE</td>
<td>Strengthening Mathematics and Sciences in Secondary Education</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
</tr>
<tr>
<td>WAEC</td>
<td>West African Examinations Council</td>
</tr>
</tbody>
</table>
ABSTRACT

The performance of students in chemistry at the KCSE level has for many years remained a matter of national concern. The purpose of this study was to investigate relationship between secondary school students' algebraic skills and their competencies in calculating reacting masses from chemical equations (in the mole concept). Specific objectives that guided the study were to: establish mastery of the students’ algebraic skills involving ratios and proportions; determine relationship between students’ algebraic skills and competencies in calculating reacting masses in the mole concept; investigate gender difference in using algebraic skills to calculate reacting masses in the mole concept and; investigate effect of enhanced program of Ratio and Proportion (RAP) on students’ competencies in calculating reacting masses in chemical equations. The study employed quasi-experimental research design where a mathematics test and chemistry pre-test were administered. Chemistry post-test was administered after experimental group was taken through enhanced program of RAP. The study found out that the students’ mastery of algebraic skills was strong for those in county schools but weak for those in sub county schools. Besides, the study established that mastery of algebraic skills is positively correlated to success in calculating reacting masses in the mole concept. In addition, the study established that there is no significant difference between boys’ and girls’ ability in calculating reacting masses in the mole concept. Finally, the study established that enhance program of RAP improved students’ competencies in calculating reacting masses in the mole concept. The implications of these findings is that students of chemistry, both boys and girls can improve their competencies in calculating reacting masses in the mole concept, and as a result their performance in chemistry if the enhanced program of RAP is emphasized in their learning.
CHAPTER ONE

INTRODUCTION

1.0 Introduction

This study investigated relationship between secondary school students' algebraic skills and their competencies in calculating reacting masses from chemical equations (in the mole concept). Calculating reacting masses in chemical equations is one of the content areas in stoichiometry, which generally involves calculation of relative quantities of reactants and products in chemical reactions. The relations among quantities of reactants and products in stoichiometry form a ratio of positive integers. The ability to understand and use algebraic skills, and particularly ratios and proportional reasoning is therefore fundamental in stoichiometry (Koch, 1995) and in the general chemistry. This chapter provides background of the study, statement of the problem, purpose, objectives of and research questions. The chapter farther outlines the significance of the study, scope, limitations and delimitations, and assumptions. It ends with an explanation of theoretical and conceptual frameworks for the study and definitions of key terms in the study.

1.1 Background to the Study

Calculating reacting masses in chemical equations is an important part of student learning in chemistry, and in particular the mole concept. Calculations in stoichiometry revolve around the mole concept (Musa, 2009). Many studies concerned with mathematical application of the mole concept have found that, students have misconceptions and make errors and in particular students do experience a lot of difficulties in calculating the reacting masses (Schmidt, 1997; Boujaoude & Barakat, 2000; Gauchon & Meheut, 2007; and Omwirhiren, 2015). A major factor contributing to these challenges is the limited proficiency in the use of algebraic skills.
of proportions, ratios and percentages (Bucat & Fensham, 1995), and this tends to more pronounced in girls than in boys (Eriba & Ande, 2006). Algebraic skills in general covers majority of applications necessary to learn chemistry and thus a student who has acquired these skills will have a higher ability in working out (Olayemi, 2009) and describing quantitative relationships among reactants and products in chemical equations in the mole concept. The difficulties in application of mathematical skills in learning chemistry are observed in a wide range of nations as illustrated with a few of them below.

In United States there are a considerable number of students who have the conceptual ability to study chemistry yet are not successful problem solvers in the chemistry (Nakhleh, 1993). That means they lack the mathematical-chemistry skills to solve problem though they are successful conceptual thinkers. Tobias, cited in Nakhleh farther observes that the students have problems using formulas, a challenge that relates to inadequate competence in algebra. Gabel and Sherwood (1984) also found that problems requiring two steps are harder than those requiring one step; problems involving scientific notation are more difficult than those that do not; problems involving the multiplication concept are easier than those involving the division concept. In a nutshell, Gabel (2008) explains that students’ lack of understanding of basic mathematical principles is a real impediment to solving mole problems correctly using reasoning methods.

Besides, in Spain, Furio, Azcona and Guisasola (2002) explained that students have great difficulty in handling the concept of mole concept; and in resolution of exercises when stoichiometric proportion in a reaction was not 1:1. Furthermore, students have great difficulties in calculating new concentrations when diluting aqueous solution of a substance (Duncan &
Among the various learning difficulties was mathematical (ability in algebra) anxiety which led to rote use of algorithms and rules, and this difficulties was connected to the students’ deficiencies in calculation of reacting masses in chemical equations.

In addition, students in Greece were also said to have challenges in solving questions on reacting masses (Papaphotis & Tsaparlis, 2008). Papaphotis and Tsaparlis farther averred that errors in solving problems involving mole concepts often occur directly or inadvertently ranging from written to oral and even computational.

Moreover, in Nigeria, Omwirhiren (2015) noted that the mole concept is pervasive in all aspects of quantitative chemistry and it poses a lot of challenges to the learners. Omwirhiren farther observed that computing reacting masses in chemical equation in the mole concept is an area that very few students like and succeed at. Ahiakwo (2015) concurred with Omwirhiren and observed that students in Nigeria generally perform poorly in chemical calculation. Omwirhiren explained that the areas that contributed to students’ failure in calculating reacting masses include inconsistency between the instructional approaches of the textbook and teacher and confusing mole concept vocabulary. In addition, Omwirhiren found that most students hate and struggle with chemical calculations because of their phobia for mathematics (mathematical anxiety), inadequate ability in proportional reasoning and lack of practice in problem-solving.

In Kenya, students’ achievement in chemistry has been low over the years (Wachanga & Mwangi, 2004), and this is partly so because of inadequate proficiency in stoichiometry, in the mole concept (Twoli, Akala & Khatete, 2015). Table 1.1 gives mean scores (out of 12) to illustrates the students’ low performance in Kenya Certificate of Secondary Education (KCSE)
chemistry at the national level and at the Kinangop Sub-County level for the years 2008 to 2015.

**Table 1.1: National and Kinangop Sub-County Students’ Mean score in KCSE Chemistry**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Kinangop Sub County Mean Score</th>
<th>National Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>3.874</td>
<td>3.7735</td>
</tr>
<tr>
<td>2009</td>
<td>3.526</td>
<td>3.4281</td>
</tr>
<tr>
<td>2010</td>
<td>3.632</td>
<td>3.5437</td>
</tr>
<tr>
<td>2011</td>
<td>3.525</td>
<td>3.5253</td>
</tr>
<tr>
<td>2012</td>
<td>3.387</td>
<td>4.3952</td>
</tr>
<tr>
<td>2013</td>
<td>3.976</td>
<td>3.5678</td>
</tr>
<tr>
<td>2014</td>
<td>4.545</td>
<td>4.4400</td>
</tr>
<tr>
<td>2015</td>
<td>3.981</td>
<td>4.9211</td>
</tr>
</tbody>
</table>


From Table 1.1, it is evident that for the period of 2008 to 2015, Kinangop Sub-County chemistry KCSE mean score was equally below average of the scale though slightly higher than the national averages for the same period. Ogembo (2012) attributes the students’ poor achievement in chemistry to a number of factors including student’s attitude towards chemistry, teacher’s attitude, availability and use of resources, poor learning environment, and poor method of instruction. Figure 1.1 illustrates the trends at both the National and Kinangop Sub-county levels.
It is clear from Fig 1.1 that the KCSE chemistry mean-scale scores at National and Kinangop Sub-county levels were about the same. However, for both levels the score are far below the half-way mark in the scale of 1 to 12. Generally then, performance in KCSE chemistry may be considered poor. The status of the poor performance in the subject is made clearer by the pattern of mean mark data for the three KCSE chemistry papers over the years 2009 to 2012, shown in Table 1.2.
Table 1.2: Students achievement in KCSE Chemistry Papers at National Level for the years 2009 to 2012

<table>
<thead>
<tr>
<th>Year</th>
<th>Paper</th>
<th>Candidature</th>
<th>Maximum mark</th>
<th>Mean mark</th>
<th>Percentage Mean Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>233/1</td>
<td></td>
<td>80</td>
<td>12.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/2</td>
<td></td>
<td>80</td>
<td>14.93</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/3</td>
<td></td>
<td>40</td>
<td>10.86</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>329,730</td>
<td>200</td>
<td>38.23</td>
<td>19.13</td>
</tr>
<tr>
<td>2010</td>
<td>233/1</td>
<td></td>
<td>80</td>
<td>18.78</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/2</td>
<td></td>
<td>80</td>
<td>16.19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/3</td>
<td></td>
<td>40</td>
<td>14.87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>347364</td>
<td>200</td>
<td>49.79</td>
<td>24.90</td>
</tr>
<tr>
<td>2011</td>
<td>233/1</td>
<td></td>
<td>80</td>
<td>18.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/2</td>
<td></td>
<td>80</td>
<td>16.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/3</td>
<td></td>
<td>40</td>
<td>11.91</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>403 070</td>
<td>200</td>
<td>47.31</td>
<td>23.66</td>
</tr>
<tr>
<td>2012</td>
<td>233/1</td>
<td></td>
<td>80</td>
<td>22.36</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/2</td>
<td></td>
<td>80</td>
<td>17.18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>233/3</td>
<td></td>
<td>40</td>
<td>16.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>427,386</td>
<td>200</td>
<td>55.86</td>
<td>27.93</td>
</tr>
</tbody>
</table>

Source: KNEC-2012 KCSE examination report

In Table 1.2, the overall mean mark for the three papers is out of 200 marks, with the highest being 55.86 in the year 2012 and the lowest being 38.23 in the year 2009. As a percentage, the mean marks in all the years were below 30% thus showing that chemistry registers poor performance. It is clear from Table 1.2 that students’ performance in chemistry has been generally low, below 30%. Figure 1.2 illustrates the trend in the performance.
Figure 1.2 shows a pattern of increasing percentage mean-mark, however, however, it is below 30%. Chemistry needs a good knowledge of basic mathematics and generally involves a lot of computation which makes mathematics an important aspect of it (West African Examinations Council (WAEC), 2006). According to Badru (2004), the understanding of mathematical concepts improves student problem-solving abilities and develops a positive attitude towards chemistry. Bayliss and Watts (2002) contend that mathematics is necessary in enabling chemistry students to draw useful conclusion about compositions, yield and energy, balances in reacting systems and other chemistry concepts that requires computation and calculations. Iweka (2010) identified some mathematics content which is applied in various chemistry calculations that include: algebra, decimals, equations, exponents, fractions, graphs, percentages, ratio and proportion, and signed numbers. Table 1.3 shows areas of chemistry where some these mathematics contents are applied.
Table 1.3: Areas in mathematics that are applied in chemistry

<table>
<thead>
<tr>
<th>Mathematics</th>
<th>Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratios</td>
<td>Mixing solutions with certain molarities, making dilutions, determining reacting ratios</td>
</tr>
<tr>
<td>Proportional reasoning</td>
<td>Analysis of molecular structure, moles</td>
</tr>
<tr>
<td>Algebra and graphs</td>
<td>Analysis of experimental plots of reaction rates; gas laws, solubility and solubility curves</td>
</tr>
</tbody>
</table>

Source: Kurumeh (2006)

Kurumeh (2006) points out significant differences in the performance of students of different mathematics ability levels in science. The Table 1.3 shows some of the areas of mathematics and their application in chemistry. It is imperative that enhanced performance in chemistry would be fostered by good knowledge of mathematics.

1.2 Statement of the Problem

According to KNEC (2001) report, the poor performance in chemistry was as a result of student's lack of basic mathematics concepts necessary for proper understanding of chemistry. Although schools have undertaken different measures to improve scores in mathematics and sciences, the challenge, however, is the application of mathematics as a foundation of science subjects such as chemistry. This situation poses a challenge owing to different students’ algebraic computation ability in chemistry subject. Researches in Kenya have place more emphasis on students performance in sciences, however, there has not been one focusing on student’s use of computational abilities in ratios and proportions in calculating reacting masses from chemical equations.
1.3 Purpose of the Study

The purpose of this study was to investigate the relationship between students' algebraic skills and their competencies in calculating reacting masses in chemical equations in public secondary schools in Kinangop Sub-County, Nyandarua, Kenya.

1.4 Research Objectives

The research was guided by the following objectives:

a. To establish students’ mastery of algebraic skills involving ratios and proportions in secondary schools.

b. To establish the impact of RAP on learners ability to calculate reacting masses in the mole concept.

c. To investigate the relationship between students’ algebraic ability involving ratios and proportions and student's ability to calculate reacting masses in the mole concept.

d. To investigate effect of enhanced program of Ratio and Proportion (RAP) on competencies in calculating reacting masses in chemical equations

e. To investigate gender differences in the use of algebraic skills in calculating reacting masses from chemical equations.

1.5 Research Hypotheses

The study was based on Null hypotheses as follows:

$H_{01}$: There is no significant difference between students’ algebraic ability and their competence in calculating reacting masses in chemical equations;
HO2: There is no significant difference between abilities of students trained through enhanced program of RAP and those not trained through the program in calculating reacting masses in chemical equations;

HO3: There is no significant difference between boys’ and girls’ abilities in calculating reacting masses from chemical equations.

1.6 Significance of the Study
This study found that the mean score of students in algebra test was generally above the overall mean for KCSE mathematics at the national level. It was at 40.5 while overall mean at the national level was 28.4. However, students at the county schools scored a mean of 61.6, outperforming those at the sub-county schools who scored a mean of 15.8. Further, the study found that high achievers in the algebra test had also a high score in the chemistry tests. In addition, the study found that using enhanced teaching program ratios and proportions significantly impacted positively on the students’ ability to calculate reacting masses in chemical equations. Finally, the study found that there is no difference between the ability of boys’ and girls’ in calculating reacting masses in chemical equations.

These finding are significant to teachers of chemistry because of the role played by students’ strong mastery of algebra in calculating reacting masses. Teachers would be better placed to evaluate teaching methodologies in Chemistry, based in part on evidence about their students' learning, and mastery in calculating reacting masses from chemical equations, which has an effect on general school performance in Chemistry.
The findings are significant to chemistry teacher educators and researchers. This is because the findings do strengthen the fact that mathematics' algebraic knowledge is necessary to chemistry's reacting masses computational achievement. Besides none of the researches in chemistry performance in the past has delved into the student’s computational skills in ratios and proportions in Kenya’s secondary schools.

Based on the findings of this study, Education policy makers may be able to put programs and systems to enhance teachers’ pedagogical competencies so as to benefit student performance in Chemistry. Besides, the findings of this study may inform curriculum developers to develop indicators that will inform chemistry classroom practices and corresponding performance in the chemistry.

1.7 Scope of the Study
The study was carried out in selected public secondary schools in Kinangop Sub County, Nyandarua County, Kenya. The study focused on investigating the effect of enhanced teaching program in ratios and proportions on students’ ability in calculating reacting masses in chemical equations. Moreover, the study targeted Form Three students.

1.8 Limitations and Delimitations of the Study

1.8.1 Limitations of the Study
The description of Problem Solving Approach (RAP) and traditional approach method and investigating computational ability in calculating reacting masses in chemical equations is technically challenging for a large sample. The fact that the group of subjects is insignificant in relation to the number of schools in the entire Nyandarua County, the researcher cannot extrapolate the results to the entire County schools population. The results of this study may not
be applicable to other schools and regions due to varying socio-economic differences. Nevertheless, this research is just the first step in a broader research aimed at highlighting the connection between Mathematics and Chemistry.

1.8.2 Delimitations of the Study
The study was carried out among Form Three students in government schools. The study only covered computational abilities in ratios and proportions and reacting masses; a sub topic in the mole in chemistry.

1.9 Assumptions of the Study
The following assumptions were made in the study:- The students had on the average comparable understanding capacity and within the specified time they were able to get the concepts of the topics being covered. The students that were selected for the study had covered the algebraic concepts in mathematics effectively together with the chemistry content on reacting masses within the period specified for the training program. The study groups were assumed to be of similar learning backgrounds and that any learning outcome was as a result of the classroom experiences and interactions. The study assumes that teacher attitude and mathematics and chemistry instructional materials did not vary during the time of the study and therefore have no effect on any changes in students’ ability in calculating reacting masses in chemical equations.

1.10 Theoretical Framework
The study was grounded on the Transfer of learning theory by Thorndike and Woodworth (1901). Transfer of learning theory states that the extent to which information learned in one situation will transfer to another is determined by the similarity of the two situations; the more
similar the situations the more likely the transfer. Identical elements must be present in both the source and task situations for transfer to occur (Lobato, 2006). Generally speaking transfer of learning is a process in which knowledge constructing in one particular context or situation (source task) is used in a different context or situation (target task) after being called up, amalgamated and or adapted (Bossard, Kermarrec, Buche, & Tisseau, 2008).

Transfer of learning theory has four tenets which include:

- **Cumulative learning** is characterized by being isolated information something new that is not a part of anything else. This type of learning occurs when one has to learn something with no context or meaning or personal importance. Often it occurs in early years of learning or in special situations where one has not interacted with prior context.

- **Assimilative learning** is characterized by addition. The new element is linked as an addition to a scheme that has already been established. Such learning is relatively easy to recall and apply when one is mentally oriented towards a context in question (most common form of learning).

- **Accommodative Learning** is characterized by the breakdown of parts of an existing schema and then reconstruction in such a way that it allows the new situation or information to be linked in. (Experienced when something takes place that is difficult to immediately relate to any existing schema but becomes experienced as something deeply internalized).

- **Transformative Learning** is characterized by simultaneously restructuring several schemes including emotional and social patterns. This is experienced as profound and extensive and typically occurs in a crisis like situation (Lobato, 2006)
Processes and transfer of learning are important to understanding how different people develop important competencies especially in learning. Since learning is basically acquired as known concepts are used to comprehend the unknown, it is important to understand the kind of learning experiences that leads to transfer. Thorndike (1913), for example, hypothesized that the degree of transfer between initial and later learning depends upon the match between elements across the two events.

In his analysis, Lave (2008) argues that the essential elements in transfer of learning were presumed to be specific facts and skills. Importantly to note is that transfer is affected by the context of original learning. However, this theory implies that transfer of learning depends on the proportion to which the learning task and the transfer task are similar, or where “identical elements are concerned in the influencing and influenced function” (Illeris, 2009). Therefore, how tightly learning is tied to contexts depend on how the knowledge is acquired, as supported by Calais (2006). This theory is thus relevant to this study in informing how knowledge of skills and procedures in algebraic computation can affect the academic attainment of students in calculating reacting masses from chemical equations.

The behaviorists explained transfer without referring to mental processes. The learner was viewed as adapting to environments and learning was essentially a passive process. The problem that scholars faced, stemming back to Thorndike’s work, was that “similarity in stimulus conditions between training and transfer situations rarely promoted far-reaching transfer” (Cox, 1997). Identifying significant transfer was proving to be a challenge. Several researchers have reported little or not transfer in their experiments and observations (Reed, Ernst & Banerji, 1974; Hays & Simon 2007; and Illeris, 2009). Detterman (1993) is often quoted as saying "the lesson
learned from studies of transfer is that if you want people to learn something, teach it to them. Don’t teach them something else and expect them to figure out what you really want them to do.” To the behaviourist’s work being conducted in laboratory settings (Campione, Shapiro & Brown, 1995), have attributed failure of transfer.

While Campione et al. (1995), give recognition to the contributions of the laboratory research, they contended that the labs are not natural settings. They contended that classroom research offers a more rich and complex environment in which to explore the concepts of transfer. Lave (2008) suggested that the root of the transfer problem was that knowledge cannot be divorced from context and was against the idea of transfer because knowledge and skills are context bound. Consequently, Brown and Duguid (2009) also claimed that knowledge is tied to sociocultural contexts and therefore only near transfer can be achieved.

Campione et al., (1995) extended the concept of transfer by defining transfer as understanding, that is, learners gain understanding from their context by constructing relationships between situations so the context is a self-constructed relationship not the setting. This facilitates transfer because learners, through understanding, are then able to explain their knowledge and processes, pushing the concept of transfer into the realm of meta-cognition. However, Calais (2006) adds that knowledge base plays a central role in our cognitive processes. Researchers have demonstrated that the absence of an appropriate knowledge base, not developmental stage, is responsible for younger children’s failure to transfer (Calais, 2006).

