Evaluating problem solving strategies used by grade 11 and grade 12 physical science learners in Highveld ridge East and West circuits when solving stoichiometry problems

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Abstract
The aims of the study was to determine the relationship between conceptual and algorithmic problem solving achievement among grade 11 and 12 Physical Science learners in Highveld Ridge East and West circuits, compare the percentage of perfectly and incorrect solutions, problems not attempted and establish the problem solving strategies used by grade 11 and 12 learners. The target populations were grade 11 and 12 Physical science learners in Highveld Ridge East and West circuits; stratified random sampling was used to select schools and 61 scripts from each grade. An achievement test was administered at schools and scored by the researcher. Pearson moment coefficients at alpha 0.05 indicated that the relationship between algorithmic and conceptual achievement was weak and a moderate for grade 11 and 12 learners respectively and it was also established that Highveld Ridge East and West learners were weak in both conceptual and algorithmic problem solving. Since these results were found using a cross sectional design it is recommended that the same study be done using a longitudinal design and further studies can be done in other topics to establish the low algorithmic and conceptual problem solving achievement is universal or restricted to stoichiometry only.
Key words: Conceptual, Algorithmic, Problem solving, Stoichiometry, Achievement

1.1 Introduction

One of the educational techniques that can improve learners' understanding at a relatively cheap cost in any environment is problem solving. This technique can be broadly divided into two categories namely algorithmic and conceptual problem solving strategies. The aim of this study is to determine the relationship between algorithmic and conceptual problem solving achievement, compare the percentages of correct, incorrect and unattempted algorithmic and conceptual stoichiometry problems in order to be able to evaluate the effects of problem solving strategies on achievement in stoichiometry problems.

Stoichiometry is the branch of Chemistry that is focuses on determining the amount of substances used, formed, the limiting reagent in a chemical reaction. The aims of problem solving in stoichiometry are to clarify and reinforce concepts, principle, laws and to improve learners' competence in strategies and procedures (Selvaratnam and Canagarama, 2008). However, Caroline et al (2008) found out that there was minimal relationship between understanding of stoichiometry and problem solving. Potgieter and Davidowitz (2010) reported that inadequate and incorrect conceptual knowledge prevents learners from solving stoichiometry problems. Pickering (1990) reported that over-reliance on using algorithms impedes successful problem solving in stoichiometry .On the contrary Yarroch et al (1985) found that learners who use algorithmic problem solving strategies can get correct numerical answers without applying content knowledge. Lythcott (1990) reported that exposure to algorithmic problem solving strategies increases the percentages of perfectly correct solutions and totally incorrect solutions.

In Mpumalanga where Highveld Ridge East and West circuits are situated Mphachoe claimed the Matriculation class of 2010 solved algorithmic and conceptual stoichiometry problems poorly. However a combination of algorithmic and conceptual problem solving is likely to improve stoichiometry achievement.

1.2 Problem Statement

For the past six years teaching Physical Science the researcher has noticed that learners were struggling to solve stoichiometry problems and has tried using the mole, proportional method, but, the difficulties remained. McFate & Olmsted (1999) found that learners lack problem solving skills and strategies. Bodner (1991) urged that there is a discrepancy between conceptual understanding and algorithmic problem solving. The National Curriculum Statement Policy in South Africa stipulates that Physical Science learners should able to solve problems (NDoE, 2002).However, Mphachoe (2009) after moderating the National Curriculum Statement examination (Physical science paper 2) in Mpumalanga province noticed that learners struggled to solve algorithmically and conceptual stoichiometry problems. Potgieter and Daviowitz (2010) reported that first year tertiary students performed poorly in stoichiometry. This was confirmed by Potgieter, Rogan and Howie (2005) and Potgieter et al (2005). While examining students' misconceptions in chemical equilibrium Huddle and Pillary (1996) found students unsuccessfully answered chemical equilibrium problems because they fail to apply stoichiometry concepts.

1.3 Aims and Objectives

The aims of this study was to evaluate problem solving strategies used by grade 11 and 12 learners in Highveld Ridge East and West when solving stoichiometry problems hence the objectives of this study were:

1. To determine the relationship between conceptual and algorithmic problem solving achievement.
2. To compare the percentage of perfectly correct and incorrect solutions, percentages of problems not attempted between algorithmic and conceptual problems.
3. To identify weaknesses in stoichiometry problem solving.

