UNIVERSITY OF EDUCATION, WINNEBA

USING COMPUTER ANIMATIONS TO ENHANCE SENIOR HIGH SCHOOL STUDENTS' ACADEMIC ACHIEVEMENTS IN RATE OF REACTIONS

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DECLARATION

Student's Declaration

I, **Gloria Asiedu**, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:……………………………..……..…..

DATE:……………………………………...………..

Supervisor's Declaration

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

NAME OF SUPERVISOR: PROF. RUBY HANSON

SIGNATURE: …………………..……………………..

DATE: …………………….…………………….…..

DEDICATION

I dedicate this thesis to my mother, Mrs. Patience Asiedu and my siblings for their prayers, support and encouragements which have led to the success of this work.

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A special thank you to all who participated in diverse ways to help in the completion of this thesis. Their contributions are sincerely appreciated and acknowledged.

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ABBREVIATIONS

WASSCE	–	West Africa Secondary School Certificate Examinations
SHS	-	Senior High School
SHTS	–	Senior High Technical School
WAEC	-	West African Examination Council
CBI	-	Computer Based Instruction

ABSTRACT

This study was designed to find out how the use of computer animations in teaching could enhance senior high school students' academic achievements in rate of reactions. The study was conducted in two public Senior High Schools in Ablekuma West Municipal in Greater Accra Region of Ghana. The study adopted the quantitative approach and quasi-experimental design to achieve its objectives. The study used purposive sampling to select 85 students for the study. The main instruments used for the collection of data were pre-test, post-test and questionnaire. Some student misconceptions were discovered when a pre-test was conducted for them. A post-test was administered after the treatment to find out whether the treatment activities helped to eliminate the misconceptions or not. The results showed that there was a statistically significant difference between the post-test scores of the experimental group and the control group. Responses of students from the questionnaire revealed that computer animation was an interesting and interactive tool in teaching rate of reactions. The study concluded that computer animations assisted senior high school students to better understand rate of reactions.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter deals with the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, delimitations of the study, and limitations of the study.

1.1 Background to Study

Chemistry is often regarded as a difficult subject, an observation which sometimes repels learners from learning this subject. This is because Chemistry includes many complicated and abstract concepts ("UKEssay", 2015). According to BouJaoude (1991), understanding many concepts in chemistry is difficult for most students because of its abstract nature. The topic, rate of reactions is one of the abstract chemical topics which students find difficult to learn (Secken & Seyhan, 2015).

According to Chang (2005), rate of reactions is the change in the concentration of a reactant or product with time while chemical kinetics refers to the rate of reactions or the reaction rate. Rate of reactions in the Senior High School syllabus looks at the following areas: definition of rate of reactions, factors that influence the rate of chemical reactions, deductions from experimental data and graphs on rate of reactions, collision theory of reaction rate, transition state and chemical reactions, the rate law as well as zero, first and second order reactions (Ministry of Education, 2010).

Rate of reactions as a highly structured topic is a central part of the chemistry curriculum (Cachapuz & Maskill, 1987). The rate of reactions concept is an essential prerequisite for some chemistry concepts such as solubility of substances, acids, bases and salts among others and especially chemical equilibrium (Kaya & Geban, 2012). According to Onwu and Ahiakwo (1986), students perceive rate of reactions and related concepts difficult to learn.

Research on students' understanding of rate of reactions has clearly indicated that students have difficulties in understanding concepts that underlie this topic. Some of the findings were students' inability to define rate of reactions (and defining reaction rate as reaction time) and difficulties in explaining how reaction rate changes as the action progresses (Cakmakci, Leach & Donnely, 2006; Calik, Kolomoc & Karagölge, 2010). Other findings were misunderstanding of the relationship between temperature change and the rate of reactions (Calik, Kolomoc & Karagölge, 2010) and misunderstandings of the relationship between concentration change and the rate of reactions (Cakmakci, Leach & Donnely, 2006; Sözbilir, Pinarbasi & Canpolat, 2010). Some researchers also had these findings, misunderstanding of the effect of catalyst on the rate of reactions and on the mechanism of their action (Cakmakci, 2010; Tastan, Yalcnkaya & Boz, 2010) and having conceptual difficulties in interpreting empirical data and graphical representation (cited in Cakmakci, Leach & Donnelly, 2006). Students' misconceptions affect their understanding of chemistry concepts since they become obstacles in integrating new concepts into existing concepts (Kaya & Geban, 2012).