The goal of education is to provide learning experiences that are useful beyond the specific conditions of initial learning. For example the design of innovative curricular materials and pedagogical approaches is often aimed at helping students develop robust understandings that
will generalize to decision making and problem solving in other situations both in and outside of the classroom” (Lobato, 2006). Therefore, the theory is relevant and provides strategies that teachers can use to create innovative classroom approaches to facilitate collaborative learning environments that promote students' algebraic skills in calculating reacting masses in chemical equations.

1.11 Conceptual Framework

The conceptual framework for the study explores the relationship between the study variables (independent and dependent variables, and also the intervening variables as presented in Figure 1.3.

**Source:** Adopted from UNESCO (2005)

**Figure 1.3: The Conceptual Framework**
### 1.12 Definition of Key Operational Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Achievement</strong></td>
<td>The realization of scores in achievement tests. In this study, it refers to student attainment scores in both Chemistry and Mathematics Assessment Tests.</td>
</tr>
<tr>
<td><strong>Algebra</strong></td>
<td>A branch of mathematics which borrows widely the use of basic operations including but not limited to addition, multiplication, division and subtraction.</td>
</tr>
<tr>
<td><strong>Conceptual mapping</strong></td>
<td>The aspect of scientific concepts being related and spiral.</td>
</tr>
<tr>
<td><strong>Computation</strong></td>
<td>The ability of a learner to work out or provide an accurate answer to a given problem.</td>
</tr>
<tr>
<td><strong>Examination malpractice</strong></td>
<td>The act of a student presenting some piece of work/assignment in written form (for this study) that is not genuine his or her measure of ability through coping or collusion.</td>
</tr>
<tr>
<td><strong>Enhanced study program</strong></td>
<td>Chemistry and Mathematics study program that promote self-learning and help students develop critical thinking skills and retain knowledge that leads to self-actualization; involves an integrated approach to teaching that blends the chemistry and Math's teachers’ interests with students’ needs and curriculum appropriate methods, to measure student learning through both formal and informal forms of assessment, like group projects, and class participation.</td>
</tr>
<tr>
<td><strong>Mole</strong></td>
<td>A unit of measurement that refers to any amount of a substance that contains Avogadro's number of particles (6.023 x 10^{23})</td>
</tr>
</tbody>
</table>
particles). It’s also one of the topics in Form Three Chemistry syllabus.

**pH:** A measure of acidity.

**Problem-solving:** Students ability to use mathematical skills creatively in calculating reacting masses in chemical equations. It also entails how far students apply mathematical ideas by actively engaging in solving a variety of rich mole concept problems.

**Reacting masses:** The ratio of a reactant to a product for a reaction can be calculated from the chemical equation using the relative formula masses. It is then possible to work out the mass produced by any mass of reactant.

**SMASSE program:** A Strengthening of Mathematics and Sciences in Secondary Education Program which was initiated by the MOEST with assistance of JICA for Secondary School Science and Mathematics teachers.

**Traditional teaching methods:** Refers to traditional teacher-centered methods focused on memorization; it makes it difficult for students to understand the study materials, students receive information unilaterally and without using means of concrete and creative illustration.
CHAPTER TWO

REVIEW OF LITERATURE

2.1. Introduction

This chapter represents a summary of review of literature on the role of mathematics in chemistry, mathematics ability and academic performance of students’ in chemistry, performance of students classified by mathematics ability and gender differences in achievement in calculating reacting masses from chemical equations.

2.2 The Role of Mathematics in Chemistry

Mathematics is widely used in the learning of chemistry as well as in all other sciences subjects. There is no science subject where at least elementary knowledge of mathematics is not required. According to Bayram (2014), Mathematics is used in every part of life, and Mathematical calculations are absolutely necessary when exploring concepts in chemistry. In addition, Wagner and Pimm (2012) argue that without some basic mathematics skills, these calculations, and therefore chemistry itself, will be extremely difficult. However, with basic knowledge of some of the mathematical skills, a student would be well prepared to deal with relational concept and theories in chemistry.

No doubt, science subjects are inter-related; a student who is good at one is likely to be good at others. Sutcliffe (2002) points out that Mathematics forms a strong binding force among the various branches of science. In recent decades, research in science education has investigated students’ ideas about all chemistry topics from basic chemical concepts (e.g., the elementary entities of matter, chemical equilibrium, mole) to conceptual development (e.g., chemical
change, conservation of mass, acids and bases, solutions and solubility equilibrium, etc.), conceptual framework (e.g., enzymes, etc.), and problem-solving skills (e.g., chemical equilibrium, acids and bases, gases and chemical reactions, Cakir (2008)). The common purpose of these studies is to determine the barriers that students encounter while learning chemical knowledge so as to make chemistry learning more effective. While significant strategies have been employed in science education, challenges experienced in students' algebraic skills in calculating reacting masses in chemical equations call for an in-depth analysis and hence the need for this study.

It is generally accepted that learning chemistry is difficult for many students, Nakhleh (1992). There are many factors that hinder students’ learning chemistry, such as inadequate mathematical skills, the hierarchical structure of concepts, textbooks, and instructional methods. In all countries, problem solving is the main part of chemistry education that leads to understanding of chemistry concepts. Although enhancing students’ problem-solving ability is a main goal of chemistry teaching, it is well known that problem solving is the most difficult part for many chemistry students, Bowen (1997). Yet, in the Kenyan context, students' algebraic skills in calculating reacting masses in chemical equations in public secondary schools has not been adequately investigated.

Conventional literature shows that there is a considerable gap between students’ ability to solve algebraic questions (symbolic or numerical) that can be answered by applying a set of procedures to generate a response, Bowen (1997) and their comprehension of chemical concepts, Boujaoude (2000); Cracolice (2008). According to Niaz (2005), students’ levels of algebraic conceptual understanding have a significant effect on their ability to comprehend and solve problems.
Moreover, recent studies (Cole, 2012; Goodheart, 2013) have identified students who can qualitatively explain but who cannot adequately calculate. Stamovlasis, Tsaparlis and Kamilatos (2005) observes that these types of students have adequate conceptual knowledge but inadequate mathematical processing skills to solve problems. While they have difficulty in using formulas, Stamovlasis, et al. farther argues that their performance on conceptual questions is better than on algebraic questions. However, while these studies explore conceptual knowledge and mathematical processing skills to solve problems, available studies on student’s abilities in use of algebraic skills in mathematics and Chemistry are still sparse and thus a priority area for research.

The goal of good chemical education is to build up an equally strong conceptual and algorithmic understanding and then to reinforce their interdependence (Boujaoude, 2000). On the same note, Cracolice (2008) contends that these aspects with respect to student learning are important and timely issues across all areas of science education. In this study, the researcher explores the question: “Is mathematical algebraic processing skills effective for solving algorithmic problems in the topic the ‘mole’?” Knowing the answer to this question will support teachers and educators in knowing where to focus their teaching and to put emphasis. As such, it was necessary to interrogate students' algebraic skills in calculating reacting masses in chemical equations in public secondary schools in Nyandarua County.

Senior secondary chemistry curriculum in West Africa's Senior Certificate syllabus shows that a proper understanding of the mathematical concepts on equations, solubility, quantitative and molar ratio, radioactivity, pH and others in chemistry needs a good knowledge of basic mathematics and generally involves a lot of computation which makes mathematics an important aspect of it ,WAEC (2006). Adeboyel (1999) ascertains that the understanding of mathematical
concepts improves student’s problem-solving abilities and develops a positive attitude towards chemistry. While the consensus above emphasizes understanding of mathematical concepts in improving student’s problem-solving abilities, existing gaps on how schools implement into school practice calls for research and hence this current study.

In Kenya, the MOEST has ratified three (3) core subjects in the secondary education. They include: English, Kiswahili and mathematics. Every student is expected to learn all primary and secondary school levels mathematic topics (Wafubwa, 2014). According to Ndigu (2010), mathematical knowledge and understanding equips a learner with the basics necessary to learn other scientific concepts. As such, it is imperative that enhanced performance in chemistry would be fostered by good background knowledge of mathematics. Mathematics study has long been recognized worldwide as important in the understanding of chemistry. Sidhu (2006), points out that there exists an impregnable link between mathematics and other science subjects. For example, the teaching of practical aspect of chemistry can hardly be achieved without the knowledge of mathematics. Sidhu hence concludes that there is a relationship of mathematics’ ability on students’ overall outcomes. That is to say, a student who is performing well in mathematics is most likely to have high scores in overall outcomes. While the literature no doubt analyzes the relationship of mathematics’ ability on students’ overall outcomes, the challenge, however, is the application of mathematics as a foundation of science subjects such as chemistry.

Leopold (2008) described the dependency of chemistry success to mathematics skills as “Maths fluency.” The qualitative as well as quantitative aspects of topics such as kinetics, chemical
equilibrium, free energy, acid-base chemistry, and electrochemistry are expressed in language liberally seasoned with conversational mathematics (Cracolice, 2008). Cracolice assessed students’ basic fluency in the specific areas of mathematics used in discussions, readings, and homework. The test consisted of questions specifically tailored to the skills needed to be successful in chemistry; algebra, graphs, logarithms, and scientific notation. The study established a significant correlation between the scores on the quiz, the test and final examination grades. The study farther established that offering mathematics at secondary school level provides students opportunities to be exposed to advanced topics chemistry. Even with such proposed measures, the disparities in science as a whole are placing ever greater pressures on the schools' performance efforts and hence this study aimed at investigating the effects of students’ algebraic computational ability on their academic performance in chemistry.

2.3 Mathematics Ability and Academic Performance of Student in Chemistry

Mathematics is core in the understanding of science thus making it a very important subject in the secondary school curriculum. It's this usefulness that makes it a crucial pillar for sustained scientific and technological development. According to Kurumeh (2006), Mathematics would also be considered as a service tool for the study of sciences especially chemistry. But despite its importance and usefulness, it is a subject that is poorly performed by students at primary, secondary and even in the tertiary levels of education. Students with poor mathematics knowledge cannot solve / calculate problems in chemistry (Kurumeh, 2006). In addition, Badru (2004) points out that the choice of science subjects in Nigerian schools is much dependent on the learner’s ability in mathematics because proficiency in mathematics is of basic importance to the study of science. However, the new and emerging curriculum provides significant and novel challenges for teachers and students and their ability to respond appropriately is critical.
Therefore, student’s algebraic computational skills in ratios and proportions in Kenya’s secondary schools are important for analysis as far as the learning process in chemistry is categorized.

The idea of the mole as the unit of the amount of a substance is an integral part of algebraic computations and calculating reacting masses from chemical equations. However, there is widespread confusion over the meaning of the mole among students and teachers (De Jong, 2002). One reason for this confusion is the different definitions that are used in textbooks and the chemistry curriculum in several countries (Furio, et al. 2002). In addition, 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 (Sanger, 2005). Understanding the mole, chemical equations and formulae has a significant bearing on students’ ability to perform stoichiometric computations in chemistry. However, as is the case with Kenyan context, students’ ability to perform well on questions requiring mathematics skills including algebraic computation skills in ratios and proportions application in Chemistry has not been fully explored.

In explaining why mathematics form the basis for the study of chemistry, Cracolice (2008) maintains that mathematics is necessary in enabling chemistry students to draw useful conclusion about compositions, yield and energy, balances in reacting systems and other chemistry concepts that requires computation and calculations. Poor mathematical conceptualization among students affects their chemistry outcome. A study done in Nigeria that involved 269 students,
students (104) who earned a mathematical mean score of 35.31 scored a grade A or B in Chemistry. Students (82) scoring a mean mathematical score of 30.70 earned a C in chemistry and students (83) scoring a mean of 27.00 earned a D or F in the chemistry course. Despite this evidence, to a broader extent, literature is majorly on the developed countries like USA, and hence the need for more investigation in the local context.

The Kenya National Examination Council (KNEC), in its 2001 KCSE report said that the poor performance in chemistry was as a result of student’s lack of basic mathematics concepts necessary for proper understanding of chemistry. The following KCSE analysis extract by (%) for both mathematics and chemistry attests to this.

<table>
<thead>
<tr>
<th>Grade</th>
<th>A</th>
<th>A-</th>
<th>B+</th>
<th>D</th>
<th>D-</th>
<th>E</th>
<th>A to B+</th>
<th>D to E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math.</td>
<td>1.68</td>
<td>1.08</td>
<td>1.46</td>
<td>13.19</td>
<td>21.24</td>
<td>39.16</td>
<td>4.22</td>
<td>66.10</td>
</tr>
<tr>
<td>Chem.</td>
<td>0.99</td>
<td>0.90</td>
<td>1.44</td>
<td>27.63</td>
<td>34.26</td>
<td>6.27</td>
<td>3.33</td>
<td>68.16</td>
</tr>
</tbody>
</table>

Source: KNEC; KCSE 2009 Report

From Table 2.1, the KCSE analysis a comparison between Mathematics and Chemistry show a varying trend in the percentage of students in grade categories. Grade A in mathematics was achieved by 1.68% of the students while only 0.99% of the students achieved the grade in chemistry. However, on the other hand, 66.10% of the students scored D to E grade in mathematics score, while there were 68.16% of the students in the same grade categories in Chemistry.

The comparison points to the obstacle that hinders students from arriving at correct answers. The obstacle has to do with problems in computational abilities in calculating reacting masses.
and conceptual understanding that correspond with level of algebraic. Besides, students have problems understanding meaning of problems, and those involving mathematical processing that consist of transformation, process skills, and encoding answers. This classification implies that the students have to interpret the meaning of the question before they proceed to mathematical processing to obtain appropriate answer. It is in the light of the above that the study set out to analyze students' algebraic skills in calculating reacting masses in chemical equations in public secondary schools in Nyandarua County, Kenya.

According to a study done by Ekpo (2011) in Nigeria on the relationship between mathematics performance and other science subjects in the years 2007 to 2010 (Table 2.2), there exists a significant relationship between mathematics and chemistry, physics and biology. The findings of this study with regards to the relationship between mathematics and sciences confirm that chemistry is one of the science subjects that require a substantial mathematical base for its understanding. While conventional literature indeed indicates a significant relationship between mathematics and chemistry, available local studies highlight the general importance of mathematics in Chemistry performance without linking it to students' algebraic skills in calculating reacting masses and hence the need for this study.
Table 2.2: Correlations between Maths/ Chem, Maths/Phys and Maths/ Bio

<table>
<thead>
<tr>
<th>Years</th>
<th>Pairs</th>
<th>N</th>
<th>Correlations (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Math/Chem</td>
<td>120</td>
<td>0.938</td>
</tr>
<tr>
<td></td>
<td>Maths/Phys</td>
<td>120</td>
<td>0.954</td>
</tr>
<tr>
<td></td>
<td>Maths/Bio</td>
<td>120</td>
<td>0.908</td>
</tr>
<tr>
<td>2009</td>
<td>Math/Chem</td>
<td>120</td>
<td>0.924</td>
</tr>
<tr>
<td></td>
<td>Maths/Phys</td>
<td>120</td>
<td>0.930</td>
</tr>
<tr>
<td></td>
<td>Maths/Bio</td>
<td>120</td>
<td>0.826</td>
</tr>
<tr>
<td>2010</td>
<td>Math/Chem</td>
<td>120</td>
<td>0.936</td>
</tr>
<tr>
<td></td>
<td>Maths/Phys</td>
<td>120</td>
<td>0.955</td>
</tr>
<tr>
<td></td>
<td>Maths/Bio</td>
<td>120</td>
<td>0.824</td>
</tr>
</tbody>
</table>

**Source: Ekpo (2011)**

Ekpo (2011) agrees with Meltzer (2002) who stated that mathematical ability or mathematical aptitude or accumulated procedural knowledge is positively correlated to success in traditional introductory chemistry courses that emphasize quantitative problem solving. In addition, Com (2008) agrees that for science material to be assimilated by students, such material must be presented in a mathematically understandable form. Farther, Kurumeh (2006) and Sidhu (2006) note that when students’ potentials and resources are properly harnessed, achievement in mathematics can indeed have a productive effect on other science subjects and precisely so chemistry.

Mathematics and chemistry have areas of intersection such as ratios, proportions and percentages in mathematics and calculating reacting masses equations in chemistry. In Kenya, Form 1 mathematics syllabus introduces students to basic operations in ratios, proportions, percentages, division, and multiplication among others. Among the intended learning outcomes of this topic are that the learners should be able to compare two or more quantities using ratios, calculate percentage change in a given quantity and apply ratios, proportions and percentages to real life
situations. This background gives learners a foundation for acquiring pre requisite knowledge in chemistry in subtopics like balancing chemical equations, making a variable the subject of the formula and interpretation of ratios and percentages among others which becomes very useful when calculating reacting masses in the topic "Mole." These analyses spotlight the fact that student’s algebraic computation ability and application of mathematics as a fundamental science which is necessary for the understanding of most other fields. Yet, despite these efforts, literature dedicated specifically to analyzing students' algebraic skills in calculating reacting masses in chemical equations still remains limited in scope and depth.

Molar ratios are used as conversion factors to relate the number of moles of one substance with the number of moles of another substance in chemistry (Boujaoude, 2000). This allows us to predict what happens when a reaction takes place. The coefficients in a balanced chemical equation can be used to determine the number of molecules, formula units, or moles of a compound involved in a chemical reaction (Cracolice, 2008). According to Anyor (2005), for students to perform well in chemistry they must be well equipped with various mathematical concepts and calculations skills. Although these studies have indicated the role of mathematical concepts and calculation skills, most such studies have been conducted in Western countries. Therefore, it was necessary to explore further in the Kenyan context.

2.4 Performance of Students in Chemistry Classified by Mathematics Ability

Anyor's (2005) study reported significant differences in the achievement in chemistry for students of different mathematics ability levels in science. The research findings revealed that students with high mathematics ability performed better than students with low mathematics ability in chemistry. The findings agree with the views of Manapure (2011), that students with
poor mathematics knowledge cannot solve mathematical problems in science. This is because there is a correlation between mathematics and problem solving abilities. The finding also agrees with the findings of Okwon (2005), that mathematics skills are required for the understanding of science and the teaching of practical chemistry. This implies that, without mathematics, subjects like chemistry and other sciences would vaguely be understood, analyzed and evaluated.

Kenya is no exception in this aspect also, as is reflected by the sampled students’ KCSE performance from Kinangop Sub County, Nyandarua County. Table 2.3 evidently shows a direct proportionality between mathematics and chemistry outcomes.

**Table 2.3: Students Mean Scale Score in KCSE Mathematics and Chemistry in Kinangop Sub County**

<table>
<thead>
<tr>
<th>Year</th>
<th>Mathematics</th>
<th>Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>3.61</td>
<td>3.905</td>
</tr>
<tr>
<td>2011</td>
<td>3.73</td>
<td>3.91</td>
</tr>
<tr>
<td>2012</td>
<td>4.384</td>
<td>4.47</td>
</tr>
<tr>
<td>2013</td>
<td>4.173</td>
<td>4.2</td>
</tr>
</tbody>
</table>

*Source:* Kinangop Sub County KCSE analysis for the years (2010- 2013)

The Table 2.3 shows that in 2010, mean scale score for mathematics was 3.61 while in chemistry it was 3.905 as compared to 2013 when mathematics had a mean scale score of 4.173 and 4.2 for Chemistry. Mathematics is a requisite subject to many advanced careers like medicine, pharmacy and other business courses (accounting, finance, and banking) (Niaz, 2005). One has to score high in mathematics for him or her to be allowed to pursue any of the above careers. All students should thus be encouraged to do well in mathematics as this will enhance their performance in chemistry. Yet, there seems to be a dearth of research to examine how students' algebraic skills in calculating reacting masses in chemical equations.
2.5 Gender Differences in Calculating Reacting Masses from Chemical Equations

Achievement test results over the years have shown an ever increasing gap in Kenya, between the performances of boys and girls in chemistry at senior secondary school level (Onekutu, 2002). In Nigeria, a pass at credit level in chemistry is required at Senior School Certificate Examination (SSCE) for admission into science programs in the universities. As a result, chemistry classes and science classes in general are dominated by boys while girls enroll for languages and art based courses (Enu & Agyman, 2015). Enu and Agyman farther found that male students were superior in the sciences than their female counter parts. According to Tobias (1990) and Gipps (1994), as boys and girls grew up, the differences they have in achievement in other subjects tend to diminish except in the sciences and mathematics. The above studies demonstrate significance in terms of recent gender issues in student performance, but the scale and complexity of analysis has been general in nature. Yet, limited studies locally have explored a connection between sound conceptual and procedural mathematical knowledge and successful problem solving in chemistry.