1.4. Significance of the Study

Evaluating problem solving strategies used by learners when solving stoichiometry problems will enable educationists to identify problem solving strategies that led to low achievement in stoichiometry, hence avoid reinforcing them. Comparing the success rate between grade 11 and grade 12 learners will inform curriculum developers whether teaching basics stoichiometry concepts in grade 10, 11 and applying them in grade 12 promotes or hinders problem solving in stoichiometry. In an effort to improve Physical Science Matriculation results, content enrichment workshops are conducted every year at the expense of pedagogical content. The results of this study can convince the Department of Education that content and strategies are integral parts of teaching and learning and teachers should be developed in these aspects. Establishing the relationship between algorithmic and conceptual problem solving strategies and achievement will enable Physical Science educators to choose a better problem solving strategy between algorithmic, conceptual or a combination of the two strategies when teaching stoichiometry.

1.5 Algorithmic and Conceptual Problem Solving Achievement

Yarroch (1985) found that the success rate for algorithmic problems solving was 100% while for conceptual problem solving was 58%. Pickering (1990) found that 95% of the learners solved algorithmic problems and 40% solved conceptual problems while Nakhleh (1993) found that 30% had high algorithmic and low conceptual problems solving proficiency, 50% had high algorithmic and conceptual problem solving proficiency, 10% had conceptual and low algorithmic problem solving proficiency and finally 10% had low algorithmic and conceptual problem solving proficiency. Alp (2007) and Chui (2002) reported that there was no statistical significant difference between algorithmic and conceptual achievement.

BouJaoude and Barakat (2000) concluded that lack of conceptual understanding causes learners to rely on algorithmic strategies and this was confirmed by Bodner and Herron (2002), and Caroline et. al, (2008). The studies cited above shows that there is no agreement on algorithmic and conceptual problem solving achievement.

1.6 Factors that Affect Problem Solving in Stoichiometry

Potgieter and Davidowitz (2010) acknowledged that stoichiometry is poorly mastered by students. This was confirmed by Glazar and Devetak (2002) who found that 46% of students solve stoichiometry problems correctly while 4% of the students did not attempt to solve stoichiometry problems and Frazer and Servant (1986, 1987) who reported that only 27% of the students solved stoichiometry problems successfully. Gamcho and Good (1989) also reported that there is a discrepancy between the desired performance and the actual performance in stoichiometry. However, Davidowitz et al (2010) noted a constant improvement in stoichiometry problem solving among tertiary students in South Africa.

Poor performance in stoichiometry is a result of a number of factors. According to Gunstone and Mitchell (1990) learners are unable to unable to calculate the molar mass because they sum up the atomic masses of the elements in the compound and either divide or multiple their answers by the coefficient. On the other hand Parchmann et al(2003) found that learners assume that the limiting reagent in a chemical reaction is the reactant with the lowest stoichiometric coefficient or they determine the number of moles and assume that the reagent with the least number of moles is the limiting reagent. Herron (1975) attributed poor performance in stoichiometry to lack of understanding of the mole concept while Taber & Bricheno (2009) reported that learners fail to solve stoichiometry problems because they lack conceptual resources to balance and interpret chemical equation.

Greenbowe (1983) found that successful problem solvers in stoichiometry use symbols, microscopic and macroscopic representation to understand the problem and that problem solving is affected by knowledge of facts, working memory load and problem representation.

Problem solving strategies used when solving stoichiometry

Toth (2004) found that learners use their own strategies to balance chemical equations and solve stoichiometry problems while Schmidt and Jigneus (2003) reported that successful problem solvers use their own strategies to solve easy stoichiometry problems and algorithmic strategies to solve difficulty problems. However, Toth and Sebestyen (2009) reported that learners who used unidentified problem solving strategies perform poorly.

Chiu and Taiwan (2002) reported conceptual and algorithmic achievement in stoichiometry problems was the same. On the contrary Gabel and Sherwood (1983) reported that successful problem solvers use algorithmic strategies more frequently than unsuccessful problem solvers and Manson (1994) contradicted the latter by reporting that algorithmic problems are frequently answered correctly by experts and novices. Toth and Sebestyen (2009) found that learners use the mole method and proportional methods in solving easy and difficulty stoichiometry problems and that there was no meaningful difference between in performance. On the contrary Gabel and Sherwood (1983) found that learners who used the proportional method in solving stoichiometry problems performed lower than learners who used the factor-label method, analogies and diagrams. Literature on stoichiometry problem solving does not agree on the effects of conceptual and algorithmic problem solving strategies on achievement. Some of the reasons for low achievement in stoichiometry problem solving in this study are failure to understand the mole concept, interpret chemical equations and lack of formal reasoning.

1.7 Research Design

The aim of this study was to evaluate problem solving strategies used by grade 11 and 12 Physical Science learners when solving stoichiometry problems. In order to attain this aim it was necessary to obtain algorithmic and conceptual problem solving achievement scores from grade 11 and 12 learners in their natural environments. In addition the learners were classified according to the problem solving strategies they used and the effects of these strategies on achievement established as well as to compare the percentage of correct, totally incorrect and unattempted problems for algorithmic and conceptual problems. Thus quantitative and qualitative methods were used to analyse the results and a causal correlation design was used in this study. A correlation design is a design in which variables are not manipulated and a relationship between variables exists if the scores of one variable are associated with the scores of the other variable.