The fear of mathematics is often transferred to chemistry, which involves one form of calculation or the other. However, it is not all aspects of chemistry that involve calculations, but mostly topics in physical chemistry and the kinetic theory of gases. Williams (1990), agrees that in early school years there is no difference in the achievement of boys and girls in the sciences but that in the higher classes, the boys perform better than the girls in the areas that have to do with calculations. Onekutu (2002) states that one needs the ability to use graphs, symbols and diagrams to be able to communicate appropriately in science. All these are in mathematics and this seems to be where the girls have fallen short. However, Gabel and Bunce (1994) claims that under achievement of students in calculating reacting masses from chemical changes was not due
to the fear of mathematical content, but due to the fact that majority of the students did not understand the basic concepts involved in the study of the topic. While policy efforts have yielded some positive results, the apparent shift to gender difference in achievement has received little scholarly attention, particularly at the national level. This is why there was need to investigate possible gender differences in achievement in calculating reacting masses from chemical equations.

According to UNESCO (1998), local customs and values have been developing in girls and they are so deeply ingrained that women themselves often subscribe to them and play a subservient role in the society. Lie (1984) observed that invincible rules within the society have provided what is feminine and what is masculine. Hence, science in most cultures is defined as a masculine domain Onekutu (2002). The situation today has degenerated such that some girls now completely view science subjects as a male only endeavor, preferring to go for other subjects. It is therefore very important to pick up one of these mathematically inclined chemistry aspects from the secondary school curriculum in an achievement test based on the area of study.

2.6 Summary and research gaps

The literature review has explored algebraic computation skills and the relationship between student’s algebraic computation ability in Chemistry application (calculating reacting masses in the mole concept). Moreover, the review has provided empirical studies on gender issues and the extent to which mathematics is widely used in the learning of chemistry. A number of gaps emerge from the literature review. First, while significant strategies have been employed in science education, challenges experienced in students’ algebraic skills in calculating reacting masses in chemical equations have received limited research. In the Kenyan context, students' algebraic skills in calculating reacting masses in chemical equations in public secondary schools
have not been adequately investigated. Second, although these studies explore conceptual knowledge and mathematical processing skills to solve problems, available studies on student’s abilities in use of algebraic skills in mathematics and Chemistry are still sparse and thus a priority area for research. Moreover, even with such proposed measures in the literature reviewed, the disparities in science as a whole are placing ever greater pressures on the schools' performance efforts and hence this study aimed at investigating the effects of students’ algebraic computational ability on their academic performance in chemistry.

Third, while conventional literature indeed indicates a significant relationship between mathematics and chemistry, available local studies highlight the general importance of mathematics in chemistry performance without linking it to students' algebraic skills in calculating reacting masses and hence the need for this study. These analyses illuminates the fact that student’s algebraic computation ability and application of mathematics as a fundamental science which is necessary for the understanding of most other fields. Yet, despite these efforts, literature dedicated specifically to analyzing students’ algebraic skills in calculating reacting masses in chemical equations still remains limited in scope and depth. In addition, while policy efforts have yielded some positive results, the apparent shift to gender difference in achievement has received little scholarly attention, particularly at the national level. This is why there was need to investigate possible gender differences in achievement in calculating reacting masses from chemical equations. Although these studies have indicated the role of mathematical concepts and calculations skills, most such studies have been conducted in Western countries. Therefore, it was necessary to explore further in the Kenyan context.
CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This study investigated relationship between secondary school students’ algebraic skills and their competencies in calculating reacting masses from chemical equations. This chapter provides a description of design and methodology used in carrying out the study. It describes the research design, target population, sample size and sampling procedures. Furthermore, it describes data collection instruments and explains the data collection procedures. In addition, it explains how the study checked reliability and validity of instruments that were used. Finally the chapter explains the procedures of data collections, analysis, and the ethical considerations.

3.2 Research Design

The study used Solomon's Four-quasi-experimental research design. The general objective of having quasi-experimental research was to aid the establishment of relationship between the antecedent (independent) variables and the consequent (dependent) variables. The variables in this study were the computational ability in ratios and proportions and ability to calculate reacting masses of different substances from given chemical equations.

The study involved an assignment of intact classes to four groups with two groups being experimental and other two being controls groups. The labels on the four research groups were: the experimental group one (E1), the experimental group two (E2), the control group one (C1) and the control group two (C2). All groups were given a mathematics test and chemistry pre-test (O1 - O4). The groups E1 and E2 were then put under treatment (X), in enhanced learning
program of RAP. All groups in the study were finally given chemistry post-test that facilitated assessment of the effectiveness of RAP in improving competencies of the students in calculating reacting masses in chemical equations. The respective research actions implemented for the experimental and control groups are as shown in Table 3.1.

**Table 3.1: Research Action on the Experimental and control groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Treatment</th>
<th>Post Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental Group 1 (E1)</td>
<td>01</td>
<td>X</td>
<td>05</td>
</tr>
<tr>
<td>Experimental Group 2 (E2)</td>
<td>02</td>
<td>X</td>
<td>06</td>
</tr>
<tr>
<td>Control Group 1 (C1)</td>
<td>03</td>
<td></td>
<td>07</td>
</tr>
<tr>
<td>Control Group 2 (C2)</td>
<td>04</td>
<td></td>
<td>08</td>
</tr>
</tbody>
</table>

*Source: Gall, Borg and Gall (1996)*

During treatment, the researcher was responsible for the enhanced learning program involving ratios and proportions problem-solving approach-based learning tasks, organizing the groups and creating a purposeful conducive atmosphere that had implications for the learners. This was aimed at ensuring consistency to both experimental groups. Students worked in small groups of four or five collaboratively to solve given problems. They participated actively in the group discussions as they shared their knowledge, expressed their ideas and experiences to each other while searching for solutions to the problems and in completing worksheet exercises. Apart from the group work, each student had to conduct their studies independently and demonstrate individual ability about their competence and levels of engagement as well, at group levels.

In the enhance RAP program leaning of calculating reacting masses was in chemistry was integrated with algebraic skills in the same lesson. The students were then put in groups to apply the learnt skills in solving further problems. This was as opposed to the traditional teaching approach, where students were taught calculating reacting masses separate from learning the
algebraic skills and without illustrations or group work. Students were allowed to develop and apply the ability to solve problems individually.

The RAP problem solving approach sessions were undertaken in the evenings, that is, after classes and on Saturdays so as not to interfere with school’s teaching/learning programs and they took a period of three weeks. At the end of treatment program, a post test was administered.

3.3 Variables
The independent variables of the study includes: student’s ability to compute problems of algebraic concepts in ratios and proportions. The intervening variables were: teaching methodologies applied in chemistry, learner’s attitudes towards mathematics and chemistry, student engagement in class work in chemistry, syllabus coverage in mathematics and chemistry and availability of the teaching and learning resources in chemistry subject. Student’s ability in calculating reacting masses from chemical equation formed the dependent variable.

3.4 Location of the Study
The study covered Kinangop Sub County Nyandarua County, Kenya. Kinangop Sub County is one of the two Sub Counties which comprise Kinangop constituency. It is also one of the 7 Sub Counties of Nyandarua County, Kenya. It is located at the extreme south of Nyandarua County and boarders Kiambu, Nakuru and Murang’a counties (though separated by the Aberdare ranges). The main activity of the residents of Kinangop Sub County is mixed farming. As at the time of the study no research had been carried out on students' algebraic skills in ratios and proportions and the ability to calculate reacting masses from chemical equations. In general, chemistry normally registers poor performance in KCSE compared to other subjects in Kinangop Sub County.
3.5 Target Population

According to Fraenkel (2006), target population is the larger group to which one is hoping to apply the findings. Kinangop Sub County is divided into two educational zones namely; Njabini and Magumu. The Sub County has 23 secondary schools; of which 15 schools are government schools while 8 are privately owned schools. The government schools comprises of 3 extra-county (former provincial) schools, 4 county (former district) schools while 8 are sub-county schools. The government schools are in various categories: boys’ boarding schools, girls’ boarding schools, mixed day and boarding schools and mixed day schools.

The target population was the Form Three students in the 4 County and 8 Sub-County Government schools. The county and sub-county schools were considered for the study because they are co-educational schools and hence rich sites for collecting data for the study. Form three class was selected for this study because they are expected to have covered much of the algebraic concepts in ratios and proportions among other contents in form one mathematics and are expected to apply these learnt concepts in working out problems of reacting masses in chemical equations from the topic 'the Mole'. This topic ‘the Mole’ is normally expected to be covered early in the 1st term of the form three (3) chemistry syllabus.

Table 3.2: Population Cluster for the Study

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of schools</th>
<th>No. of Form Three Students</th>
<th>Pilot study (schools)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-county</td>
<td>8</td>
<td>621</td>
<td>1</td>
</tr>
<tr>
<td>County</td>
<td>4</td>
<td>432</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>1053</td>
<td>2</td>
</tr>
</tbody>
</table>
3.6 Sample Size and Sampling Procedures

According to Borg and Gall (1989), a sample size of any study should be based on what a researcher considers being statistical and practicable. In this study, four schools were identified, and an intact class from each of the schools in each stratum was assigned to either control or experimental group. Therefore, stratified random sampling technique was used in selecting the schools in each stratum.

However, the numbers of students in each of the classes in the selected schools were well within the range that is required for Pearson’s correlation to detect significant correlation between two variables and for an independent t-test to detect a significant difference in students’ scores. According to Cohen (2008), a Pearson’s correlation test requires a minimum sample size of twenty-one for a large effect size and a one tailed alpha of 0.05. In addition, for an independent t-test, a minimum sample size of twenty-one cases per group is needed for a large effect size and a one tailed alpha of 0.05.

Table 3.3: Sample size determination for the study

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of schools</th>
<th>Experimental Group (Schools)</th>
<th>No. of Students</th>
<th>Control Group (Schools)</th>
<th>No. of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub- county</td>
<td>8</td>
<td>1</td>
<td>20 M, 21 F, 41</td>
<td>1</td>
<td>24 M, 15 F, 39</td>
</tr>
<tr>
<td>County</td>
<td>4</td>
<td>1</td>
<td>24 M, 21 F, 45</td>
<td>1</td>
<td>26 M, 22 F, 48</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>2</td>
<td>44 M, 42 F, 86</td>
<td>2</td>
<td>50 M, 37 F, 87</td>
</tr>
</tbody>
</table>

3.7 Research Instruments

The research instruments were developed to fit the research design and the plan of data analysis so that the data to be collected facilitated the testing of the hypothesis. A mathematics achievement test (MAT) (See Appendix II), and a chemistry achievement pre-test (CAT-pre)
(See Appendix I) were set. A chemistry achievement post-test (CAT-post) (See Appendix IV) was also set. The three tests; MAT and CAT used were adopted from past KNEC examinations to ensure content validity.

MAT was used to assess the learners’ mastery of the algebraic concepts in ratios and proportions in secondary school mathematics. The instrument was a 1¾ hour (common duration for school tests) exam containing 18 items of which 16 of them were KCSE mathematics section I-type questions while two were section II-type questions with a maximum of a total of 100 marks. (CAT-pre) was used to assess the learners’ ability to transfer the already learnt algebraic concepts and skills in ratios and proportions from school mathematics into calculation of reacting masses of different substances from given chemical equations. The instrument was also a 1¾ hour exam containing 20 items. It comprised of KCSE chemistry paper one type questions with a maximum of a total of 100 marks. CAT-post was administered also in a 1¾ hour duration and contained 20 items of KCSE chemistry paper one type questions with a maximum of a total of 100 marks (KNEC, 2015).

The respondents were asked to work out all the items and show their workings in the spaces provided in the three tests. Marks were distributed accordingly depending on the methodology and the working shown.

3.8 Pilot Test
Piloting ensures that research instruments are clearly structured and that they have some meaning to the respondents. Piloting was done to enable the researcher modify, restructure and eliminate any ambiguous items. Piloting can also be done to check the content validity of the instruments and their reliability. Reliability helps in measuring the internal consistency of the instruments; to
ensure that it answers the questions correctly in order to meet the objectives of the study (Mugenda & Mugenda, 2003).

To carry out pilot study, two schools were randomly selected, one from the county and another form the sub-county categories schools. The researcher compiled test questionnaire which was applied to a pilot group of twelve (12) students and one Chemistry teacher from each school. Specifically, the pilot group targeted a total of two Chemistry teachers and 24 students. The sample that was used for pilot purposes were not involved in the final data collection process.

3.9 Validity and Reliability of Instruments

3.9.1 Validity of Instruments

This test was validated using content validity. Content validity is a measure of the degree to which data is collected using a particular instrument is valid Kothari (2004). This validation was ensured through adoption of past KCSE chemistry and mathematics examinations. Consultations and discussions with supervisors were done to further ensure content validity by reviewing the tests and answers. Their valuable comments, corrections, and suggestions enabled the validation of the instruments.

3.9.2 Reliability of Instruments

Wiersma (1985) defines reliability as the level of internal consistency and stability over time of the research instrument. A measurement that yields consistent results over time is said to be reliable. Reliability enhances dependability, accuracy and adequacy of the instrument. Kothari (2004) states that an instrument is reliable if it yields consistent results over a period of time. Piloting was done in 2 public secondary schools. The correlation coefficient of the scores from both tests was calculated using Pearson's coefficient to establish the extent to which the content
of the instrument were consistent. According to Best and Kahn (2005), a reliability coefficient of 0.6 and above is sufficient for an instrument. Then the research instruments were retested and found to be reliable as they had a reliability coefficient of 0.868 as the composite score of all variables.

3.10 Data Collection Procedures

An introductory letter was obtained from the School of Education to help obtain a research permit from the National Council for Science, Technology and Innovation (NACOSTI). A copy of the permit and an introductory letter was presented to Sub County Director of Education Officer to request for permission for data collection. Finally, the researcher visited the sampled schools to make appointments with the principals. These appointments discussed on the modalities of the administration of research instruments to the students.

Both the control and experimental groups were subjected to a pre-test involving both the Mathematics and Chemistry achievement tests. The researcher administered both the tests, marked and recorded the student's scores. An enhanced learning program using the Ratio and Proportions problem solving approach (RAP) was formulated and carried out to the experimental group / treatment groups.

After the enhanced Ratio and Proportions problem solving approach (RAP) learning / teaching program, the researcher then administered a post-test in chemistry, to the two groups. Assistance of subject teachers in various schools was sought to help in administration of the instruments both at pre and post testing stage. Marking and recording of the student's scores were done by the researcher.
3.11 Data Analysis Techniques

After the collection of the answer sheets from the learners both at pre and post test stage, marking was done by the researcher. Data for each objective was analyzed as illustrated in the matrix in Table 3.4

Table 3.4: Procedure of Data Analysis for each Objective

<table>
<thead>
<tr>
<th>Objective</th>
<th>Type of Data</th>
<th>Procedure of Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Establish students’ mastery of algebraic skills involving ratios and proportions in secondary schools.</td>
<td>Mathematics test data</td>
<td>Mean scores in the mathematics test for the different groups in the study.</td>
</tr>
<tr>
<td>b) Determine relationship between students’ algebraic skills and their competencies in calculating reacting masses in the mole concept</td>
<td>Mathematics test and chemistry pre-test data</td>
<td>Correlate mathematics test data with the chemistry pre-test data</td>
</tr>
<tr>
<td>c) Investigate effect of enhanced program of Ratio and Proportion (RAP) on competencies in calculating reacting masses in chemical equations</td>
<td>Chemistry pretest and post test data</td>
<td>Inferential statistics on the significance of difference between chemistry pre- and post-test group mean scores</td>
</tr>
<tr>
<td>d) Investigate gender difference in using algebraic skills to calculate reacting masses in the mole concept</td>
<td>Boys’ and Girls’ Chemistry post test data</td>
<td>Inferential statistics on the significance of difference between boys’ and girls’ mean scores in each group</td>
</tr>
</tbody>
</table>

Through the use of the measures of central tendencies and dispersion including but not limited to percentages, frequencies, mode, median, mean, standard deviation and coefficient of variance. So as to test the significance levels at $\alpha 0.05$, inferential statistics using ANOVA, was employed.

The summary of the basic logic of ANOVA is the discussion of the purpose and analysis of the variance. The purpose of the analysis of the variance is to test differences in means (for groups or variables) for statistical significance. The accomplishment is through analyzing the variance, which is by partitioning the total variance into the component that is due to true random error
and the components that are due to differences between means. The ANOVA analysis is intended to investigate whether the variation in the independent variables explain the observed variance in the outcome in this study the pre test chemistry performance.

Correlation analysis was done to establish the relationship between the student algebraic concepts computational ability in ratios, division, multiplication, proportions and percentages and the ability to calculate reacting masses from given chemical equations.

3.12 Ethical and Logistical Consideration

Prior to embarking on a research process, the researcher and the participant are required to enter into an agreement that clarifies obligation and responsibilities through informed consent (Kerlinger & Lee, 2000). The ethical principles that were observed by study, therefore, were related to the researcher as the person conducting the study. The second level of ethics was related to the respondents as parties who needed to be aware of their basic rights that needed to be protected during the research process. As a critical part of honoring the ethical requirement, permission to conduct this study was obtained from the County Education Office, head teacher and pupils.

Also important to note was that the data collected was safeguarded and not disclosed to the public in a way that could identify the participants. To enhance confidentiality, the researcher used identification numbers, rather than names of the respondents. Among the steps taken to ensure anonymity included non-indication of names of respondents on the instruments. The researcher also sought for authority to collect data from the National Council for Science, Technology and Innovation (NACOSTI).
CHAPTER FOUR

PRESENTATION OF FINDINGS, INTERPRETATION AND DISCUSSION

4.1: Introduction

This chapter presents, interprets and discusses findings on computational ability in calculating reacting masses in chemical equations among public secondary school students in Nyandarua County. The chapter first presents demographic information followed by presentation of data, interpretation and discussion of findings in line with the four study objectives. The study objectives are:

- Students’ algebraic computation ability in calculating ratios and proportions.
- Comparing students’ computation ability between Problem Solving Approach (RAP) and the traditional approach method.
- Comparing student’s abilities in use of algebraic skills in mathematics and Chemistry.
- Gender differences in calculating reacting masses from chemical equations.

4.2: Biographical Information

4.2.1: Response Rate

The purpose of presenting this table was to help in getting the correct number of the tests that were successfully done out of the total number of what was targeted, and again to check whether the number was adequate for data processing to continue, Borg and Gall (2008). The study targeted 86 students for experimental group, and 87 students for control group. All the students in experimental and control group participated in the tests, making a response rate of 100%
According to Babbie and Earl (2009), 50% response rate is deemed adequate for this study and one can proceed with data analysis.

4.2.2: Gender of the Respondents

From the data in Table 4.1, the experimental group comprised of 53.33% male students and 46.66% female students. In the experimental group 2 the male students were 48.78% while the female students were 51.21%. The control group 1 had 54.16% male while students and 45.83% female students. On the other hand, control group 2 comprised of 61.53% male students and 38.46% female students. This statistics indicates that the study balanced on issue of gender representation. According to West and Zimmerman (2007) there is need to balance gender when carrying out research as it may affect the study results. Furthermore the study sought establish whether there is significant gender differences in achievement in calculating reacting masses from chemical equations, thus it was important to balance gender when carrying out research. The results of the analysis are summarized in Table 4.1.

Table 4.1: Gender composition

<table>
<thead>
<tr>
<th></th>
<th>Experimental group 1 (schools)</th>
<th>Experimental group 2 (schools)</th>
<th>Control Group 1 (schools)</th>
<th>Control Group 2 (schools)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>%</td>
<td>Frequency</td>
<td>%</td>
</tr>
<tr>
<td>Male</td>
<td>24</td>
<td>53.33%</td>
<td>20</td>
<td>48.78%</td>
</tr>
<tr>
<td>Female</td>
<td>21</td>
<td>46.66%</td>
<td>21</td>
<td>51.21%</td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>100%</td>
<td>41</td>
<td>100%</td>
</tr>
</tbody>
</table>

4.3: Levels of Students’ Competence in Computation Ability in Ratios and Proportions

The study set out to establish the level of students’ competence in algebraic skills. To achieve this, the study administered a test involving ratios and proportions to experimental and control groups. The results of the test gave mean score for the county schools as 59.64% for
experimental group (E1) and 63.50% for control group (C1). While the sub county schools had a low mean score of 15.39% for experimental group (E2) and 16.30% for control group (C2). The results are as shown in Table 4.2 and Figure 4.1.

Table 4.2: Performance in Mathematics by each of the Study Groups

<table>
<thead>
<tr>
<th>Study Group</th>
<th>N</th>
<th>Lowest Score</th>
<th>Highest score</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>45</td>
<td>33.00</td>
<td>82.00</td>
<td>59.64</td>
<td>11.88</td>
</tr>
<tr>
<td>E2</td>
<td>41</td>
<td>0.00</td>
<td>51.00</td>
<td>15.39</td>
<td>13.48</td>
</tr>
<tr>
<td>C1</td>
<td>48</td>
<td>34.00</td>
<td>82.00</td>
<td>63.50</td>
<td>12.03</td>
</tr>
<tr>
<td>C2</td>
<td>39</td>
<td>0.00</td>
<td>46.00</td>
<td>16.31</td>
<td>9.77</td>
</tr>
</tbody>
</table>

Figure 4.1: Mathematics Mean Score by each Study Group

Table 4.2 and Fig. 4.1 indicate that all groups had comparable characteristics: the county schools had equivalent performance, and the sub-county schools had also comparable performances. However, the achievement is generally rather low as and in line with KNEC (2004) observation.
that despite importance and usefulness of mathematics, it is a subject that registers poor performance at secondary schools and even in the tertiary levels of education.

4.4 Impact of RAP on Learners' Ability to Calculate Reacting Masses in Mole Concept

In the second objective, the study compared the students’ computation ability between learners taught through an enhanced program of Ratio and Proportion problem solving approach (RAP) and those taught using traditional teaching methods. This was done by comparing mean of experimental and control group pre-test and post-test performance of chemistry (Table 4.3).

<table>
<thead>
<tr>
<th></th>
<th>Minimum score</th>
<th>Maximum score</th>
<th>Mean score</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM-E1</td>
<td>31.00</td>
<td>94.00</td>
<td>61.9556</td>
<td>15.54021</td>
</tr>
<tr>
<td>POST TEST CHEM-E1</td>
<td>47.00</td>
<td>99.00</td>
<td>75.1556</td>
<td>12.36740</td>
</tr>
<tr>
<td>CHEM-E2</td>
<td>4.00</td>
<td>67.00</td>
<td>19.1463</td>
<td>14.85524</td>
</tr>
<tr>
<td>POST TEST CHEM-E2</td>
<td>6.00</td>
<td>88.00</td>
<td>37.0976</td>
<td>16.59187</td>
</tr>
<tr>
<td>CHEM-C1</td>
<td>40.00</td>
<td>83.00</td>
<td>63.3542</td>
<td>11.10202</td>
</tr>
<tr>
<td>POST TEST CHEM-C1</td>
<td>45.00</td>
<td>89.00</td>
<td>64.2292</td>
<td>11.65504</td>
</tr>
<tr>
<td>CHEM-C2</td>
<td>1.00</td>
<td>33.00</td>
<td>14.0256</td>
<td>7.40372</td>
</tr>
<tr>
<td>POST TEST CHEM-C2</td>
<td>2.00</td>
<td>30.00</td>
<td>14.4103</td>
<td>7.34746</td>
</tr>
</tbody>
</table>

Table 4.3 presents mean scores for chemistry pre- and post tests for both the experimental and control groups. The mean score for pre test chemistry for the treatment group E1 was CHEM-E1 = 61.9556, and CHEM-E2 = 19.1463. After E1 and E2 underwent treatment RAP their post test performance was greatly improved to Post Test CHEM-E1 = 75.1556 and Post Test CHEM-E2 = 37.0976. The study results indicate that RAP treatment greatly improved the chemistry performance.
Table 4.3 gives the pre test performances of chemistry for the control groups as Pre-CHEM-C1=63.3542 and Pre-CHEM-C2=14.0256. The post test performances of chemistry for the control groups were Post CHEM-C1=64.2292 and Post CHEM-C2=14.4103. The study results indicate that the performance of control group has no significant change.

The results from Table 4.3 means that at the 0.05 significance level, (from E1 and C1 to E2 and C2) a positive and significant correlation exists, indicating a relatively significant impact of enhanced teaching/ learning processes through RAP on the learners' ability to transfer algebraic skills in ratios and proportions to calculate reacting masses in the mole concept. The study rejects the null hypothesis that there is no significant impact of enhanced teaching/ learning processes through RAP between the learners' transfer ability of algebraic skills to calculate reacting masses in the mole concept.

The findings of the study concurs with Bayliss and Watts (2002) who indicated that mathematics is necessary in enabling chemistry students to draw useful conclusion about compositions, yield and energy, balances in reacting systems and other chemistry concepts that require computation and calculations and even the ability to calculate reacting masses in the mole concept. Poor mathematical conceptualization among students affects their chemistry outcome. KNEC (2001) KCSE report said that the poor performance in chemistry was as a result of student’s lack of basic mathematics concepts necessary for proper understanding of chemistry.

Furthermore, the study found that positive and significant correlation exists in the pre and post performances for the experiment groups, indicating a relatively significant impact of enhanced teaching/ learning processes through RAP on the learners' ability to calculate reacting masses in the mole concept. When students are taught a skill, such as solving a mathematical problem, they
often fail to recognize that their new skill can be used to solve a similar problem outside of school. In other cases, students who are skilled with certain tasks outside of school often have difficulty transferring concepts learned from these experiences (Daughterty & Lowanto, 2011). The low performance of students on standardized tests, however, is still a major concern for educators and the general public. While these curricula offer more authentic problem solving, it is not clear if these experiences also allow students to connect learned concepts to the solving of mathematics and science standardized test items.

In addition, Dixon and Brown (2012) argue that a student’s comprehension of a problem and his or her ultimate ability to transfer concepts learned previously to the current problem is inextricably linked to his or her ability to properly represent the problem. Embedded within each representation are concepts that the solver deems analogous to the problem being tackled, and he or she will transfer these concepts to arrive at a satisfying solution. Students who can identify the connection between concepts across algebraic skills domains will likely demonstrate an understanding of calculating reacting masses in chemical equations. When students are cognizant of the requirements of a problem, they will more proficiently focus on critical elements of the problem, connect or abstract common themes from previous problem solving episodes or learning experience, and evaluate their progress towards the right solution for well-structured problems or a good solution for ill-structured problems (Sutton, 2003).

The process of understanding is iterative, and full understanding is often complex. When the problem solver completely understands the problem and its underlying structure, then transfer to similar situations can occur. When students are exposed to multiple contexts in their instructions that include examples that demonstrate a wide application of what is being taught, they develop a
flexible representation of knowledge and are likely to abstract the relevant features of concepts that make two unique problem scenarios similar (Dixon & Brown, 2012). In addition, Com (2008); Kurumeh (2006); Sidhu (2006) agrees that for any science material to be assimilated by students, such material must be presented in a mathematically understandable form.

4.5 Comparison of Abilities of Students Taught Through RAP and those Taught Through Conventional Methods in Calculating Reacting Masses in Mole Concept

In the third objective the study sought to compare abilities of students taught through RAP and those taught through conventional methods in calculating reacting masses in chemical equations, ANOVA was conducted on post-test achievement results for the experimental and the control groups. The accomplishment is through analyzing the variance, which is by partitioning the total variance into the component that is due to true random error and the components that are due to differences between means. The ANOVA analysis is intended to investigate whether the variation in the independent variables explain the observed variance in the outcome in this study the post test of chemistry performance.

The ANOVA results indicate that the independent variables do significantly explain the variance in post test of chemistry performance. This is so because Post Test Chem-E1 (0.05 significance level) confidence level revealed (F=3.013, p=.023); Post Test Chem-E2 (F=8.351, p=.000); Post Test Chem-C1 (F=12.160, p=.000) and Post Test Chem-C2 (F=5.948, p=.000). In this context, the dependent variable is the post test of chemistry performance while the independent variables or the predictors are ratio and proportion problem solving approach (RAP) and traditional teaching methods (Table 4.4).
The study result infers that there was significant difference on students’ computation ability in ratios and proportions between the experimental and control groups. The findings from this study are consistent with Hartzlers (2000) findings; which showed integrated curricula programs outperform students in traditional class on standardized test and state testing programs. The results are summarized in Table 4.4

**Table 4.4: Comparison of Students’ Computation Ability between Experimental and Control Groups**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>POST TEST CHEM-E1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>5985.078</td>
<td>32</td>
<td>187.034</td>
<td>3.013</td>
<td>.023</td>
</tr>
<tr>
<td>Within Groups</td>
<td>744.833</td>
<td>12</td>
<td>62.069</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6729.911</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POST TEST CHEM-E2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>10273.443</td>
<td>25</td>
<td>410.938</td>
<td>8.351</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>738.167</td>
<td>15</td>
<td>49.211</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11011.610</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POST TEST CHEM-C1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>5986.813</td>
<td>26</td>
<td>230.262</td>
<td>12.160</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>397.667</td>
<td>21</td>
<td>18.937</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6384.479</td>
<td>47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POST TEST CHEM-C2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>1805.686</td>
<td>21</td>
<td>85.985</td>
<td>5.948</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>245.750</td>
<td>17</td>
<td>14.456</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2051.436</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the results in Table 4.4, a possible explanation resides in the nature of the test problem, which required that students also draw heavily on their understanding of mathematics and science concepts. Therefore, topics covered in mathematics and chemistry classes, likely, played a major part in the students’ ability to solve the problems.
4.6 Relationship Between Students’ Algebraic Skills and Ability to Calculate Calculating Reacting Masses in Mole Concept

In objective three, the study investigated the relationship between students’ algebraic skills involving ratios and proportions and their ability to calculate reacting masses in the mole concept. Pearson correlation coefficient between achievement results in mathematics test and pre-test and post-test chemistry was determined for each of the groups in the study. The findings are presented and discussed here below.

4.6.1 Correlation Among Achievement Results for Experimental Group E1

Table 4.5 gives the correlation among the achievement results for the experimental group, E1.

<table>
<thead>
<tr>
<th></th>
<th>PRE-TEST CHEM-E1</th>
<th>POST TEST CHEM-E1</th>
<th>MATHS-E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-TEST CHEM-E1</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.855**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>POST TEST CHEM-E1</td>
<td>Pearson Correlation</td>
<td>.855**</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>MATHS-E1</td>
<td>Pearson Correlation</td>
<td>.794**</td>
<td>.851**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

The study computed Pearson correlation coefficient between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole
concept (Table 4.5) for experimental group E1. Strong correlation coefficient of 0.794 (p-value of 0.000) between chemistry pre-test and mathematics tests, and a coefficient of 0.851794 (p-value of 0.000) between chemistry post test and mathematics test were obtained. The values are quite high indicating a strong positive and significant relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept. Similar findings were obtained for experimental group E2, and control groups C1 and C2 as illustrate in Table 4.6; Table 4.7 and Table 4.8.

4.6.2 Correlation Among Achievement Results for Experimental Group E2

Table 4.6 presents values of Pearson’s’ correlation coefficients between the mathematics and chemistry pre- and post – tests for experimental group E2.

<table>
<thead>
<tr>
<th></th>
<th>PRE-TEST CHEM-E2</th>
<th>POST-TEST CHEM-E2</th>
<th>MATHS-E2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-TEST CHEM-E2</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.846**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>POST TEST CHEM-E2</td>
<td>Pearson Correlation</td>
<td>.846**</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>MATHS-E2</td>
<td>Pearson Correlation</td>
<td>.789**</td>
<td>.708**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>41</td>
<td>41</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
Evaluation of the test results gave a Pearson correlation coefficient of 0.789 and p-value of 0.000 between mathematics and chemistry pre-test was obtained. On the other hand, the correlation value for mathematics and chemistry post-test was found to be 0.78 and p-value of 0.00. These findings present a strong positive and significant, relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept. Therefore basing on these findings the study deduces that there is a significant relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept.

4.6.3 Relationship Between Math C1 and Chem C1 and Post Test Chem-C1

The study assessed the relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept (Table 4.7) for control group C1. A Pearson correlation coefficient of 0.632 and p-value of 0.000 between mathematic and chemistry pre-test was obtained while that for mathematics and chemistry post-test was 0.686 and p-value of 0.00. Again the coefficients show strong positive and significant, relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept. Therefore basing on these findings the study deduces that there is a significant relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept. The study results are as shown in Table 4.7 below.
Table 4.7: Correlation among Math C1 and Chem C1 and Post Test Chem-C1

<table>
<thead>
<tr>
<th></th>
<th>CHEM-C1</th>
<th>POST TEST CHEM-C1</th>
<th>MATHS-C1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM-C1</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.913**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>POST TEST CHEM-C1</td>
<td>Pearson Correlation</td>
<td>.913**</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>MATHS-C1</td>
<td>Pearson Correlation</td>
<td>.632**</td>
<td>.686**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>48</td>
<td>48</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

4.6.4 Relationship Between Math C2 and Chem C2 and Post Test Chem-C2

The study assessed the relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept for the control group C2. The results gave a Pearson correlation coefficient of 0.754 and p-value of 0.000 between mathematics test and chemistry pre-test. On the other hand a coefficient of 0.706 for mathematics test and chemistry post-test. The results show a strong positive and significant, relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept. Therefore basing on these findings the study deduces that there is a significant relationship student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept. The study rejects the null hypothesis that there is no significant relationship between
student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in mole concepts (Table 4.8).

Table 4.8: Correlation among Math C2 and Chem C2 and Post Test Chem-C2

<table>
<thead>
<tr>
<th></th>
<th>CHEM-C2</th>
<th>POST TEST CHEM-C2</th>
<th>MATHS-C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM-C2</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.902**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>POST TEST CHEM-C2</td>
<td>Pearson Correlation</td>
<td>.902**</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>MATHS-C2</td>
<td>Pearson Correlation</td>
<td>.754**</td>
<td>.706**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>39</td>
<td>39</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

Chemistry needs a good knowledge of basic mathematics and generally involves a lot of computation which makes mathematics an important aspect of it. The study concurs with Sidhu (2006), points out that there exists an impregnable link between mathematics and other science subjects. For example, the teaching of practical aspect of chemistry can hardly be achieved without the knowledge of mathematics. He concludes that there is a relationship of mathematics’ ability on students’ overall outcomes. That is to say, a student who is performing well in mathematics is most likely to have high scores in overall outcomes. Leopold (2008), described the dependency of chemistry success to mathematics skills as “Maths fluency”. They established a significant correlation between the scores on the quiz, the test and final examination grades. Therefore, offering mathematics at secondary school level provides students opportunities to be exposed to advanced topics chemistry.
4.7: Gender Differences in Achievement in Calculating Reacting Masses

In objective five, the study sought to establish whether there is significant gender difference in achievement in calculating reacting masses from chemical equations. The study compared means of pre test chemistry performance of boys and girls by carrying out ANOVA test and the results are as in Table 4.9.

**HO:** There is no significant difference in calculating reacting masses from chemical equations between boys and girls.

### Table 4.9: Gender Differences in Achievement in Calculating Reacting Masses from Chemical Equations

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Between Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEM-E1</td>
<td>279.334</td>
<td>1</td>
<td>279.334</td>
<td>1.161</td>
<td>.287</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>10346.577</td>
<td>43</td>
<td>240.618</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>10625.911</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEM-E2</td>
<td>264.705</td>
<td>1</td>
<td>264.705</td>
<td>1.206</td>
<td>.279</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>8562.417</td>
<td>39</td>
<td>219.549</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8827.122</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEM-C1</td>
<td>754.025</td>
<td>1</td>
<td>754.025</td>
<td>6.883</td>
<td>.012</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>5038.955</td>
<td>46</td>
<td>109.542</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5792.979</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEM-C2</td>
<td>100.016</td>
<td>1</td>
<td>100.016</td>
<td>1.866</td>
<td>.180</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>1982.958</td>
<td>37</td>
<td>53.593</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2082.974</td>
<td>38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.9 indicates that gender (boys and girls) does not significantly explain the variance in the pre-test chemistry performance for all groups except CHEM-C1, which had $F=6.883$, $p=.012$. The other groups that showed no significant difference in the pre-test chemistry achievement had: Pre Test Chem-E1 ($F=1.161$, $p=.287$); Pre Test Chem-E2 ($F=1.206$, $p=.279$) and Pre Test Chem-C2 ($F=1.866$, $p=.180$. The null hypothesis ($H_0$: There is no significant difference in calculating reacting masses from chemical equations between boys and girls) was thus accepted.

The study finds that the ability of boys and girls to calculate reacting masses in chemical equations is quite comparable. This finding disagrees with Williams (1990), that in early school years there is no difference in the achievement of boys and girls in the sciences but that in the higher classes, the boys perform better than the girls in the areas that have to do with calculations. It also disagrees with Onekutu (2002) study in Nigeria who indicated that achievement test results over the years have shown an ever increasing gap between the performances of boys and girls in chemistry at senior secondary school level. These findings represent a small scholarly endeavor, among many others, to examine whether gender-based and enhanced-based programs can also help to improve students’ performance on math and chemistry tests. However, in order to make more generalized statement about the effectiveness of these studies, more robust experimental designs with larger random samples are necessary.

4.8 Summary

The findings from the study's objectives can be summarized as follows. Regarding the first objective, ANOVA of the test exam score show F-ratio and p-value ($<0.001$) for this ANOVA
calculation are statistically significant; hence a significant difference among students mastery of algebraic skills in calculating reacting masses in chemical equation within the scores.

Regarding the second objective, the ANOVA results indicate \((F=8.351, \ p=.000)\); \((F=5.948, \ p=.000)\) established a significant difference in comparing Problem Solving Approach (RAP) to and the traditional approach method. Although these variables have statistically significant relationships, this relationship is considered weak based on the percentage variances of the respective scores and the total scores respectively.

On the third objective of the study, analysis (A Pearson coefficient of 0.789 and p-value of 0.000) shows a significant positive correlation between the student’s abilities in use of algebraic skills in mathematics and Chemistry. Student’s algebraic computation ability in ratios and proportions allowed for greater comprehension of the student's ability to calculate reacting masses in the mole concept. Regarding the fourth objective, the ANOVA results indicate that gender (boys and girls) does not significantly explain the variance in pre-test of chemistry performance. This is so because Pre Test Chem-E1 \((F=1.161, \ p=.287)\); Pre Test Chem-E2 \((F=1.206, \ p=.279)\) and Pre Test Chem-C2 \((F=1.866, \ p=.180)\).
CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents summary of the key findings presented in chapter four, conclusions drawn based on the findings and recommendations. This chapter is, thus, structured into summary of major findings, conclusions, recommendations.

5.2 Summary of Major Findings

The mastery of secondary school students’ algebraic computation skills involving ratios and proportions in secondary schools.

The findings from the study's objectives can be summarized as follows;

- \( HO_1: \) There is no significant difference between students mastery of algebraic skills and mastery of mathematics in general

ANOVA on the test exam score was also calculated for the groups and it was determined that C1 had a significantly lower average score than E1 students. The results show F-ratio and p-value (<0.001) for this ANOVA calculation are statistically significant. Thus the study rejects the null hypothesis that there are no significant differences between students’ mastery of algebraic skills and mastery of mathematics in general.

- \( HO_2: \) There is no significant difference in between abilities of Problem Solving Approach (RAP) learners and the traditional approach method learners
The ANOVA results indicate (F=8.351, p=.000); (F=5.948, p=.000) significant positive correlation between the Problem Solving Approach (RAP) and the traditional approach method. In other words, the scores of the students who had gone through Problem Solving Approach (RAP) increased significantly on the total score on the test as compared to students who received traditional approach method. Although these variables have statistically significant relationships, this relationship is considered weak based on the percentage variances of the respective scores and the total scores respectively. The Null Hypothesis (There is no significant difference in comparing Problem Solving Approach (RAP) to and the traditional approach method) was thus rejected.

- **HO3**: There is no significant difference in student’s abilities in use of algebraic skills in mathematics and in calculating reacting masses in chemical equations.

A Pearson coefficient of 0.789 and p-value of 0.000 show a strong positive and significant, relationship between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole concept. Therefore basing on these findings the study deduces that there is no significant difference between student’s algebraic computation ability in ratios and proportions and student's ability to calculate reacting masses in the mole. .

This positive and significant correlation exists, indicating a relatively significant impact of enhanced teaching/learning processes through Ratio and Proportions problem solving approach (RAP) on the learners' ability to calculate reacting masses in the mole concept.
• **H04:** There is no significant difference between the abilities of boys and girls in calculating reacting masses from chemical equations.

The ANOVA results indicate that gender (boys and girls) does not significantly explain the variance in pre-test of chemistry performance. This is so because Pre Test Chem-E1 (F=1.161, p=.287); Pre Test Chem-E2 (F=1.206, p=.279) and Pre Test Chem-C2 (F=1.866, p=.180). This indicates that both groups ability to make connection to algebraic computation ability to calculate reacting masses may also arise from previous learning experiences when solving standardized mathematics and chemistry test items. Therefore, it can be assumed that both groups functioned at similar levels of understanding regardless of gender. However, their ability to master algebraic computation skills may also be indicative of teaching methods applied.