1.8 Subjects

Highveld East and West are circuits in Mpumalanga province. In these circuits are five high schools situated in towns and ten high schools in townships. The Physical Science learners in these circuits are blacks, whites, Indians coloureds and they come from the low class, middle class and high class. There are about 2500 grade 11 and 1300 grade 12 learners studying Physical Science in these circuits.

At two schools learners studying Physical Science are learners who had attained 50% and above in Mathematics and Natural science in grade 9. At one school, Physical Science is compulsory and at the remaining thirteen schools, learners' choice to study Physical Science or not. Learners who obtain above 30% at the end of the year are promoted to the next grade; however, some of the learners are condoned to the next grade.

At two schools Africans is the medium of instruction, at two other schools English and Afrikaans are the medium of instruction and at the remaining schools taught is the medium of instruction. However English is the second language for the majority of the learners studying Physical Science.

1.9 Sampling

Stratified sampling was used to select one town school and three township schools to participate in this study and to select 61 scripts from grade 11 and 62 scripts from grade 12 for scoring. Stratified sampling was used because a representative sample will be obtained and this enables the researcher to use parametric tests which are powerful and to generalize the results of the sample to the population.

1.10 Instrument

1.11 Development of the Instrument

An achievement test was used because problem solving is an internal process, hence proficiency in problem solving can only be inferred from the problem solvers' behaviour.

The content of the test was derived from the Physical Science national curriculum statement grade 10-12 general guidelines (June 2006).The test had nine (9) paired problems. The first part of each problem tested learners' ability to solve algorithmic problems and the second part tested learners' abilities to solve conceptual problems. The total marks for the test was 52.

1.12 Validity of Instrument

Instrument validity is the degree to which the instrument measures what it intends to measure. This is important because a valid instrument will provide valid data which leads to valid conclusions. Content validity is how appropriate the test is. In this case the content of the test was derived from the national curriculum statement grade 10 -12 (General) and questions were selected using Bretz, Smith and Nakhleh (2004) framework in Bruck and Towns (2009) see table below

Table 1: Classification of test items according to Bretz, Smith and Nakhleh (2004) framework

Question number	**Description in terms of Bretz, Smith and Nakhleh (2004) framework**
1.1	Algorithmic multi-step
1.2	Analysis of pictorial representation
2.1	Algorithmic microscopic-symbolic conversion
2.2	Explanation of underlying ideas.
3.1	Algorithmic multi-step
3.2	Analysis of pictorial representation
4.1	Algorithmic multi-step
4.2	Explaining underlining ideas
5.1	Algorithmic multi-step
5.2	Explaining underlining ideas
6.1	Algorithmic multi-step
6.2	Analysis of data
7.1	Algorithmic multi-step
7.2	Predicting outcomes
8.1	Algorithmic unit conversion of macroscopic quantities
8.2	Prediction of outcomes

9.1	Algorithmic microscopic-symbolic conversion
9.2	Interpretation of data

The test was sent to a Lecturer of chemistry and a Chemistry Doctorate student who is currently teaching Physical science at F.E.T phase. The instrument was adjusted in line with their recommendations.

1.13. Reliability of Instrument

Reliability is the consistency of the research instrument ie the extent to which the same result is obtained if the same instrument was utilized under the same conditions. In this study reliability was established by half-split. The problems were divided into two halves as shown in the table below and the scores of each half split were used to determine reliability which was 0.91.

	Questions in group
First half	1.1, 2.2, 3.1, 4.2, 5.1, 6.2, 7.1, 8.2, 9.1
Second half	1.2, 2.1, 3.2, 4.1, 5.2, 6.1, 7.2, 8.1, 9.2

1.14 Procedures

Permission was obtained from the Mpumalanga Department of Education and from Principals of four schools where the test was to be administered. The researchers then seek for cooperation from teachers' grade 11 and 12 Physical science teachers from the chosen schools. The researcher discussed with the teachers the aims, the importance of the study, emphasized the need to stick to standard procedures of administering a test, to inform learners of their right to participate in the study and to completing the consent. The test was administered to grade 11 and grade 12 learners at their respective schools by their Physical science teachers during the last week of August. At the end of the test, teachers withdrew the papers to avoid contamination. The test was scored by the researcher. A mark was given for each correct answer for both conceptual and algorithmic problems and for algorithm problems two marks were awarded for providing the correct procedure and one mark for an impartially answer. For conceptually questions two marks were awarded providing the correct explanation and one mark for an impartially explanation. No marks were awarded for incorrect answers, procedures and explanations.