### 5.3 Conclusions

The study concludes that there was above average performance in algebraic computation ability in ratios and proportions in county schools but a poor performance in algebraic computation ability in ratios and proportions in sub county schools. The study further concludes that the poor performance in chemistry was as a result of student's lack of basic mathematics concepts necessary for proper understanding of chemistry. Without some basic mathematics skills, these calculations, and therefore chemistry itself, will be extremely difficult. However, with basic knowledge of some of the mathematical skills, a student would be well prepared to deal with relational concept such as mole concept. Thus mathematics achievement could be used to predict a corresponding performance in the chemistry.

Students with poor mathematics knowledge cannot solve some problems in chemistry. There exists a significant relationship between mathematics and chemistry. The findings of this study
with regard to the relationship between mathematics and sciences confirm that chemistry is one of the science subjects that require a substantial mathematical base for its understanding. The study concludes that that mathematical ability is positively correlated to success in chemistry courses that emphasize quantitative problem solving.

The study further concludes that Ratio and Proportion problem solving approach (RAP) enhances chemistry performance and thus a student who has acquired these computational skills will have a higher ability in working out given chemical equations. As such a student with RAP knowledge would experience difficulties when doing calculations in chemistry. Ratio and Proportion problem solving approach has great impact on Mathematical knowledge and understanding; equips a learner with the basics necessary to learn other scientific concepts. As such, it is imperative that enhanced performance in chemistry would be fostered by good background knowledge of mathematics using RAP approach.

The study results indicated mixed results on whether there was a significant gender difference in achievement in calculating reacting masses from chemical equations. Finally the study concludes that there is no significant difference in calculating reacting masses from chemical equations between boys and girls.

Finally, in any further investigations, it is necessary to keep in mind the important role of individual student motivations. While the motivation level could in fact be increased or decreased by prior mathematics knowledge (increased because students may feel more confident, decreased because students may believe they do not need to work hard since they already know mathematics), it is important to realize that individual students are driven by a variety of factors, and the implementation of the mathematics prerequisite may not impact these factors enough to lead to noticeable change. With that being said, student motivation, which is difficult to measure
and variable, may play a role in course grade that outweighs other factors enough to make predictions of chemistry course success based on mathematics background at all quite a challenge.

Overall, a strong foundation of mathematics skills would seem to point toward improved performance with chemistry. While the reasons behind this cannot be measured absolutely, it seems clear that chemistry success requires not only science knowledge, but also a solid foundation of mathematical skills and a logical method of thinking. Therefore, it seems reasonable that the stronger the mathematics background an individual possesses, the greater the likelihood of meeting success with chemistry.

5.4 Recommendations

Recommendations made in this section were derived from the conclusions about the study findings as presented in the previous section and focus on the direct interventions. It is the view of the researcher that the recommended solutions could help educational policy makers and school administrators implement holistic approaches for promoting the requisite mathematics for chemistry calculations in secondary schools in Kenya at large.

- The significance of the levels of students’ algebraic computation ability in ratios and proportions in secondary schools can be achieved. In order for students to perform well in chemistry they must be well equipped with various mathematical concepts and calculations skills. Specifically, the Ministry of Education Science and Technology (MOEST) should organize frequent and intensive trainings programs for teachers of mathematics and chemistry in order to improve general performance.
• The study identified significant difference in computational abilities between learners in RAP and those taught using traditional teaching methods. Therefore, there is need to apply RAP approach in secondary schools to enhance computational ability in the calculation of reacting masses from chemical equations, and thus overall performance of chemistry. Mathematics and Science teachers should employ more intentional efforts to integrate more mathematics in science project-based and problem-based curricula. The emerging trends in Chemistry performance demand for more integrated curricula as an essential feature in education. The pedagogy of integrated learning in Mathematics and Chemistry is needed to clearly define the best strategy to optimize learning by students.

• Although the study results indicated mixed results on gender difference in achievement in calculating reacting masses in chemical equations, gender issues remains a key aspect in the ongoing educational reforms. The study recommends that teachers should be gender sensitive when teaching chemistry and mathematics. This is so because there was difference in calculating reacting masses from chemical equations between boys and girls, although it was not significant.

Overall, the study's findings point to the need for schools to adopt a broad approach in advancing mathematics as a language of science and a central intellectual discipline. This means that both the National and County governments' education stakeholders should broaden their thinking and involve students and parents in addressing issues of science subjects and the secondary school curriculum. While support from the government is needed, there is need for the school heads to work with the school community to identify, implement and manage local issues so as to enhance the importance of mathematics to science.
5.5 Recommendations for Further Study

The results of this research have shown that mathematics' algebraic knowledge is necessary to chemistry's reacting masses computational achievement. Given the importance of student’s computational ability in ratios and the extent to which the ability is reflected in calculating reacting masses in chemical equations, this study has implores the importance of further research into the topic. The suggestions for future research are presented to indicate further studies into areas which will benefit researchers and secondary school teachers, students and policy makers in the educational sector in Kenya and beyond. In effect, the following suggestions were made after research findings and discussions:

- Firstly, the study's objective was to analyze computational ability in the calculation of reacting masses from chemical equations among public secondary school students in Kinangop Sub County, Nyandarua, Kenya. The findings were only limited to chemistry. Thus, more research and studies should be carried out to determine effect of algebraic computational ability and RAP approach on performance of physics.

- Secondly, it would be benefiting to adapt a research to analyze the role of school culture on the student’s algebraic concepts computational ability in ratios and proportions in Kenya’s secondary schools. Further studies which focus on specific variables (i.e., effective or ineffective leadership behavior) are needed.

- Thirdly, since teachers act as facilitators in the teaching-learning process, a study to establish the appropriate student friendly pedagogical approach that influences performance in mole concept is critical.

- With mixed results in the current research, the gender difference in achievement in calculating reacting masses from chemical equations requires further investigation.
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Appendix I: Chemistry Assessment Pre-Test

Introduction
My name is Joseph Kiiru Warungi, a student at Kenyatta University. I am undertaking a study on “Students' Algebraic Skills in Calculating Reacting Masses in Chemical Equations: A Case of Public Secondary Schools in Nyandarua County, Kenya.” I have identified a list of individuals who play prominent roles in my research subject area. For this reason, I would like to ask for permission to undertake this test. Your participation will be of help for this study and I will be grateful if your participation. The test results and all responses will be kept private, and I will not include any information that will make it possible to identify your school or individual in any report.

Having consented to participate in the study, please complete the test below. Answer all questions. The test takes exactly a 1¾ hour and contains 20 items.

Indicate your gender   a) Male     b) Female     
1. 0.318g of an oxide metal M was completely reduced by hydrogen gas to 0.254g of the metal. Calculate the empirical formula of the metal oxide (M = 63.5, O = 16.0). (5mks)
2. Calculate the concentration of Sulphuric acid in moles per litre if 15cm$^3$ of the acid is completely neutralized by 20cm$^3$ of one molar potassium hydroxide. (5mks)
3. 20.0cm$^3$ of a sodium hydroxide solution containing 8.0g dm$^{-3}$ was required for complete neutralization of 0.18g of a dibasic acid. Calculate the relative molar mass of the acid (Na=23.0, H=1.0, O=16.0). (5mks)
4. A salt contains 59.0% sodium and 41.0% oxygen. Given that the formula mass of the salt is 78. Determine its formula. (Na = 23, O=16.0). (5mks)
5. An element H consists of isotopes of masses 10 and 11 with a percentage composition of 18.7% and 81.3% respectively. Determine the relative atomic mass of H. (5mks)
6. Determine the volume of hydrogen gas formed when excess Zinc metal is added to 100cm$^3$ of one molar hydrochloric acid. (Molar Gas Vol. = 24.0 dm$^3$ at r t p). (5mks)
7. Calculate the number of chloride ions 250 cm$^3$ solution 1M calcium chloride. (Avogadro's number is 6.0 x 10$^{23}$) (5mks)
8. An organic compound P contains 64.9% carbon, 13.5% hydrogen and 21.6% oxygen. The relative formula mass of P is 74. (C=12.0, H=1.0, O=16.0)
   (i) Determine the empirical formula of P. (3mks)
   (ii) Determine the molecular formula of P. (2mks)
9. 22.2cm$^3$ of sodium hydroxide solution, containing 4.0g per litre of sodium hydroxide were required for complete neutralization of 0.1g of a dibasic acid. Calculate the relative formula mass of the dibasic acid(Na=23.0, 0=16.0, H=1.0) (5mks)
10. When 34.8g of hydrated sodium carbonate \((\text{Na}_2\text{CO}_3\cdot\text{XH}_2\text{O})\) were heated to constant mass, 15.9g of anhydrous sodium carbonate were obtained. Calculate the value of \(x\) in the hydrated carbonate \((\text{Na}=23.0, \text{O}=16.0, \text{C}=12.0, \text{H}=1.0)\). (5mks)

11. In an experiment, 100cm\(^3\) of hydrogen gas was mixed with 100cm\(^3\) of oxygen gas and the mixture heated to form \(\text{H}_2\text{O}\) (g). Which of the gases was in excess and by how much? (5mks)

12. Calculate the amount of calcium carbonate that would remain if 15.0g of calcium carbonate were reacted with 0.2 moles of hydrochloric acid. \((\text{C}=12.0, \text{O}=16.0, \text{Ca}=40.0)\) (5mks)

13. A compound has an empirical formula. \(\text{C}_3\text{H}_6\text{O}\) and a relative formula mass of 116.
   a) Determine its molecular formula. \((\text{H}=1.0, \text{C}=12.0, \text{O}=16.0)\) (3 mks)
   b) Calculate the percentage composition of carbon by mass in the compound. (3mks)

14. 90cm\(^3\) of 0.01M calcium hydroxide were added to a sample of water containing 0.001 moles of calcium hydroxide.
   (i) Write a balanced chemical equation for the reaction which took place (1mks)
   (ii) Calculate the number of moles of calcium ions in 90cm\(^3\) of 0.01M calcium hydroxide. (3mks)

15.Calculate the mass of nitrogen (iv)oxide gas that would occupy the same volume as 10g of hydrogen gas at the same temperature and pressure. \((\text{H}=1.0, \text{N}=14.0, \text{O}=16.0)\) (5mks)

16. On complete combustion of a sample of a hydrocarbon, 3.52g of carbon (iv)oxide and 1.44g of water were formed. Determine the molecular formula of the hydrocarbon. \((\text{Rmm of hydrocarbon} = 56, \text{H}=1.0, \text{and C}=12.0)\). (5mks)

17. 50g of potassium hydroxide were dissolved in distilled water to make 100cm\(^3\) of solution. 50cm\(^3\) of the solution required 50cm\(^3\) of 2M nitric acid for complete neutralization. Calculate the mass of D. (5mks)

18. In an experiment 3.36g of iron fillings were added to excess aqueous copper (II) sulphate. Calculate the mass of copper that was deposited \(\text{Cu} = 63.5, \text{Fe} = 56.\) (5mks)

19. When a certain hydrocarbon of the formula \(\text{C}_x\text{H}_y\) was burnt in excess oxygen, 0.264 g of carbon (IV) oxide and 0.108g of water were formed. If the molecular mass of the hydrocarbon is 5.6g, determine the hydrocarbon's molecular formula. (5mks)

20. What is the mass of 4.12litres of chlorine gas if the volume is measured at s.t.p (at stp, molar gas vol = 22400cm\(^3\))? 5mks
ANSWERS TO CHEMISTRY PRE- TEST

1. Mass of oxygen = 0.318 – 0.254 = 0.064 (1mk)

\[
\begin{array}{c|c|c}
M & O \\
0.254 & 0.064 & (3mks) \\
63.5 & 16 \\
\end{array}
\]

Formula = MO (1mk)

2. \(2\text{KOH}(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow 2\text{H}_2\text{O}(l) + \text{K}_2\text{SO}_4(aq)\)

Moles of KOH = \(20 \times \frac{1}{1000} = 0.02\) (1mk)

Moles of \(\text{H}_2\text{SO}_4\) = \(\frac{1}{2}\) (Moles of KOH) = \(\frac{1}{2} (0.02)\) = 0.01 moles (2mks)

15cm\(^3\) contain 0.01 moles

1000cm\(^3\) will contain \(\frac{1000 \times 0.01}{15} = 0.6667\) moles (2mks)

3. Moles of NaOH on 20.0cm\(^3\) = \(8.0 \times 20.0\) = 4 \times 10\(^{-3}\)

reacting ratios NaOH : Acid 1: 2

Moles of acid = \(\frac{1}{2} \times \frac{4}{10^{-3}}\) = 2 \times 10\(^{-3}\) (2mks)

RFM of acid = \(0.18 \div 2 \times 10^{-3}\) (1mk) = 90

4. Na

\[
\begin{array}{c|c|c}
\text{Na} & \text{O} \\
59.0 & 41.0 \\
23 & 16 \\
2.5652 & 2.5625 (2mks) \\
1 & 1 \\
\end{array}
\]

Empirical formula = NaO

Empirical formula mass = 23 + 16 = 39 (2mks)

\((39)n = 78\) \(n = \frac{78}{39} = n = 2\) \(= \text{Na}_2\text{O}_2\) (1mk)

5. RAM of H = \((10 \times \frac{18.7}{100}) + (11 \times \frac{81.3}{100})\) (3mks)

\[= 1.87 + 8.94 = 10.8\ (1mk)\]
6. \[ \text{Zn}(s) + 2\text{HCl} \text{ (aq)} \rightarrow \text{Zn}^{2+} \text{ (aq)} + 2\text{Cl}^{-} \text{ (aq)} + \text{H}_2 \text{ (g)} \]

- \[100\text{cm}^3 \text{ 1M HCl} = 0.1 \text{ moles} \] (2mks)
- \[\text{moles of } \text{H}_2 \text{ (g)} = 0.1/2 = 0.05 \] (2mks)
- \[\text{but 1 mole at rtp } 24.0 \text{ litres} \]
- \[0.05 \text{ moles } = 12.0 \text{ litres} \] (1mk)

7. Moles of \( \text{CuCl}_2 = 250 \times 10^{-3} = 0.25 \) (2mks)

\[
\text{No. of chloride ions} = 0.25 \times 6.0 \times 10^{23} \times 2 = 3.0 \times 10^{23} \] (3mks)

8. (a) (i) \[ \begin{align*}
\text{C} & = \frac{64.9}{12} = 5.4 \\
\text{H} & = \frac{13.0}{1} = 13.5 \\
\text{O} & = \frac{21.6}{16} = 1.35
\end{align*} \]

\[
\text{Ratio } \frac{5.4}{1.35} = 4 \\
\frac{13.5}{13.5} = 10 \\
\frac{1.35}{1.35} = 1
\]

(ii) Empirical formula = \( \text{C}_4\text{H}_{10}\text{O} \)

\[
(12 \times 4) + (1 \times 10) + (16 \times 1) \times n = 74 \] (2mks)

\[
74n = 74 \\
n = 1
\]

Molecular formula = \( \text{C}_4\text{H}_{10}\text{O} \) (1mk)

9. Conc of NaOH = \( \frac{\frac{1}{10}}{1} = 0.1 \text{M} \) (1mk)

Moles of NaOH = \( 0.1 \times 22.2 \times 10^{-3} \)

\[= 2.22 \times 10^{-3} \] (2mks)

Moles of dibasic acid = \( \frac{1}{2} \left( 2.22 \times 10^{-3} \right) \)

\[= 1.11 \times 10^{-3} \] (1mk)

RF mass of acid = \( \frac{0.1}{1.11 \times 10^{-3}} \)

\[= 90.09 \] (1mk)

10. Mass of water \( 34.8-15.9 = 18.9 \text{g} \) (1mk)

\[
\frac{\text{Na}_2\text{CO}_3 = (2 \times 23) + 12 + 42 = 106}{15.9} = \frac{18.9}{18x} \]

\[x = \frac{18.9 \times 106}{18 \times 15.9} = 2003.4 \] (3mks)

\[18 \times 15.9 = 286.2 \]

\[x = 7 \] (1mk)

11. 2 Moles of \( \text{H}_2 \text{ (g)} \) = 1 mole of oxygen = 2 Moles of \( \text{H}_2\text{O} \)

\[
\begin{align*}
2 : 1 & \text{ : } 2 \text{ (2mks)} \\
\text{ = 100cm}^3 \text{ of } \text{H}_2 \text{ (g)} & \text{ = 50cm}^3 \text{ O}_2 \text{ (g)} \text{ = 100cm}^3 \text{ H}_2\text{O} \text{ (2mks)} \\
\text{Oxygen is excess by 50cm}^3 \text{ (1mk)}
\end{align*}
\]

12. 1 mole \( \text{CaCO}_3 \) : 2 moles of \( \text{HCl} \) (1mk)

Therefore \( \left( \frac{1}{2} \times 0.2 \right) = 0.1 \text{ mole : CaCO}_3 \) 0.2 Mole (1mks)

79
\[
\text{CaCO}_3 = 40 + 12 + 48 = 100 \text{g}
\]
Therefore \(15 \text{g CaCO}_3 = \frac{15}{100} = 0.15 \text{Moles (2mks)}\)

Excess moles \(0.15 - 0.1 = 0.05 \text{moles}\)
Excess mass = \((0.05) \times 100 \left(\frac{1}{2}\right) = 5 \text{g}\) (1mk)

13. a) \((\text{C}_3\text{H}_6\text{O})_n = 116\)

\[
(3 \times 12 + 6 + 16)n = 116 \text{ (1mk)}
\]
Molecular formulae = \(2(\text{C}_3\text{H}_6\text{O}) = \text{C}_6\text{H}_{12}\text{O}_2\) (1mk)

\[
n = \frac{116}{58} = 2 \text{ (1mk)}
\]

b) Percentage of Carbon = \(\frac{12 \times 6 \times 100}{116} = 62.07\) or \(\frac{3 \times 12 \times 100}{58} = 62.07\) (2mks)

14. a) \(\text{Ca(OH)}_2(aq) + \text{Ca(HCO}_3\text{)}_2(aq) \rightarrow 2\text{CaCO}_3(s) + \text{H}_2\text{O(l)}\) (1mk)

(b) Moles = \(\frac{\text{Volume} \times \text{Molarity}}{1000}\)

Moles of \(\text{CO}_3^{2-}\) = \(\frac{90 \times 0.01}{1000}\) (2mks)

= \(0.009 \text{ moles}\) (1mk)

15. No. of moles of hydrogen \(\text{H}_2\) = \(\frac{10}{2}\) = 5 Moles (2mks)

Relative molecular mass of \(\text{NO}_2\) = 46
5 Mole of \(\text{NO}_2\) = \(5 \times 46\) (2mks)

= 230g (1mk)

16. ALT 1

\[
\text{C}_x\text{H}_y + \text{O}_2 \rightarrow x \text{CO}_2 + \frac{y}{2} \text{H}_2\text{O}
\]

\[
\text{XCO}_2 \frac{y}{2} \text{H}_2\text{O} \text{ (1mk)}
\]

3.52 \(= 0.08\)
\[\frac{3.52}{44} = 1\]
\[\frac{1.44}{18} = 0.08 \text{ (1mks)}\]

= 0.08 \(= 1\)

\[
\text{X} = 1 \quad \frac{y}{2} = 1
\]

\[
y = 2 \text{ (1mk)}
\]

E.F = CH\(_2\)

E.F.M = 14

\[
n = \frac{56}{14} = 4 \text{ (1mk)}
\]

M.F. (CH\(_2\))\(_4\) = C\(_4\)H\(_8\) (1mk)

Or
Mass of CO₂ = \(12 \times 3.52 = 0.96\)  
\[
\text{Mass of H₂O} = \frac{2 \times 1.44}{18} = 0.16\text{g}
\]
Moles of C = \(0.96 = 0.08\)  
Moles of H = \(0.16 = 0.16\)

\[
\begin{align*}
\text{C} & : \text{H} \\
0.08 & : 0.16 \\
1 & : 2
\end{align*}
\]

\[\text{EF} = \text{CH}_2 \quad n = \frac{56}{14} = 4\]

\[\text{MF} = (\text{CH}_2)_4 = C_4 H_8\]

17. Moles of nitric acid = \(\frac{50 \times 2}{1000} = 0.1\) moles (1mk)

\[1000\]
Moles of KOH in 50cm³ = 0.1 (1mks)
No of moles of KOH in 100cm³ = 0.1 x 2 = 0.2 moles
Mass (D g) of KOH = 0.2 x 56 = 11.2g (1mk)

\[\text{Fe(s)} + \text{Cu}^{2-} (aq) \rightarrow \text{Fe}^{2+} (s) + \text{Cu} (s)\]

Moles of Fe (s) = \(\frac{3.36}{56} = 0.06\) (2mks)

\[
\text{mole ratios} \quad 1 : 1
\]

Moles of Cu = 0.06 (2mks)
Mass of Cu = 0.06 x 63.5 = 3.81 g (1mk)

19. Products

\[\text{CO}_2 \quad \text{H}_2\text{O}\]

| Mass (g) | 0.264 | 0.108 |
| Form. mass | 44 | 18 |
| Moles | 0.264 = 0.006 | 0.108 = 0.006 (1mk) |
| 44 | 18 |

\[
\text{Mole ratio} = \frac{1}{1}
\]

Mass of carbon = \(\frac{12 \times 0.264}{44} = 0.072\)

\[
\text{Mass of hydrogen} = \frac{2 \times 0.108}{18} = 0.012 \quad (2\text{mk})
\]

No of moles = \(\frac{0.072}{12} = 0.006\)

Mole ratio = \(\frac{0.006}{0.006} = 1\)

Empirical formula is \(\text{CH}_2\)
Empirical formula mass = 14g
Multiples of \(\text{CH}_2\) present = \(56g\)
Therefore, the molecular formula of the hydrocarbon is \( \text{C}_4\text{H}_8 \).

20.

\[ 1 \text{lt} = 1000\text{cm}^3 \]

\[ 1 \text{mole} = 22,400\text{cm}^3 \]

\[ ? = 4,120 \text{ cm}^3. \]

\[ \frac{1 \times 4,120}{22,400} = 0.1839 \text{ moles of nitrogen gas (2mks)} \]

but 1 mole of chlorine gas = \((35.5 \times 2)\) g = 71 g (2mks)

\[ 0.1839 \text{ mole} \]

\[ = ? \]

\[ = 13.06 \text{g (1mk)} \]
Appendix II: Mathematics Assessment Pre-Test

My name is Joseph Kiiru Waruingi, a student at Kenyatta University. I am undertaking a study on “Students' Algebraic Skills in Calculating Reacting Masses in Chemical Equations: A Case of Public Secondary Schools in Nyandarua County, Kenya.” I have identified a list of individuals who play prominent roles in my research subject area. For this reason, I would like to ask for permission to undertake this test. Your participation will be of help for this study and I will be grateful if your participation. The test results and all responses will be kept private, and I will not include any information that will make it possible to identify your school or individual in any report. Having consented to participate in the study, please complete the test below. Answer all questions. The test takes exactly a 1¾ hour and contains 20 items.

Indicate your gender  a) Male  b) Female

1. In a factory, when green tea leaves are dried, the mass decreases in the ratio of 3:5. Find the mass of the green tea leaves that would be dried to give 210 kg of dry tea leaves. (5mks)

2. A green grocer bought 216 oranges at ksh 100 for every dozen. She sold all of them at ksh 200 for every 18. What was her percentage profit? (5mks)

3. A motorist travelled at an average speed of 68 km/h for 95 km and then for the next \(3\frac{3}{4}\) hours he travelled at an average speed of 83 km/h. Find the average speed for the whole journey. (5mks)

4. A man is now three times as old as his son. In twelve years time he will be twice as old as the son. Find their present ages. (5mks)

5. Two different types of buckets used by students for washing have base areas of 540 cm\(^2\) and 240 cm\(^2\) respectively. Calculate the volume of the larger bucket in liters given that the volume of the smaller one is 244 cm\(^3\). (5mks)

6. Mary left ksh 211,680 in her will to be shared between his mother, father and son in the ratio 1:2:3. Her ailing and sick mother decided to divide her share equally between her husband and grandson. Find how much Mary's son finally got. (5mks)

7. In order to complete a job in 10 days, a flower farm employed 30 men to work at an assumed average rate of 8 hours a day. Determine how long it would take 40 men working at the rate of 12 hours a day to complete the same job. (5mks)

8. A tourist wanted to exchange 250 sterling pounds into dollars. A Kenyan forex bureau exchange had the following exchange rates;

\[
\begin{align*}
1 \text{ US dollar} &= \text{ksh 76.85} \\
1 \text{ sterling pound} &= \text{ksh 115.30}
\end{align*}
\]

Calculate to 3 significant figures the number of dollars that the tourist got. (5mks)

9. A farmer has twice as many sheep as cows and two thirds as many chickens as sheep. Find the total number of animals given that the farmer has 28 chickens. (5mks)

10. The longer parallel side of a trapezium is twice as long as the shorter parallel side. The perpendicular distance between the parallel sides is 10 cm. If the area of the trapezium is 225 cm\(^2\), find the length of the longer parallel side. (5mks)
11. The radius of a cylindrical tin is increased by 20% while its height is reduced by 15%. Find the percentage increase in the volume of the cylinder. (5mks)

12. Two pipes \( P_1 \) and \( P_2 \) each running alone can fill a tank in 6 hours and 8 hours respectively. A pipe \( P_3 \) empties the tank when full in 10 hours. Pipes \( P_1 \) and \( P_2 \) are turned on and left to run for \( \frac{3}{2} \) hrs. \( P_3 \) is then opened and all the three pipes left running. Find how much longer it takes to fill the tank. (5mks)

13. Given the ratio \( a : b = 3:2 \), find the ratio \( (2a - 2b) : (a - b) \). (5mks)

14. On a certain map, an estate is represented by an area of 90cm\(^2\). If the actual area of the estate is 810 hectares, find the scale of the map in the form of 1: \( n \). (5mks)

15. An alloy is made of aluminium, zinc and copper in the ratio 2:3:5 by mass. Find the mass of aluminium and zinc in an alloy containing 575kg of copper. (5mks)

16. The diagram below represents a circular flower bed surrounded by a path of uniform width. Given that \( R = 1.4 \) m and \( r = 1.26 \) m, calculate to the nearest whole number the area of the path. (Take \( \pi = \frac{22}{7} \)) (5mks)

17. The diagram below represents a cone of base radius 20cm from which a small cone is cut off to form a frustum. The top radius of the frustum is 15cm and its height is 10cm as shown. Calculate to the nearest whole number the total surface area of the frustum. (10mks)

18. A trader bought some eggs at ksh 64 a dozen and sold two thirds of them at ksh 210 per tray and the remaining ones at ksh 240 per tray. In doing so she made a profit of ksh 540. Given that a dozen holds 12 and a tray 30, determine
   a) The number of eggs she bought. (4mks)
   b) The percentage profit she made giving your answer to one decimal place. (3mks)
   c) The percentage profit she would have made if she sold all the eggs at sh 240 per tray (3mks)
1. Mass of dried tea leaves: mass of green tea leaves = 3:5 (1mk)
   Let the mass of green tea leaves be x kg.
   \[
   \frac{210}{x} = \frac{3}{5} \quad (1\text{mk})
   \]
   i.e
   \[
   3x = 210 \times 5
   \]
   \[
   \therefore x = \frac{210 \times 5}{3} \quad (2\text{mks})
   \]
   \[
   = 350\text{kg} \quad (1\text{mk})
   \]

2. Buying price = \[
\frac{216}{12} \times 100 = \text{ksh 1800} \quad (1\text{mk})
\]
   Selling price = \[
\frac{216}{18} \times 200 = \text{ksh 2400} \quad (1\text{mk})
\]
   % profit = \[
\frac{2400 - 1800}{1800} \times 100 \quad (2\text{mk})
\]
   \[
\quad = 33.33\% \quad (1\text{mk})
\]

3. Time taken for the 1\text{st} part of journey \(T = \frac{95}{68} = 1.397\text{hrs.} \quad (1\text{mk})\)
   Distance for the 2\text{nd} part journey \(D = S \times T = 3.75\text{hrs} \times 83\)
   \[
= 311.25\text{km} \quad (1\text{mk})
\]
   Total distance = 311.25 + 95
   \[
= 406.25\text{km} \quad (1\text{mk})
\]
   Total time taken = 5.147hrs \(1\text{mk})
   Average Speed = \[
\frac{311.25\text{km}}{5.147\text{hrs}} \quad (1\text{mk})
\]
   \[
\quad = 60.4721\text{km/hr} \quad (1\text{mk})
\]

4. let son’s age be y years: man’s age is 3y years \(1\text{mk})
   In 12 years time; son will be \(y + 12\) years old
   Man will be \((3y + 12)\) years old \(1\text{mk})
   Thus \(3y + 12 = 2(y + 12)\)
   \(3y + 12 = 2y + 24\)
   \(3y - 2y = 24 - 12\)
   \(y = 12\) \(2\text{mks})
   Son’s age is \(12\) years and man’s age is 36yrs \(1\text{mk})

5. Area scale factor = ratio of base areas
   \[
\frac{240}{240} = \frac{9}{4} \quad (1\text{mk})
\]
   Thus, linear scale factor = \[
\sqrt{\frac{9}{4}} = 3/2 \quad (1\text{mk})
\]
   Volume scale factor = \(\left(\frac{3}{2}\right)^3\)
   \[
\quad = \frac{27}{8} \quad (1\text{mk})
\]
   Vol. of larger container = \[
\frac{27}{8} \times 244
\]
   \[
= \frac{662.8\text{CM}^3}{1000\text{CM}^3} \quad (2\text{mks})
\]

85
6. Total number of shares $1 + 2 + 3 = 6$ (1mk)
   Mother’s share $= \frac{1}{6} \times 211,680$ (1mk)
   $= \text{sh. 35,280}$
   Son’s share $= \frac{3}{6} \times 211,680$ (1mk)
   $= \text{sh 105,840}$
   Son’s share $= \text{sh 105,840} + \frac{1}{2} \text{ of sh 35,280}$ (1mk)
   $= \text{sh 105,840} + \text{sh 17,640}$
   $= \text{sh 123,480}$ (1mk)

7. Let the number of days be $x$.
   Work to be done $= 30 \text{men} \times 8 \text{hrs} \times 10 \text{days}$ (2mks)
   $40 \times 12 \times X = \frac{30 \times 8 \times 10}{40 \times 12}$ (2mks)
   $= 5 \text{days}$ (1mk)

8. Sterling into Kenya shillings
   250 Sterling pounds $= \text{kshs 250} \times 115.30$ (2mks)
   Converting kshs into dollars $= \frac{250 \times 115.30}{75.86}$ (2mks)
   $= \$375.08$ (1mk)

9. Let the number of cows $= x$
   Thus the number of sheep $= 2x$
   The number of chicken $\frac{2}{3}$ of $2x$ $= \frac{4x}{3}$ (1mk)
   Total number of animals $= x + 2x + \frac{4x}{3}$
   $= \frac{15x}{3}$ (1mk)
   No. of chicken $= 28$
   $\frac{4x}{3} = 28$
   $x = \frac{28 \times 3}{4}$ (1mk)
   $x = 21$
   Total No. of animals $= \frac{13 \times 21}{3}$ (1mk)
   $= 91$ (1mk)

10. Let the length of the shorter side be $X \text{ cm}$.
    Longer side $= 2X \text{ cm}$
    Area of trapezium $= \frac{1}{2} (2X + X) \times 10 = 225 \text{ cm}$ (2mks)
    $\frac{90}{X} = 225$
    $X = \frac{90 \times 2}{15}$ cm
    $= 30 \text{ cm}$ (1mk)

11. Original volume of cylinder $V_1 = \pi r^2 h$
    Increase radius (r) by 20% $= R = \frac{1.2r}{100} = 1.2r$ (1mk)
    Decrease height (h) by 15% $= H = \frac{0.85h}{100} = 0.85h$ (1mk)
New volume of cylinder $V_2 = \pi r^2 H$

$$= \pi (1.2r) \times 0.85h$$

$$= 1.224 \pi r^2 h \quad (1\text{mk})$$

$$V_2 = 1.224V_1$$

$\%$ increase in volume $= \frac{V_2 - V_1}{V_1} \times 100$

$$= \frac{V_2 - V_1}{V_1} \times 100 \quad (1\text{mk})$$

$$= (1.224 - 1) V_1 \times 100$$

$$= 0.224 \times 100 \quad (1\text{mk})$$

$= 22.4\%$

12. fraction filled by $P_1$ and $P_2$ in 1 hour

$$= \frac{1}{6} + \frac{1}{8} = \frac{4 + 3}{24} = \frac{7}{24} \quad (1\text{mk})$$

Fraction filled by $P_1$ and $P_2$ in $\frac{3}{2}$ hrs

$$= \frac{7}{24} \times \frac{3}{2} = \frac{21}{48} \quad (1\text{mk})$$

Remaining fraction $= 1 - \frac{21}{48} = \frac{27}{48} \quad (1\text{mk})$

Fraction filled by all 3 pipes in 1 hr

$$= \frac{1}{6} + \frac{1}{8} - \frac{1}{12}$$

$$= \frac{20 + 15 - 12}{120}$$

$$= \frac{23}{120} \quad (1\text{mk})$$

Time taken to fill $\frac{23}{48}$ of the tank at the rate of $\frac{23}{120}$ per hr

$$= \frac{23}{48} \div \frac{23}{120} = \frac{27}{48} \times \frac{120}{23}$$

$$= \frac{27 \times 100}{23}$$

$$= 1164 \quad (1\text{mk})$$

$= 176\text{mins} 09\text{sec}$

$= 2\text{hrs} 56\text{min} 09\text{sec}$

13. $a:b = 3:2$

$$\frac{a}{b} = \frac{2k}{2k}$$

where $k$ is constant $\quad (2\text{mks})$

Substitute $a = 3k$ and $b = 2k$

Hence $(2a - 2b) : (a - b) = (6k - 4k) : (3k - 2k) \quad (2\text{mks})$

$$= 2k : k$$

$$= 2:1 \quad (1\text{mk})$$

14. A.S.F. $= \frac{\text{Actual area on a map}}{90}$

$$= \frac{9 \times 10^8}{90}$$

$$= 9 \times 10^8 \quad (2\text{mks})$$

L.S.F. $= \sqrt{\text{A.S.F.}} = \sqrt{9 \times 10^8} = 3 \times 10^4 \quad (2\text{mks})$

$$= 30,000$$

Scale of map is 1 : 30,000 $\quad (1\text{mk})$
15. Copper $= \frac{5}{10}$ of $x = 575$ (1mks)

$$\frac{5x}{10} = 575$$

$$X = \frac{575 \times 10}{x}$$ (2mks)

Copper = 1150kg

Aluminium $= \frac{2}{10} \times 1150$

$= 230$ kg (1mk)

Zinc $= \frac{3}{10} \times 1150 = 345$ kg (1mk)

16. Area of big circle $= \pi r^2 = \frac{22}{7} \times 1.4 \times 1.4$

$= 6.16m^2$ (2mks)

Area of small circle $= \pi r^2 = \frac{22}{7} \times 1.26 \times 1.26$

$= 4.9896m^2$ (2mks)

Area of path $= 6.16m^2 - 4.9896m^2$

$= 1.1704m^2$ (1mk)

17. Ratio of radius $= \frac{\frac{20cm}{15cm}}{\frac{20cm}{15cm}} = \frac{4}{3}$ (1mk)

\[\begin{align*}
V & = \text{h} + 10 \\
\text{therefore } \frac{\text{h} + 10}{\text{h}} & = \frac{4}{3} \\
4\text{h} & = 3\text{h} + 30 \\
\text{therefore } \text{h} & = 30\text{cm} \\
\text{Height of small cone} & = 30\text{cm} \\
\text{Height of big cone} & = 40\text{cm} \\
\text{In } \triangle \text{VMB } \quad \text{VB}^2 = \text{VM}^2 + \text{MB}^2 \\
\text{(L)} & = \text{VB} = \sqrt{1600 + 400} = \sqrt{2000} \\
\end{align*}\]
In \( \triangle VNA \)  
\[
VA^2 = VN^2 + NA^2 = 30^2 + 15^2
\]
\[
(I) = VA = \sqrt{1125} = 33.54 \text{ (1mk)}
\]
Curved surface area of big cone
\[
\pi RL = \frac{22}{7} \times 20 \times 44.72 = 2810.97 \text{cm}^2 \text{ (1mk)}
\]
Curved surface area of small cone
\[
\pi r_1 = \frac{22}{7} \times 15 \times 33.54 = 1581.17 \text{ cm}^2 \text{ (1mk)}
\]
Curved surface area of the frustum
\[
2810.97 - 1581.17 = 1229.8 \text{ cm}^2 \text{ (1mk)}
\]
Area of top
\[
\pi r^2 = \frac{22}{7} \times 15 \times 15 = 707.14 \text{ cm}^2 \text{ (1mk)}
\]
Total surface area
\[
1229.8 + 1257.14 + 707.14 = 3194.08 \text{ cm}^2 \text{ (1mk)}
\]
18. a) Let the No. of eggs be \( x \)

B/Price at ksh 64 per dozen
\[
= \frac{x}{12} \times 64 = \frac{16x}{3} \text{ (1mk)}
\]

\( 2/3 \times x \) sold at sh210 per tray
\[
= \frac{1}{3} \times x \text{ sold at sh240 per tray}
\]
\[
= \frac{1}{3} \times x \times \frac{240}{30} = \frac{8x}{3} \text{ (1mk)}
\]

Selling price for all eggs
\[
= \frac{14x}{3} + \frac{8x}{3} = \frac{22x}{3} \text{ (1mk)}
\]

Profit
\[
= \frac{22x}{3} - \frac{16x}{3} = 6x
\]
\[
\frac{6x}{6} = \frac{540}{6} = 90 \text{ (1mk)}
\]

b) percentage profit

buying price
\[
= \frac{6x}{5} = \frac{540}{6} = 480 \text{ (1mk)}
\]
profit made = sh540
\[
\% \text{ profit} = \left(\frac{540}{480}\right) \times 100 = 112.5\% \quad (2\text{ mks})
\]

c) Number of trays \[= \left(\frac{90}{30}\right) = 3\text{ trays} \quad (1\text{ mk})\]

selling price \[= 3 \times 240 = \text{ksh 720} \quad (1\text{ mk})\]

Profit \[= 720 - 480 = \text{ sh 240} \quad (1\text{ mk})\]

\[= \left(\frac{240}{480}\right) \times 100 = 50\% \quad (1\text{ mk})\]
Appendix III: Enhanced Teaching Program

The treatment/experimental population received instructions during lecture and practical lessons that emphasizes on problem-solving strategies using the *Ratio and Proportions (RAP) problem solving approach*. Lessons offered focused on solving stoichiometric problems to further support the incorporation of algebraic proportional reasoning in the treatment group. The control group received conventional instructions during the lecture method.

**Student engagement on reacting ratios:**

Day to day human activities involve basic knowledge in ratio and proportions; for example meal ingredients are mixed together using ratios and proportions' basic knowledge.

**Example:**

The preparation of a githeri meal in a secondary school, requires beans and maize as the main ingredients in a ratio of 1:2 respectively, how many kilograms of maize would be required if there were 73kgs of beans?

\[
\begin{align*}
\text{Beans: maize} \\
1 : 2 \\
73 : ?
\end{align*}
\]

\[
= \frac{73 \times 2}{1} = 146 \text{ kg of maize}
\]

**Questions**

a) You want to make 10 dozen standard sized cookies as specified by a recipe that requires 1.5 litre of water, 1 litre of oil, 4 eggs, 3 kg of flour and 0.75 kg sugar.

i. Using the combining ratios of the ingredients given, how much of each ingredients would be required to make 25 dozens of the standard sized cookies?

ii. Supposing in the store there are 5 litres of oil, 16 eggs, 13 kg of flour, 3 kg sugar and plenty of water, How many standard sized cookies can you make?

b) You have 100 bolts, 150 nuts and 150 washers. The equation below gives assembling formula;

\[
2 \text{ washers} + 1 \text{ bolt} + 1 \text{ nut} = 1 \text{ set}
\]

How many sets can be assembled?

If in an experiment, standard grains of rice were weighed on a balance and gave their corresponding masses as follows,

<table>
<thead>
<tr>
<th>Number of grains of rice</th>
<th>Corresponding mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>5.0g</td>
</tr>
<tr>
<td>400</td>
<td>10.0g</td>
</tr>
<tr>
<td>800</td>
<td>20.0g</td>
</tr>
</tbody>
</table>
Question;
Is there a ratio of the number of grains of rice to their weight?