1.15 Data Analysis

The data of the study was analyzed quantitatively and qualitatively. The advantages of quantitative data analysis are that the results can be generalized, facilitates comparison across categories and eliminate subjectivity of judgments. Qualitative data analysis helps to describe, explain and to explore trends.

1.16 Descriptive Data Analysis

Table 1 below provides the descriptive statistics of means, standard deviations and minimum scores, maximum scores, possible scores and Pearson coefficients.

Table 2: Means, Standard deviations, Minimum scores, Maximum scores, highest possible scores and Pearson coefficients.

Grade	Type of problem	Maximum score	Minimum Scores	Mean	SD	r
11	Algorithmic	76.92%	0%	0.07%	3.18	0.11
	Conceptual	26.92%	0%	0.00%	1.70	
12	Algorithmic	80.77%	3.85%	37.83%	5.22	0.37
	Conceptual	34.62%	0%	17.59%	2.72	

For grade 12 the highest score for algorithmic and conceptual problem solving were 20 and 6 and the lowest scores were 1 and 0 out of 26 respectively. The means for algorithmic and conceptual problem solving were 9.84 and 4.57 respectively with standard deviations of 3.18 and 1.70. For grade 11 the highest score for algorithmic and conceptual problem solving problems were 20 and 7 and the lowest scores was 0 with means of 2.10 and 1.39 respectively. The Pearson moment of coefficients between algorithmic scores and conceptual for grade 11 and 12 are 0.11 and 0.37 respectively. There is a minimal relationship between algorithmic and conceptual problem solving achievement among grade 12 learners and is non existent among grade 11 learners.

1.16 Inferential Statistics

Pearson correlation was used because it takes into account each and every score in both distributions and is the most stable measure of correlation (Gay & Airasian, 1992).
The t-test for Pearson correlation coefficient was used and the results are summarized in table 2 below.

Table 3: Results of t-test for Pearson (r) correlation coefficient

Aspect being tested	r	Degree of freedom	t-value	Critical value
Algorithmic and conceptual achievement for grade 11	0.11	59	0.85	2.00
Algorithmic and conceptual performance for grade 12	0.37	59	3.06	2.00

$p>0.05$

The t-value for grade 11 shows that there is insignificant evidence to correlate algorithmic proficiency with conceptual proficiency of the population and for grade 12 there is significant evidence to correlate algorithmic proficiency with conceptual proficiency of the population.

1.17 Qualitative Analysis

Learners were classified on the basis of their algorithmic and conceptual achievements. Scores were classified as low (L) for less than 50% and high (H) for scores above 50%.

LC → Low conceptual achievement
HC → High conceptual achievement
LA → Low algorithmic achievement
HA → High algorithmic achievement

Table 3 below summarizes the problem solving categories of the learners in stoichiometry problem solving.

Table 3: Classification of learners according to problem solving proficiency

Category	Number of learners in grade 11	Number of learners in grade 12	Total number of learners
LA and LC	60	41	101
HA and HC	0	0	0
HA and LC	1	20	21
HC and LA	0	0	0

According to the table, 82%,17.21%, 0% and 0% of the students were classified as having the following problem solving abilities; low algorithmic and conceptual, high algorithmic and low conceptual problem, high conceptual and high algorithmic and final low algorithmic and high conceptual respectively

The percentages of learners who provided perfectly correct solutions, completely incorrect solutions and did not attempt to provide solutions for algorithmic and conceptual problems were calculated for each grade and the results are summarized in table 4 below.

Table 4: Percentages of learners who provide perfect solutions, totally incorrect solutions and no solutions for algorithmic and conceptual problems

Grade	11	12	Total
% of perfect algorithmic solutions	4.01	26.78	15.39
% of incorrect algorithmic solutions	38.07	34.06	36.07
% of algorithmic problems not attempted	48.27	13.84	31.06
% of perfect conceptual solutions	1.64	0.05	11.64
% of incorrect conceptual solutions	37.39	44.63	40.98

% of conceptual problems not attempted	52.64	27.87	40.26

40.98% and 38.07% of the learners answered conceptual and algorithmic problems incorrectly and 40.26% of the learners did not attempt conceptual problems. The lowest percentage (11, 64%) was for learners who provided perfectly correct conceptual solutions. More grade 12 learners compared to grade 11 learners provided perfectly correct algorithmic solutions.