RELATIVE ATOMIC MASSES AND THE MOLE
Consider a kilogram of sugar. How many sugar particles are present? It's true that the number of particles is so many. The size of each particle is negligible. The mass of each individual atom of an element is also very small. Its thus very difficult to weigh them (they are in the order of $10^{-22}$g) while a chemical balance in the laboratory can weigh a mass of about 0.001g. It is thus convenient to express the mass of any atom relative to that of a chosen element. Carbon-12 isotope was recommended by IUPAC (International Union of Pure and Applied Chemists) to be the reference element. This comparison gives the relative atomic masses (RAM) of different elements.

Examples of R. A. M of some of the common elements;

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>RAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>1</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>4</td>
</tr>
<tr>
<td>Lithium</td>
<td>Li</td>
<td>7</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Be</td>
<td>9</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
<td>11</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
<td>12</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
<td>16</td>
</tr>
<tr>
<td>Fluorine</td>
<td>F</td>
<td>19</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>20</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>23</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>24</td>
</tr>
<tr>
<td>Aluminium</td>
<td>Al</td>
<td>27</td>
</tr>
<tr>
<td>Silicon</td>
<td>Si</td>
<td>28</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>31</td>
</tr>
<tr>
<td>Sulphur</td>
<td>S</td>
<td>32</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>35.5</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>39</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>40</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
<td>63.5</td>
</tr>
</tbody>
</table>

THE MOLE AND AVOGADRO'S CONSTANT, 'L'.
Assuming there are $6.023 \times 10^{23}$ particles in 1 Kenya shilling where $6.02 \times 10^{23}$ is equal to a term called mole, how many particles would be equal to 2 moles and 0.5 moles.

Elements are made up of atoms. The number of atoms in one relative atomic mass unit in grams of any element has been established to be $6.023 \times 10^{23}$. This number is referred to as Avogadro’s number, symbolized as 'L' or $N_A$.

The amount of any substance that contains $6.023 \times 10^{23}$ particles (atoms, molecules, ions, electrons, etc) is called a mole.

MOLAR MASS
The mass of one mole of a substance is referred to as molar mass.

Example: The following table shows the molar masses of different elements; (molar mass is equal to the RAM of an element).

<table>
<thead>
<tr>
<th>Element</th>
<th>C</th>
<th>S</th>
<th>Ca</th>
<th>Mg</th>
<th>Al</th>
<th>Fe</th>
<th>Sodium</th>
<th>O</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molar Mass (g/mol)</td>
<td>12</td>
<td>32</td>
<td>40</td>
<td>24</td>
<td>27</td>
<td>56</td>
<td>23</td>
<td>16</td>
<td>14</td>
</tr>
</tbody>
</table>

No. of moles = Mass given
RAM

Example 1: To determine the number of moles in 1.68 g of iron,
1 mole of iron = 56g
? = 1.68g
= 1x 1.68g
= 0.03 moles

Example 2: To determine the number of atoms present in the same mass of iron,
56g of iron = 6.023 x 10^{23} atoms
1.68g = ?
= \frac{1.68g \times 6.023 \times 10^{23} \text{ atoms}}{56g}
= 1.8069 \times 10^{22} \text{ atoms of iron}

Question
a) Given 1.35g of aluminum, determine (i) the number of moles. (Al = 27)
   (ii) the number of atoms present.
b) How many atoms are there in 3g of carbon?
c) Calculate the mass in 3.01115 \times 10^{23} \text{ atoms of sodium}

**RELATIVE MOLECULAR MASS**
The mass of one mole of a molecule is equivalent to its RMM (relative molecular mass)
Example: The mass of a chlorine molecule (Cl_2): 35.5 \times 2 = 71g; while that of ammonia molecule (NH_3): 14 + (1 \times 3) = 17g.

Question
Work out the relative molecular masses of:
- 1 mole of SO_2 molecules
- 0.5 moles of CO_2 molecules
- 2 moles of H_2O molecules

**THE FORMULA MASS**
The mass of one mole of an ionic compound is equivalent to its relative formula mass
Example: The mass of 1 mole of NaCl = 23.0 g of Na + 35.5g of Cl = 58.5g.

Question
Using the RAMs chart given complete the table below:

<table>
<thead>
<tr>
<th>Name of the compound</th>
<th>Formula</th>
<th>Relative formula mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium carbonate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions
How many moles are there in 1.06g of sodium carbonate?
What is the mass of 0.35 moles calcium chloride (Ca= 20.0, Cl= 35.5).
What is the percentage by mass of sodium in one mole of sodium nitrate?

**EMPIRICAL AND MOLECULAR FORMULAE**
Quantitative chemical analysis gives information about proportions by mass of the elements making up a compound. The elements' relative atomic masses are used to calculate the amounts of the elements which react together or the product formed. Once the proportions by mass of the elements are established, the chemical formula of the compound can be determined.

**Example**
Given that a compound contains 0.84g of magnesium and 0.56g of oxygen, determine its empirical formula.

<table>
<thead>
<tr>
<th>Reacting elements</th>
<th>Magnesium</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reacting masses( in gm)</td>
<td>0.84</td>
<td>0.56</td>
</tr>
<tr>
<td>Relative atomic mass</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>No. of moles</td>
<td>( \frac{0.84}{24} = 0.35 )</td>
<td>( \frac{0.56}{16} = 0.35 )</td>
</tr>
<tr>
<td>Moles ratio</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>(divide by the smallest)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Combining ratios</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>empirical formula</td>
<td>MgO</td>
<td></td>
</tr>
</tbody>
</table>

**Example 1:**
A compound of carbon, hydrogen and oxygen contains 54.55% Carbon, 9.0% Hydrogen, and the rest Oxygen. If its relative molecular mass is 88g, determine its molecular formula. (C=12.0, O=16.0, H=1.0).

Step 1: determine the empirical formula as shown above.

The empirical formula is \( \text{C}_2\text{H}_4\text{O} \).

To determine the molecular formulae, add up the masses of individual elements in the empirical formulae, \( \text{(C}_2\text{H}_4\text{O}) \)

\[
2\text{C} = (2 \times 12)\text{g} \\
+ 4\text{H} = (1 \times 4)\text{g} \\
+ \text{O} = 16\text{g} \\
= 44\text{g}
\]

To determine the multiples of \( \text{C}_2\text{H}_4\text{O} \) present, divide relative molecular mass given by the empirical formulae mass obtained:

\[
\frac{88\text{g}}{44\text{g}} = 2
\]

Thus the molecular formulae is twice the empirical formulae;

\( \text{(C}_2\text{H}_4\text{O})_2 \)

Therefore, the molecular formula is \( \text{C}_4\text{H}_8\text{O}_2 \)

**Example 2:**
When a certain hydrocarbon of the formula \( \text{C}_x\text{H}_y \) was burnt in excess oxygen, 2.64 g of carbon (IV) oxide and 1.08 g of water were formed. If the molecular mass of the hydrocarbon is 56g, it is possible to determine the hydrocarbon's molecular formula as follows;
(This is an example where the mole ratio of the products can be used to determine the formula of the reactants).

<table>
<thead>
<tr>
<th>Products</th>
<th>CO₂</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (g)</td>
<td>2.64</td>
<td>1.08</td>
</tr>
<tr>
<td>Formula mass</td>
<td>44</td>
<td>18</td>
</tr>
<tr>
<td>No. of moles</td>
<td>( \frac{2.64}{44} = 0.06 )</td>
<td>( \frac{1.08}{18} = 0.06 )</td>
</tr>
<tr>
<td>Mole ratio</td>
<td>1 : 1</td>
<td></td>
</tr>
</tbody>
</table>

Therefore, it implies that only one mole of each of CO₂ and H₂O were produced. Then determine the empirical formula.

<table>
<thead>
<tr>
<th>Products</th>
<th>CO₂</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of carbon</td>
<td>( \frac{12 \times 2.64}{44} = 0.72 )</td>
<td>( \frac{2 \times 1.08}{18} = 0.12 )</td>
</tr>
<tr>
<td>No of moles</td>
<td>( \frac{0.72}{12} = 0.06 )</td>
<td>( \frac{0.12}{1} = 0.12 )</td>
</tr>
<tr>
<td>Mole ratio</td>
<td>( \frac{0.06}{0.06} = 1 )</td>
<td>( \frac{0.12}{0.06} = 2 )</td>
</tr>
</tbody>
</table>

Empirical formula is CH₂

Thus the molecular formulae is four times the empirical formulae; (CH₂)₄

Therefore, the molecular formula of the hydrocarbon is C₄H₈

**Question**

A Chloride of sulphur was found to have a relative molecular mass of 135.0g. A 5.4g sample of the chloride was found to contain 2.84g of chlorine. Determine the molecular formula of the chloride. (S = 32.0, Cl= 35.5).

**Molar Gas Volumes**

Molar gas volume is the volume occupied by 1 mole of any gas. The density of a gas can be found by measuring the volume of a known mass of a gas and then dividing the mass by the volume. However, the volume of a gas depends on temperature and pressure, therefore, the density of a gas may also depend on the two. In order to compare the results of different gases, standard conditions have been chosen.

i) **Standard Temperature and Pressure (s.t.p)**

Standard temperature is stated as 0°C or 273K while standard pressure is one atmosphere or 760mmHg or 101325 Pa. At s.t.p conditions, the volume occupied by one mole of molecules of any gas is 22.4litres or dm³.
ii) Room Temperature and Pressure (r.t.p)
Room temperature is measured at 25°C/298K while pressure is one atmosphere or 760mmHg or 101325 Pa. At r.t.p conditions, the volume occupied by one mole of molecules of any gas is 24litres or dm³.

Example:
What is the mass of 2.24litres of nitrogen gas if the volume is measured at s.t.p and r.t.p?

s.t.p
1 mole = 22.4lts
? = 2.24lts.

\[ \frac{1 \times 2.24 \text{ lts}}{22.4} = 0.1 \text{ moles of nitrogen gas} \]

but 1 mole of nitrogen gas = \((14 \times 2)\)g
\[ \frac{28 \text{ g}}{0.1 \text{ mole}} = ? \]
\[ = 2.8 \text{ g} \]

r.t.p
1 mole = 24lts
? = 2.24lts.

\[ \frac{1 \times 2.24 \text{ lts}}{24 \text{ lts}} = 0.0933 \text{ moles of nitrogen gas} \]

but 1 mole of nitrogen gas = \((14 \times 2)\)g
\[ \frac{28 \text{ g}}{0.0933 \text{ mole}} = ? \]
\[ = 2.6133 \text{ g} \]

Question:
An evacuated flask has a mass of 90.050g. When filled with gas X, at s.t.p, the flask weighs 90.121g. If the volume of the flask was 22.2cm³, calculate the relative molecular mass of gas X.

Molar Solution
A molar solution is a solution that contains one mole of a solute in one litre of the solution.

Note: 1 lt = 1 dm³ = 1000cm³
Consider, 4.0g of NaOH pellets dissolved in 500cm³ of distilled water, determine its concentration in g/lt and in moles/lt.

Concentration in g/lt
\[ \frac{4 \text{ g}}{500 \text{ cm}^3} = \frac{?}{1000 \text{ cm}^3} \]
\[ = 8.0 \text{ g/lt} \]

Concentration in moles/lt i.e molarity (M)
No. of moles = \(\frac{4 \text{ g}}{40 \text{ g}}\)
\[ = 0.1 \text{ moles} \]
0.1 moles = \(\frac{500 \text{ cm}^3}{1000 \text{ cm}^3}\)
\[ = 0.2 \text{ moles/lt or } 0.2 \text{ M} \]

Question.
Determine the molarities of the following solutions given their masses as;
8.0g of NaOH dissolved in 250 cm³ of water
31.8g of Na₂CO₃ dissolved in 500cm³ of water
12.7 g of Zn(NO₃)₃ dissolved in 800 cm³ of water

**DILUTION OF A SOLUTION**

Dilution is a process by which the concentration of a solution is lowered by adding more solvent into the solution. During dilution, the amount of solute remains the same as the volume of the solution increases.

Note: \[ M_2V_2 = M_1V_1 \]
where \( M_1 \) = Molarity of solution 1
\( M_2 \) = Molarity of solution 2
\( V_2 \) = volume of solution 2
\( V_1 \) = volume of solution 1

Determine the number of moles in 25 cm³ of 2.0 M HCl,
- moles of HCl in 1000 cm³ = 2.0 moles
- moles of HCl in 25 cm³ = \( \frac{2 \times 25}{1000} \) = 0.05 moles

The solution was diluted to a volume of 60 cm³, determine the new molarity.
- \( M_1 = 2 \), \( M_2 = ? \), \( V_1 = 25 \) cm³, \( V_2 = 60 \) cm³
- \[ M_2 = \frac{M_1V_1}{V_2} = \frac{2 \times 25}{60} = 0.833 \text{M} \]

**The RAP approach**:  
RAP problem-solving focuses on proportional reasoning. RAP approach is useful in calculating masses of different substances. It uses individual elements/compounds units until the final answer. Utilizing RAP approach in solving stoichiometric problems leads to a greater understanding of the concept.

The following examples illustrate the use of RAP approach:

To determine the mass in grams of zinc metal that would be required to completely react with 85.0 grams of iron (III) oxide.

\[
\text{Fe}_2\text{O}_3(s) + 3\text{Zn}(s) \rightarrow 3\text{ZnO}(s) + 2\text{Fe}(s)
\]

The reacting ratios are
- 1 mol Fe₂O₃ : 3 mol Zn

thus; \( 1 \text{mol} \left[ \frac{160.0 \text{g Fe}_2\text{O}_3}{\text{mol}} \right] : 3 \text{mol} \left[ \frac{65 \text{g Zn}}{\text{mol}} \right] \)

Therefore
- 160.0 g of \( \text{Fe}_2\text{O}_3 \) : 195 g Zn

A proportional relationship can be used to solve for the unknown variable:

\[
\frac{85.0 \text{g Fe}_2\text{O}_3}{160.0 \text{g Fe}_2\text{O}_3} = \frac{X \text{g Zn}}{195 \text{g Zn}}
\]

\[ X = 103.5 \text{g Zn} \]

**Question**:  
Calculate the volume of a 5M H₂SO₄ Solution that will be required to make a 10 litres of solution of 0.05M H₂SO₄.
RAP can also be used in problem-solving that involves conversions:

Example:
To determine the number of atoms of Al that would be needed in a reaction with iron (III) oxide to produce \(4.25 \times 10^{-3}\) moles of \(\text{Al}_2\text{O}_3\).

From a previous lesson, \(4.25 \times 10^{-3}\) moles of \(\text{Al}_2\text{O}_3\) contains \(2.56 \times 10^{21}\) particles.

Reacting equation gives the reacting ratios of the reactants:

\[
\begin{align*}
\text{Fe}_2\text{O}_3(s) + 2\text{Al}(s) & \rightarrow \text{Al}_2\text{O}_3(s) + 2\text{Fe}(s) \\
\text{thus; } 2 \text{ mol Al} & : 1 \text{ mol } \text{Al}_2\text{O}_3 \\
2 \text{ mol} & : 1 \text{ mol} \\
6.02 \times 10^{23} \text{ atoms Al} & : 6.02 \times 10^{23} \text{ particles } \text{Al}_2\text{O}_3 \\
\text{mol} & : \text{mol} \\
1.20 \times 10^{24} \text{ atoms Al} & : 6.02 \times 10^{23} \text{ particles } \text{Al}_2\text{O}_3 \\
X \text{ atoms Al} & = 2.56 \times 10^{21} \text{ particles } \text{Al}_2\text{O}_3 \\
1.20 \times 10^{24} \text{ atoms Al} & : 6.02 \times 10^{23} \text{ particles } \text{Al}_2\text{O}_3 \\
X & = 5.10 \times 10^{21} \text{ atoms Al}
\end{align*}
\]

STOICHIOMETRIC EQUATIONS AND REACTING RATIOS

i) Consider a reaction between 25.0 cm\(^3\) of 0.2 M barium chloride solution and 14.5 cm\(^3\) of sodium carbonate solution. (Ba = 137.0, Cl = 35.5, Na = 23.0, C = 12.0, O = 16.0)

a) To determine the number of moles of barium chloride used.

\[
\begin{align*}
0.2 \text{ moles} & = 1000 \text{cm}^3 \\
? & = 25 \text{ cm}^3 \\
\text{no. of moles used} & = \frac{0.2 \times 25 \text{ cm}^3}{1000 \text{cm}^3} \\
& = 0.005 \text{ moles of barium chloride solution.}
\end{align*}
\]

b) How would the number of moles of sodium carbonate used be determined?

Determine the reacting ratios from the chemical equation,

\[
\begin{align*}
\text{BaCl}_2(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) & \rightarrow \text{BaCO}_3(s) + 2\text{NaCl (aq)} \\
\text{Reacting ratios; } 1 : 1 & : 1 : 2 \\
\text{Barium chloride} : \text{ sodium carbonate} & : 1 : 1 \\
0.005 \text{ moles of barium chloride} : 0.005 \text{ moles of sodium carbonate}
\end{align*}
\]

c) To determine the mass of sodium carbonate used.

\[
\begin{align*}
1 \text{ mole of Na}_2\text{CO}_3 & = 106 \text{ g} \\
\text{thus } 0.005 \text{ moles of sodium carbonate} & = ? \\
& = 0.005 \text{ moles x 106g} \\
& = 0.53 \text{ g of sodium carbonate}
\end{align*}
\]

d) Determine the molarity of sodium carbonate solution used.

Molarity is moles/litre

since 0.53 g of sodium carbonate were contained in 14.5 cm\(^3\)
then how many grams would be in 1000 cm\(^3\)

\[
0.53 \text{ g} = 14.5 \text{ cm}^3 
\]
? = 1000cm³
  = 0.53g x1000cm³
  = 36.55g
but 1mole = 106 g
? = 36.55g
? = 1mol x 36.55g
  = 0.34mol/lt

e) What mass of sodium chloride was formed?
The ratios from the chemical equation shows 2 moles of NaCl are formed.
  but 1 mole of NaCl = 58.5 g
  2 moles " = ?
  = 58.5g x2
  = 117g of NaCl will be formed.

Question
11cm³ of 0.1M lead (II) nitrate was reacted with 17cm³ of potassium Iodide to precipitate yellow lead (II) iodide.
a) Determine the number of moles of lead (II) nitrate solution used.
b) Determine the number of moles of potassium Iodide solution used.
c) Determine the molarity of potassium Iodide used.
d) Calculate the mass of the yellow precipitate (lead (II) iodide) formed.

STANDARDISATION OF SOLUTIONS
Standardization is the process by which an unknown concentration of a solution is determined by use of a standard solution in a titration experiment. Supposing the volume of the HCl solution of unknown concentration used for the three titres were 22.5cm³, 22.7cm³, 22.6cm³ respectively,
a) Determine the average titre.
   This requires averaging the three consistent titres (within a range of ± 0.2),
   \[
   \frac{22.5cm³ + 22.7cm³ + 22.6cm³}{3} = 22.6cm³
   \]
b) If 1.325g of anhydrous sodium carbonates was dissolved in 100cm³, the molarity of the sodium carbonate solution would be determined as follows; no. of moles of sodium carbonate used = 1.325g
   \[
   \frac{106g}{0.0125moles}
   \]
   0.0125moles are contained in 100cm³ of solution, then how many moles would be in 1000cm³ solution.
   \[
   \frac{0.0125moles}{100cm³} = \frac{100cm³}{1000cm³}
   \]
   \[
   \frac{0.0125moles x 1000cm³}{100cm³} = 0.125mol/lt
   \]
c) If 20cm³ of sodium carbonate solution was titrated against the acid,
0.125 mol of sodium carbonate = 1000 cm$^3$

? = 20 cm$^3$

= 0.125 mol x 20 cm$^3$

1000 cm$^3$

= 0.0025 moles

0.0025 moles of sodium carbonate that reacted with the HCl acid. But to determine the number of moles of HCl acid used, deduce the reacting ratios

Na$_2$CO$_3$ : HCl

1 : 2

therefore

0.0025 moles : ?

= 0.005 moles of HCl acid were used.

d) To determine the concentration of the HCl acid in mol dm$^{-3}$ Relate the 0.005 moles of HCl acid used to the average titre, then determine how many moles would be in 1000 cm$^3$.

0.005 moles of HCl = 22.6 cm$^3$

? = 1000 cm$^3$

= 0.22 mol dm$^{-3}$

concentration of HCl in g dm$^{-3}$

1 mol = 36.5

0.22 mol = ?