1.18 Discussions

In this study it was found that relationship between algorithmic problem solving achievement and conceptual problem solving achievement for grade 11 learners was weak and moderate for grade 12 learners. This contradicted Chui (2002) and Alp (2007) and Yarroch (1985) who found that there was no statistical significant difference between algorithmic and conceptual performance. However, these results contradict the results reported by Chiu and Taiwan (2000) that algorithmic and conceptual achievements were the same and Nurrenburg and Pickering (1987) who reported higher conceptual achievement compared to algorithmic achievement.82% of the learners had low algorithmic and conceptual achievements, 17.2% had high algorithmic and low conceptual achievement and 0% had low algorithmic and high conceptual achievement as well as high algorithmic and high conceptual achievement. These results contradict Pickering (1990) who found that 50% learners had high achievement in both algorithmic and conceptual problems, followed by 30% who had high achievement in algorithmic problems and low achievement in conceptual problems and 10% who had high achievement in conceptual problems and low achievement in algorithmic problems as well as 10% who had low achievement in algorithmic problems and low achievement in conceptual problems. In addition these results contracted Chui and Taiwan (2002) who reported high achievement in algorithmic and conceptual problems.

The percentage of incorrect solutions and problems not solved were higher for conceptual and algorithmic problems compared to the percentage of correct solutions. The high percentage of incorrect solutions obtained in this study agrees with the results reported by Lythcott (1990). However the low percentage of correct solutions contradicts the high percentage of correct solutions that was reported by Lythcott (1990). The percentage of perfectly correct solutions for grade 12 algorithmic problems was higher than for grade 11. This result confirms the study done by Sweller (1989) and Manson (1984) who reported that there was a positive correlation between frequency of encountering worked problems and the duration of encounter. In addition the result of the current study confirms the results that were reported by Siegler (2003), who found that problem solving proficiency is enhanced by practice.

In this study 51% and 44% of the learners answered algorithmic and conceptual problems respectively. This result contracts the study done by Mason (1994) who found that learners answer algorithmic problems more frequently compared to conceptual problems. Learners fail to answer problem 1.2, 4.2 and 3.2 revealing that they have poor interpretation of diagrams. This confirms the results of Gabel (1999) and contradicts Gabel and Sherwood (1983) who reported that learners who used learners who used diagrams perform better than those who use the proportional method. Finally, solutions to problem 1.2, 3.2 and 4.1 show that learners have limited understanding of subscripts and coefficients as was reported by Robinson (2002).

1.19 Weaknesses

The weaknesses of this study are drawing conclusions from observations made once and that tests make some learners anxious thereby underperforming.

1.20 Implications

Every year the final Matriculation examination test learners to calculate equilibrium constants. These problems require learners to apply algorithmic and conceptual problem solving strategies. As the situation is Highveld Ridge learners are likely to perform poorly in chemical equilibrium Low proficiency in solving stoichiometry problems will also affect the performance of these learners at tertiary and workplaces.

1.21 Recommendations

This study was cross sectional, it is recommended that the same study be conducted using a longitudinal design**.** Mphachoe (2009) reported low proficiency in solving stoichiometry problems as well as this study. It is high time to determine the cause of low proficiency in stoichiometry problem solving. Lastly it is recommended that Highveld Ridge East and West circuits should conduct content enrichment as well as pedagogical workshops in stoichiometry.

1.22 Reference

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Stoichiometry test

Task	Stoichiometry test
Duration	60 minutes
Grade	11 & 12
Examiner	TIGERE EDWIN
Total	52

Instructions and information

1. Answer all questions.
2. Number your answers correctly according to the numbering system used in this questionnaire.
3. Give a reason or show your working on the space provided.
4. Do not write your name on your answer script. Write the name of your school, your Grade, location of your school (Low density or High density)

RELATIVE ATOMIC MASSES

C: 12 O: 16 N: 14 Cl: 35.5 S: 32 Ca: 40
H: 1 Ag: 107.87

FORMULA

$C = m/v$
$n = m/M$

$$\frac{n_a}{n_b} = \frac{C_aV_a}{C_bV_b}$$

CONSTANTS

Volume of mole of a gas at STP =22,4dm^3
Avogadro's constant = 6, 02 x 10^{23}

QUESTION 1

1.1 Balance the following chemical equation and show how you balanced the equation:

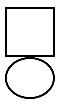
$N_{2\,(g)} + H_{2\,(g)} \longrightarrow NH_{3\,(g)}$ (2)

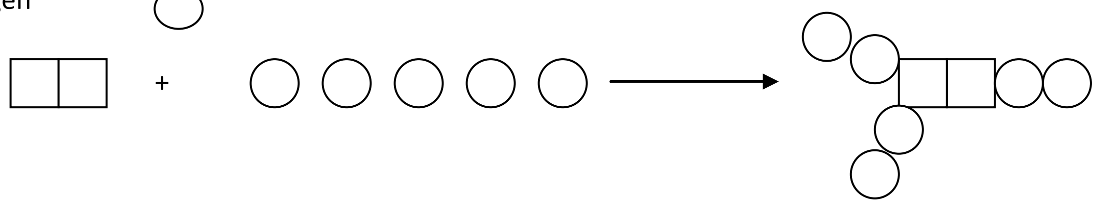
1.2 Which of the following diagrams represents a balanced chemical equation of a reaction between nitrogen (N_2) and hydrogen (H_2)? Give a reason for your answer. (2)

KEY

Nitrogen

Hydrogen





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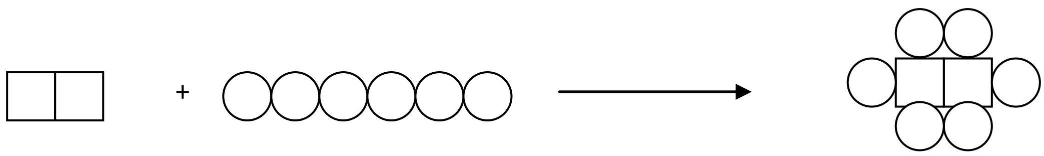

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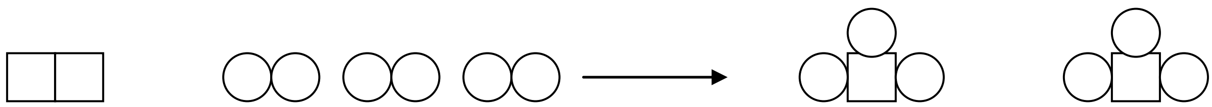

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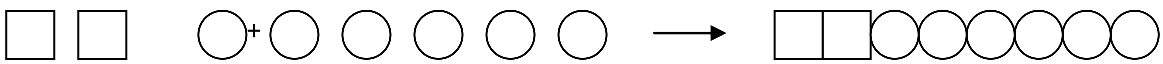


QUESTION 2

2.1 Which one of the following contains equal number of atoms as in 8 grams of oxygen (O_2)? Show how you have arrived at your answer above.

A. 0, 4 moles N_2 gas at STP
B. 11.2 litres of CO gas at STP
C. 1.2 grams of carbon
D. 5.6 litres of Cl_2 at STP

.

2.2. Gases X and Y occupy the same volume at volume at standard pressure and temperature. Which one of the following is true for gases X and Y? Explain your answer.

A. They have equal masses
B. They have equal molecular masses
C. They are the same gases
D. They contain equal number of atoms.

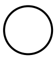
QUESTION 3

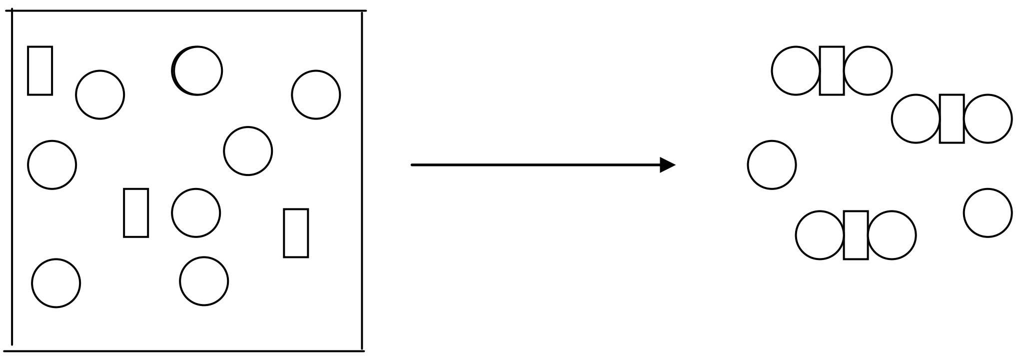
3.1 The equation below shows the reaction between hydrogen and oxygen;

$2H_{2\,(g)} + O_{2\,(g)} \longrightarrow 2H_2O_{(g)}$

A mixture has 2 moles of H_2 and 2 moles of O_2. What is the limiting reagent. Show how you have arrived at your answer.

3.2 The diagram below represents a chemical reaction between element A and B

A =  B = 



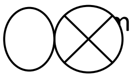
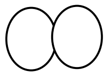
Write a balanced equation for the above reaction.