= 36.5 g/mol x 0.22 mol

= 8.03 g dm$^{-3}$

**Question:**

In a titration lesson, form 3 students used 12 cm$^3$ of a solution that was made by dissolving 1.6 g of NaOH pellets in 100 cm$^3$ and the solution topped to 1000 cm$^3$ of solution. An average volume of 16.3 cm$^3$ of HCl acid solution was required for complete neutralization.

a) Determine the molarity of the sodium hydroxide solution.

b) Determine the number of moles of sodium hydroxide solution that reacted with the acid.

c) Determine the number of moles of acid used.

d) Calculate the concentration of the acid in (i) mol dm$^{-3}$ (ii) g dm$^{-3}$

**COMBINING VOLUMES OF GASES**

The relationship between reacting volumes of gases is summarized by Gay Lussac's law:

When gases react, they do so in volumes that bear a simple ratio to one another and to the volumes of the product if gaseous, temperature and pressure remaining constant.

**Example**

a) If 40 cm$^3$ of carbon (II) oxide was exploded with oxygen gas, what was the volume of the oxygen gas used?

Reacting ratios

2CO$_{(g)}$ + O$_2(g)$ $\rightarrow$ CO$_2(g)$

40 cm$^3$ : 20 cm$^3$ $\rightarrow$ 20 cm$^3$

volume of oxygen gas used = 20 cm$^3$

b) Ammonia (NH$_3$) can be formed from the gaseous elements of N$_2$ and H$_2$, as in the following equation;
\[
\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})
\]

Supposing there are 3.0 moles each of the N\(_2\) and H\(_2\) available to react, to determine which of the reactants would be the limiting reactant, then deduce the reacting ratios from the equation

\[
\text{N}_2 : \text{H}_2 = 1 : 3
\]

Thus, 3 moles of hydrogen gas, (H\(_2\)) would only react with 1 mole of nitrogen gas, (N\(_2\)) meaning 2 moles of nitrogen gas would be in excess. Hydrogen gas would be the limiting reactant.

**Question**

Harber process involves manufacture of ammonia. How many moles of ammonia could be made if 2000 litres of each gas was used? Would any of the reactants be left over? How many litres would be left if any?
Appendix IV: Chemistry Assessment  Post Test

Introduction

My name is Joseph Kiiru Waruingi, a student at Kenyatta University. I am undertaking a study on “Students' Algebraic Skills in Calculating Reacting Masses in Chemical Equations: A Case of Public Secondary Schools in Nyandarua County, Kenya.” I have identified a list of individuals who play prominent roles in my research subject area. For this reason, I would like to ask for permission to undertake this test. Your participation will be of help for this study and I will be grateful for your participation. The test results and all responses will be kept private, and I will not include any information that will make it possible to identify your school or individual in any report.

Having consented to participate in the study, please complete the test below. Answer all questions. The test takes exactly a 1¾ hour and contains 20 items.

Indicate your gender   a) Male              b) Female

1. Determine the volume of hydrogen gas formed when excess magnesium metal is added to 100cm$^3$ of 1M HCl. ($H=1.0$, $Mg=24.0$, Molar Gas Vol. = 24.0 dm$^3$ at r. t. p)    (5 mks)

2. What's the mass occupied by $12.046 \times 10^{23}$ atoms of iron ($Fe = 56.0$).       (2 mks)

3. What is the mass of 1.05 moles calcium chloride ($Ca=20.0$, $Cl=35.5$).      (3 mks)

4. 8.0g of NaOH pellets were dissolved in 500cm$^3$ of distilled water, determine its concentration in moles/lt. ($Na = 23.0$, $O=16.0$, $H=1.0$)                                        (3mks)

5. Calculate the number of chloride ions 1250 cm$^3$ solution 1M MgCl$_2$

   ($Mg= 24.0$, $Cl=35.5$, $L= 6.0 \times 10^{-23}$).                  (5mks)

6. What is the relative molecular mass of oxygen given that 0.4g of oxygen occupies 280cm$^3$ at s.t.p. (Volume at s.t.p = 22.4 litres, $O=16.0$) (3mks)

7. A volume of 50cm$^3$ of oxygen was exploded in 50cm$^3$ of carbon (II) oxide. Calculate the volume of the residual gas at room temperature.       ($C = 12.0$, $O=16.0$) (5mks)

8. An organic compound A contains 64.9% carbon, 13.5% hydrogen and 21.6% oxygen. The relative formula mass of A is 74 g.         ($C=12.0$, $H=1.0$, $O=16.0$)
(i) Determine the empirical formula of A. (3mks)

(ii) Determine the molecular formula of A. (3mks)

9. When 3.48g of hydrated sodium carbonate \((\text{Na}_2\text{CO}_3\cdot\text{XH}_2\text{O})\) were heated to constant mass, 1.59g of anhydrous sodium carbonate were obtained. Calculate the value of \(x\) in the hydrated carbonate. \((\text{Na}=23.0, \text{O}=16.0, \text{C}=12.0, \text{H}=1.0)\) (5mks)

10. In an experiment, \(40\text{ cm}^3\) of oxygen gas was mixed with \(33\text{ cm}^3\) of hydrogen gas and the mixture heated to form water vapor. Which of the gases was in excess and by how much? (5mks)

11. In an experiment excess aqueous copper(II) sulphate was reacted with 33.6g iron fillings. Calculate the mass of copper that was deposited \((\text{Cu}=63.5, \text{Fe}=56.0)\) (4mks)

12. Calculate the volume of carbon (IV) oxide in cm\(^3\) produced when 25g of calcium carbonate is heated at r.t.p \((\text{Ca}=40.0, \text{C}=12.0,0=16.0)\) (4mks)

13. When 50cm\(^3\) of 2M potassium hydroxide solution was diluted, the final concentration was 0.1M. Calculate the volume of the diluted solution. \((\text{K}=39.0, \text{O}=16.0, \text{H}=1.0)\) (5mks)

14. Form 3 students carried out a redox titration that involved dissolving 9.8 g of an iron (II) salt, \(\text{FeSO}_4\cdot(\text{NH}_4)_2\text{SO}_4\cdot6\text{H}_2\text{O}\) in 250cm\(^3\) of distilled water. 25cm\(^3\) of this solution was transferred into a conical flask and titrated against potassium manganate (VII). An average titre of 24.0cm\(^3\) was obtained. \((\text{Fe}=56.0, \text{S}=32.0, \text{O}=16.0, \text{N}=14.0, \text{H}=1.0)\)

(i) calculate the molarity of the iron (II) salt solution. (3mks)

(ii) calculate the number of moles of iron (II) ions used. (3mks)

(iii) given reaction equation is: \(\text{MnO}_4^-\text{(aq)}+8\text{H}^+\text{(aq)}+5\text{Fe}^{2+}\text{(aq)}\rightarrow \text{Mn}^{2+}\text{(aq)}+5\text{Fe}^{3+}\text{(aq)}+4\text{H}_2\text{O(l)}\) determine:

(a) the number of moles of \(\text{MnO}_4^-\) ions in 24.0cm\(^3\) solution. (3mks)

(b) the molarity of the \(\text{KMnO}_4\) (aq) solution (3mks)

15. When 100cm\(^3\) of Ethene \((\text{C}_2\text{H}_4)\) gas burns in 400cm\(^3\) of oxygen gas, 100cm\(^3\) of oxygen was not used. Determine the volume of carbon (IV) oxide and steam formed. (5mks)

16. Ammonia gas decomposes according to the following equation: \(2\text{NH}_3\text{(g)}\rightarrow\text{N}_2\text{(g)}+3\text{H}_2\text{(g)}\)

Determine the volume of nitrogen and hydrogen produced if 30 litres of ammonia gas is allowed to decompose completely (5mks)
17. When a certain hydrocarbon was burnt in excess oxygen, 5.28 g of carbon (IV) oxide and 2.16g of water were formed. If the molecular mass of the hydrocarbon is 84g, determine the hydrocarbon's molecular formula. (5mks)

18. Calculate the amount of calcium carbonate that would remain if 19.0g of calcium carbonate were reacted with 0.3 moles of hydrochloric acid. (C=12.0, O=16.0, Ca=40.0) (5mks)

19. Yg of sodium hydroxide were dissolved in distilled water to make 100cm$^3$ of solution. 15.0cm$^3$ of the solution required 19.5cm$^3$ of 2M nitric acid for complete neutralization. Calculate the mass of Y in gram (5mks)

20. Determine the empirical formula of a metal oxide P which when 31.8g of its oxide was completely reduced by hydrogen gas, 25.4g of the metal was formed. (M = 63.5, O = 16.0). (5mks)

**ANSWERS TO CHEMISTRY POST TEST**

1. \[ \text{Mg(s)} + 2\text{HCl(aq)} \rightarrow \text{Mg}^{2+}(aq) + 2\text{Cl}^-(aq) + \text{H}_2(g) \]

   - 100cm$^3$ of 1M HCl = 0.1 moles (1mk)
   - moles of \( \text{H}_2(g) \) = 0.1/2 = 0.05 (2mk)
     - but 1mole at rtp 24.0 litres
     - 0.05moles = 1.2 litres. (2mks)

2. 1mole = $6.0 \times 10^{23}$
   - = $12.046 \times 10^{23}$
   - = $12.046 \times 10^{23} \times 1$ mole / $6.0 \times 10^{23}$ (2mks)
   - = 2 moles of iron (1mk)
   - but 1mole = 56g
   - 2moles = 56x2
   - = 112g (2mks)

3. 1mole \( \text{CaCl}_2 = 111g \) (1mk)
   - 1.05moles = ?
     - = $(1.05 \times 111)g$ (1mk)
     - = 116.55g (1mk)

4. Concentration in moles/litre i.e molarity (M)
   - No. of moles = 8g/40g
     - = 0.2 moles (2mks)
     - 0.2moles = 500cm$^3$
     - ? = 1000cm$^3$ (1mk)
     - = 0.4 moles/litre or = 0.4M (1mk)

5. Moles of \( \text{MgCl}_2 = 1250 \times 10^{-3} = 1.25 \) (1mk)
   - No. of chloride ions = $1.25 \times 6.0 \times 10^{23} \times 2$ (2mks)
     - = $1.5 \times 10^{24}$ ions (1mk)

104
6. 22.4 litres = 22,400 cm³
   0.4 g = 280 cm³
   \( x = \frac{22,400}{280} \) (2mk)
   = 0.4 \times 22400
   = 32 g (1mk)

7. \( \text{O}_2(g) + 2\text{CO}(g) \rightarrow 2\text{CO}_2(g) \)
   1 : 2
   25 : 50
   residual gas is oxygen
   by 50 - 25 = 25 cm³ (2mks)

8 (a) (i)
   \[
   \begin{array}{ccc}
   \text{C} & \text{H} & \text{O} \\
   12 & 5.4 & 13.5 & 1.35 \\
   \frac{5.4}{1.35} & \frac{13.5}{1.35} & \frac{1.35}{1.35} & \frac{21.6}{1.35} = 1.35
   \end{array}
   \]
   Ratio = 4
   (ii) Empirical formula = \( \text{C}_4\text{H}_{10}\text{O} \)
   \( 12 \times 4 + 1 \times 10 + 16 \times 1 \times n = 74 \) (2mks)
   \( 74n = 74 \)
   \( n = 1 \)
   Molecular formula = \( \text{C}_4\text{H}_{10}\text{O} \) (1mk)

9. Mass of water 3.48 - 1.59 = 1.89 g (1mk)
   \( \text{Na}_2\text{CO}_3 = (2 \times 23) + 12 + 42 = 106 \)
   \( x = \frac{1.89 \times 106}{18 \times 1.59} = 200.34 \) (3mks)
   \( x = 78.62 \)
   \( x = 78.62 \) (1mk)

10. 2 Moles of \( \text{H}_2(g) \) = 1 mole of oxygen = 2 Moles of \( \text{H}_2\text{O} \)
    \( 2 \) : 1
    \( = 33 \text{cm}^3 \text{ of } \text{H}_2(g) = 16.5 \text{cm}^3 \text{ O}_2(g) = 33 \text{cm}^3 \text{ H}_2\text{O} \) (2mks)
    Oxygen is excess by 40 - 16.5 = 23.5 cm³ (1mk)

11. \( \text{Fe}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Fe}^{2+}(s) + \text{Cu}(s) \)
    Moles of \( \text{Fe} \) (s) = \( \frac{33.6}{56} \)
    ratios 1 : 1 (1mk)
    Moles of \( \text{Cu} \) = 0.6 (1mk)
    Mass of \( \text{Cu} \) = \( 0.6 \times 63.5 \) = 38.1 g (2mks)
12. \[
\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2
\]
ratios \[1 : 1 : 1 \] (1mk)
moles of \( \text{CaCO}_3 \) = \[\frac{25}{100} = 0.25 \text{ moles} \] (1mk)
\[0.25 \text{ moles} : 0.25 \text{ moles} : 0.25 \text{ moles}\]
volume of \( \text{CO}_2 \) = \[0.25 \text{ moles} \times 24000 \text{ cm}^3\] (1mk)
\[= 6000 \text{ cm}^3\] (1mk)

13. \[M_1V_1 = M_2V_2\]
\[M_1 = 2 \text{ M}, \quad V_1 = 50 \text{ cm}^3, \quad M_2 = 0.1 \text{ M}, \quad V_2 = x\]
\[V_2 = 2 \times 50 \text{ cm}^3\] (3mks)
\[= 0.1 \text{ cm}^3\]
\[V_2 = 1000 \text{ cm}^3\] (1mk)

14. (i) Moles of iron (II) in \[250 \text{ cm}^3 = \frac{9.8}{392} = 0.025 \text{ moles}\] (1mk)
\[0.025 \text{ moles} = 250 \text{ cm}^3\]
x = \[1000 \text{ cm}^3\]
x = \[0.025 \times 1000\] (1mk)
\[= 250 \text{ cm}^3\]
Molarity = \[0.1 \text{ moles} / 1000 \text{ cm}^3 = 0.1 \text{ M}\] (1mk)
(ii) \[0.1 \text{ moles} = 1000 \text{ cm}^3\] (1mk)
x = \[25 \text{ cm}^3\]
\[= 0.1 \text{ moles} \times 25 \text{ cm}^3\] (1mk)
\[= 0.0025 \text{ moles}\] (1mk)
(iii) a mole ratios \[1 : 5\] (1mk)
x = \[0.0025\]
\[= 0.0025 \times 1\] (1mk)
\[= 0.0025 \text{ moles}\] (1mk)
b \[0.0005 \text{ moles} = 24 \text{ cm}^3\] (1mk)
x = \[1000 \text{ cm}^3\]
\[= 0.0005 \text{ moles} \times 1000 \text{ cm}^3\] (1mk)
\[= 24 \text{ cm}^3\]
Molarity = \[0.002 \text{ M}\] (1mk)

15. \[\text{C}_2\text{H}_4 + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O}\]
\[1 : 3 : 2 : 2\] (2mks)
using mole ratios;
\[100 \text{ cm}^3 : 300 \text{ cm}^3\]
\[200 \text{ cm}^3 : 200 \text{ cm}^3\] (1mk)
\[\text{volume of CO}_2 = 200 \text{ cm}^3\] (1mk)
\[\text{volume of water} = 200 \text{ cm}^3\] (1mk)
16. \[2NH_3 \rightarrow N_2 + 3H_2\]

ratio \[\frac{2}{3} : \frac{1}{3} : 1\] (1mk)

30 lts : 15 lts : 45 lts (1mk)

but 1 litre = 1000 cm$^3$

hence 15 litres = 15 x 1000 cm$^3$

= 15,000 cm$^3$ of nitrogen gas (1mk)

and 45 lts x 1000 cm$^3$

= 45,000 cm$^3$ of hydrogen gas (1mk)

17. Products: CO$_2$, H$_2$O

<table>
<thead>
<tr>
<th></th>
<th>CO$_2$</th>
<th>H$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>5.28</td>
<td>2.16</td>
</tr>
<tr>
<td>Formula mass</td>
<td>44</td>
<td>18</td>
</tr>
</tbody>
</table>

No. of moles = \[\frac{5.28}{44} = 0.12\]
\[\frac{2.16}{18} = 0.12\] (1mk)

Mole ratio = \[\frac{1}{1} : \frac{1}{1}\] (1mk)

Mass of carbon \[\frac{12}{44} \times 5.28 = 1.44\]
Mass of hydrogen \[\frac{2}{18} \times 2.16 = 0.24\] (1mk)

No of moles \[\frac{1.44}{12} = 0.12\]
\[\frac{0.24}{1} = 0.24\]

Mole ratio \[\frac{0.12}{0.12} = 1\]
\[\frac{0.24}{0.24} = 2\] (1mk)

Empirical formula is CH$_2$ (1mk)

\[(CH_2)_n = 84\]
\[(12 + 2)n = 84\]
\[n = 6\]

Therefore, the molecular formula of the hydrocarbon is C$_6$H$_{12}$ (1mk)

18. 1 mole CaCO$_3 : 2$ moles of HCl (1mk)

Therefore \[\frac{1}{2} \times 0.3 = 0.15\] mole CaCO$_3 = 0.3$ Mole HCl (1mk)

CaCO$_3 = 40 + 12 + 48 = 100$ g (1mk)

Therefore 19g CaCO$_3 = \frac{19}{100} = 0.19$Moles (1mk) 100g

Excess moles \[0.19 - 0.15 = 0.04\]moles (1mk)

Excess mass \[0.04 \times 100 = 4.0\]g (1mk)

19. Moles of nitric acid = \[\frac{19.5 \times 2}{1000} = 0.039\] moles (1mk)

Moles of NaOH in 15 cm$^3 = 0.039$ (1mk)

moles of NaOH in 100 cm$^3 = \frac{0.039 \times 100}{107} = 0.26$moles (1mk)
mass (Y g) of NaOH = \(0.26 \times 40\) (1mk)
=10.4g (1mk)

20. Mass of oxygen = 31.8 – 25.4 = 6.4 (1mk)

\[
\begin{array}{ccc}
\text{M} & \text{O} \\
25.4 & = 0.4 & 6.4 \\
63.5 & = 0.4 & 16 \\
0.4 & = 1 & 0.4 \\
0.4 & = 1 & 0.4 \\
1 & = 1 & 1
\end{array}
\]

Formula = MO (1mk)
Appendix V: Performance Results in Mathematics and Chemistry Pre- and Post- Tests by Experimental and Control Groups

### Experimental Groups (E1 and E2)

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<thead>
<tr>
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<th>GENDER</th>
<th>MATHS TEST</th>
<th>CHEM PRE TEST</th>
<th>CHEM POST TEST</th>
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<th>MATHS TEST</th>
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Female = 22 , male =26 TOTAL =48

FEMALE= 15, MALE =24, TOTAL = 39
Appendix VI: Budget For The Research Project
1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.

2. Government Officers will not be interviewed without prior appointment.

3. No questionnaire will be used unless it has been approved.

4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.

5. You are required to submit at least two (2) hard copies and one (1) soft copy of your final report.

6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.
Appendix VII: Research Authorization Letter by NACOSTI

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Ref: No. NACOSTI/P/16/0734/7795

Date: 18th February, 2016

Joseph Wanuntingi Kiiu
Kenyatta University
P.O. Box 43844-01000
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on “Algebraic computational ability in the calculation of reacting masses from chemical equations among public secondary school students in Kinangop Sub County, Nyandarua County, Kenya” I am pleased to inform you that you have been authorized to undertake research in Nyandarua County for a period ending 17th February, 2017.

You are advised to report to the County Commissioner and the County Director of Education, Nyandarua County before embarking on the research project.

On completion of the research, you are expected to submit two hard copies and one soft copy in pdf of the research report/thesis to our office.

DR. S. K. LANGAT, OGW
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nyandarua County.

The County Director of Education
Nyandarua County.
MINISTRY OF EDUCATION SCIENCE AND TECHNOLOGY
State Department Of Education
E-mail: kinangopedu@gmail.com
Telephone 051-8063724

SUB-COUNTY EDUCATION OFFICE
KINANGOP SUB-COUNTY
P.O BOX 92
SOUTH KINANGOP
18TH FEBRUARY 2016

REF: KIN/ED/GEN/2633

JOSEPH WARUINGI KIRU
KENYATTA UNIVERSITY
P.O. BOX 43844-01000
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your request to research on 'Algebraic Computational Ability In The Calculation Of Reacting Masses From Chemical Equation Among Public Secondary School Students In Kinangop Sub county Nyandarua County, Kenya, Authority is hereby granted to undertake the research in Kinangop Sub County for a period ending 17th February 2017

NJUGUNA J.A.
SUB-COUNTY DIRECTOR OF EDUCATION
KINANGOP SUB-COUNTY
Appendix IX: Map of Kinang'op Sub-County