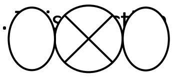
QUESTION 4

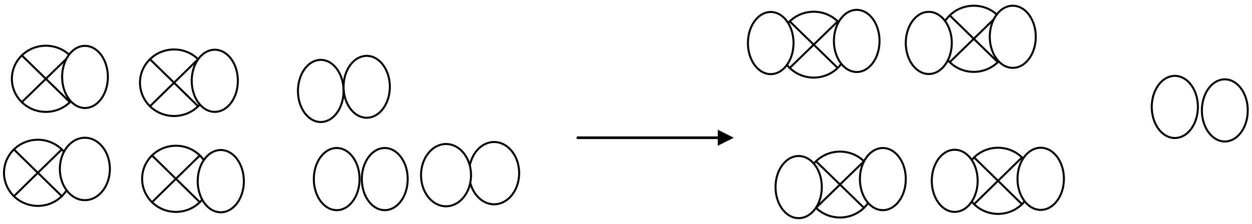
4.1 The balanced chemical equation below shows a reaction between ammonia oxygen.

$4NH_{3\,(g)} + 5O_{2\,(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(l)}$

If 750g of ammonia and 750g of oxygen are reacted, which reagent will be the limiting reagent? Show how you arrived at your answer.

4.2 Four molecules of  mixed with three molecules of 

And they react to form . This reaction is represented below.



Which molecule is the limiting reagent in the reaction above? Explain how you arrived at your answer.

QUESTION 5

5.1 When methane is burnt in oxygen, the reaction produces carbon dioxide, water and heat. Below is an equation for this reaction.

$CH_{4\ (g)} + 2O_{2\ (g)} \longrightarrow CO_{2\ (g)} + 2H_2O_{\ (l)}$

How many grams of water will be produced if 20g of methane are burnt in excess oxygen? Show your working.

5.2.1 If 15g of coal is burnt in excess oxygen. What will be the relationship between the mass of the reactants and the mass of the products? Explain your answer.

QUESTION 6

6.1 70 cm^3 of sodium hydroxide solution of concentration 0, 18 mol dm^{-3} reacted completely with 30 cm^3 of a solution of sulphuric acid.

$2NaOH_{\ (aq)} + H_2SO_{4\ (aq)} \longrightarrow Na_2SO_{4\ (aq)} + 2H_20_{(l)}$

What is the concentration of the sulphuric acid used? Show your working.

6.2.1 Hydrochloric acid solution (HCl) is titrated by sodium hydroxide solution (NaOH). It was found out that 20ml of hydrochloric acid of concentration of 0,1moldm^{-3} is neutralized by X ml of sodium hydroxide solution of concentration 0.1moldm^{-3}.If the same 0.1mol.dm^{-3} of sodium hydroxide is used to titrate to 10ml of 1mol.dm^{-3} of trioxonitrate (V) solution (HNO_3), Yml of sodium hydroxide solution is needed. What is the relationship between X and Y

QUESTION 7

7.1 If 500g of sulphur (IV) oxide (SO_2) is burnt in air (O_2)

$2SO_{2\ (g)} + O_{2\ (g)} \longrightarrow 2SO_{3\ (g)}$

What is the mass of oxygen that is used in this reaction? Show your working.

7.2 A 2.392 grams sample of an unknown chloride with a formula MCl_3 is dissolved in water and treated with excess silver nitrate solution. The mass of the silver chloride (AgCl) precipitate formed is 5.168g. What is the relative atomic mass of the unknown metal (M)?

QUESTION 8

8.1 Use the following equation

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{(l)}$$

If 11.2g of $CaCO_3$ is reacted with 3 moles of HCl, what is the volume of CO_2 produced at standard conditions?

8.2 If the same mass of $CaCO_3$ is reacted with 3 moles of tetraoxosulphate (VI) acid (H_2SO_4). Will the volume of carbon dioxide produced in this case be greater than, smaller than or equal to the volume of carbon dioxide calculated in 8.1? Give a reason for your answer. (2)

QUESTION 9

Use the information in the passage below to answer question 9.1 and 9.2

A group of learners reacted hydrochloric acid and magnesium powder to investigate one of the factors that affect the rate of reaction. The equation below shows the reaction that took place:

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

During the investigation the learners followed the procedure outlined below.

Method

Experiment 1:

Step 1: Place a spatula of magnesium powder in a conical flask and add 50cm^3 of hydrochloric acid (HCl aq) of known concentration.

Step 2: Simultaneously start the stopwatch and close the flask with the rubber stopper carrying a delivery tube.

Step 3: Measure the volume of the hydrogen (H_2) gas formed in time interval of 20 seconds.

Experiment 2:

Step 1: Repeat steps 1 and 3 above, but use only 25cm^3 of the same hydrochloric acid diluted to 50cm3 with distilled water.

RESULTS

Time	0	20	40	60	80	100	120
Experiment 1	0	32	52	60	60	60	60
Experiment 2	0	26	30	42	50	57	60

9.1 How does the concentration of the acid used in experiment 2 differ from the concentration of the acid used in experiment 1?

9.2 Give a reason why the final volume of gas produced in the two experiments is the same.

Memorandum

1.1 Step 1

$N_2 + H_2 \longrightarrow NH_3$

Step 2

Left side	Right side
H = 2	H = 3
N = 2	H = 1 (1 mark)

Step balancing the left side and the right side

Left side	Right side
H = 3 x 2	H = 2 x 3
N = 1x 2	H = 2 x 1 (1 mark)

1.2 Answer C (1 mark)

Explanation

The number of atoms on the left side is equal to the number of atoms on the right side (1 mark) and on the left side the diatomic nature of hydrogen and nitrogen is shown (1mark).

2.1 Answer D (1 mark)

Working

n= m/M

= 8/(16 x 2) = 0.25 moles

Number of moles in 0.25 moles

$0.25 \times 6.02 \times 10^{23} = 1.505 \times 10^{23}$ (1mark)

$5.6/ 22,4 \times 6.02 \times 10^{23} = 1.505 \times 10^{23}$ (1 mark)

2.2 Answer D (1mark)

Explanation

The volume of a gas is proportional to the number of moles (1mark) and the number of number of particles is proportional to the number of moles if the gas is an ideal gas(1 mark)

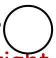
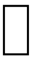
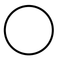
3.1 Answer Hydrogen (1 mark)

Working

	Hydrogen	Oxygen
Molar ratios from the equation	2	1

2 of given mole 1 mole of the given moles (1mark)

Therefore there will be 1 mole of oxygen in excess.(1mark)

3.2 8 + 3  → 3   (1 mark for left side & 1 mark for right side)

8 A + 3B → $3A_2B$ + 2B (1 mark)

4.1 numbers of moles present

	NH_3	O_2
	n = m/M	n = m/M
	= 750/17	= 750/32
	= 44.12 moles	= 23.44 moles (1mark

From the equation 4 moles of NH_3: 5 moles of O_2

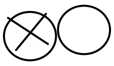
4moles : 5moles

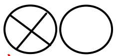
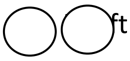
44.12moles : x moles

(44.12 * 5) = 4x

X = 55.15 moles of O_2 needed which are not available (1 mark)

Therefore oxygen is the limiting reagent (1mark)

4.2 Answer  (1 mark)

The equation indicates that all the  molecules are used up in the reaction and one molecule of  ft. (2 marks)

5.1 Number of moles of methane present n = m/M

= 20/(12 +4)

= 1.25 moles (1 mark)

From the equation

1 mole of CH_4 produces 2 moles of H_2O

1.2 X 2 = 2.5 moles (1 mark)

2.5 moles x 18 = 45g (1 mark)

5.2 Mass of reactant is equal to mass of products (1 mark)

Explanation

Matter is not destroyed nor created during a chemical reaction. (2 marks)

6.1 na/nb = CaVa/CbVb (1mark)

½ = x*30/(0.18 *70) (1mark)

X = 0.21 mol.dm3 (1mark)

6.2 X and Y are equal

HCl + NaOH → NaCl + H_2O

$HNO3 + NaOH \longrightarrow NaNO_3 + H_2O$

Molar ratios of the reactants are the same in all the cases. (1 mark)

7.1 n = m/M

= 500/(32+32)

= 7.81 moles of SO2 (1 mark)

From the equation 2moles of SO2 reacted with 1 mole of O2

-Moles of oxygen used

7.82 /2 = 3.905 moles (1 mark)

Mass of oxygen used n = m/M

3.905 = m/ (16 x 2)

M = 124.96g (1 mark)

7.2 $MCl_3 + 3AgNO_3 \longrightarrow M(NO_3)_3 + 3AgCl$

Moles of AgCl n = m/M

= 6.168/ (107.87 + 35.5)

= 0.036 moles (1 mark)

From the equation 1 mole of MCl_3; 3 moles of AgCl

X moles: 0.036 moles of AgCl

X = 0.036/3

X = 0.012 moles (1 mark)

0.012 x (M + 106.5) = 2.392

M = 92.83 g (1 mark)

81 Moles of $CaCO_3$

n = m/M

= 11.2/(40+12+ 48)

= 0.112 moles (1 mark)

From the equation 1mole of $CaCO_3$ produces 1mole of CO_2

0.112 moles of $CaCO_3$ produces x moles of CO_2

0.112/1 X 1 = 0.112 moles (1 mark)

1 mole occupies 22.4dm^3 at STP

0.112 X 22.4 = 2.51dm^3 (1 mark)

8.2 Answer 2.51 dm^3 (1 mark)

Because the same quantity of limiting reagent was used (2marks)

9.1 The concentration of acid used in experiment 2 is half the concentration of the acid used in experiment 1. (2marks)

9.2 The limiting reagent (Mg) was used up (2marks)