Chemistry teachers, notwithstanding the difficulties encountered by students are making frantic efforts in making rate of reactions less difficult and interesting to learn (Ahiakwo & Isiguzo, 2015). If we teach today as we taught yesterday we rob our children of tomorrow (Peake, 2010). According to Kaya and Gehan (2012), teachers should design and use conceptual change-oriented instruction which is an effective way to help students to understand chemical concepts meaningfully in their chemistry classes. This conceptual change-oriented instruction also encourages students to participate in classroom activities (Kaya & Gehan, 2012). Since understanding concepts related to reaction rate is crucial in learning other chemical concepts, appropriate teaching strategies should be designed by considering results of their search about rate of reactions in the literature (Secken & Seyhan, 2015). Students are required to conceptualize descriptive, particulate and mathematical modeling regarding chemical kinetics and the interrelationship between them in order to improve their understanding of rate of reactions concepts (Cakmakci, Donnelly & Leach, 2003).

Ikwuka and Samuel (2017) stated that to make chemistry more relevant, enjoyable, easy and meaningful to students, adequate instructional materials need to be provided and properly utilised as the teaching and learning situation may demand. This is where information and communication technology (ICT) comes in. Islam et al. (2014) also said that it is time to engage students with interactive learning systems so that they can improve their learning and memorising capabilities. Yussif (2006) argued that ICT and computer assisted instruction (CAI) as computer-based tools should be used by teachers to make teaching more meaningful. Computer animation is a useful tool for instruction and making information meaningful. When computer animation is used in teaching, students view animated pictures as real objects which help to improve their understanding of complex concepts (Ikwuka & Samuel, 2017).

Ikwuka (2010) has shown that learners are motivated when their learning is supported by technology, which in turn leads to increased understanding. According to Wright (as cited in Ültay, 2015) cartoons can be successful in integrating cognitive domain with psychomotor domain because they have the power of integrating visual, auditory and kinesthetic learning abilities. Cartoons can be used effectively in teaching because they do not only provide information, they also capture the students' attention and stimulate the active involvement of students in the learning process (Dalacosta, et al., 2009). Computer models permit students to link their microscopic explanations of chemical phenomena with their macroscopic observations and students can visualize microscopic processes in chemistry and they have better understanding of chemical knowledge (Ebenezer, 2001).

According to WAEC (2013), students' persistent mass failure in chemistry at West African Senior Secondary Certificate Examination (WASSCE) has been attributed to many factors among which are the chemistry topics which research has identified to be difficult for students to learn. This could be because teaching strategies such as the use of ICT in computer-assisted modes of teaching, cartoons and other innovative and interactive approaches have not been applied by teachers in their lesson executions. Some of the topics which have persistently proved to be difficult at Senior High School level include rate of reactions, chemical equilibrium, periodic chemistry, mole concept, organic chemistry, redox reactions, chemical bonding and solubility of substances, among others (Euchekwube, 2009; Chief Examiner's Report, West African Examination Council (WAEC), 2016, 2017, 2018, 2019, 2020). A careful look at St. Margaret Mary SHTS general science students' performance in class tests, exercises and general class interaction assessment indicated that students had difficulties in understanding rate of reactions and this has affected their performance. The inability of students to fully understand rate of reactions, which is one of the identified difficult topics (Cakmakci, 2010) makes it difficult for them to understand related concepts like chemical equilibrium (Cunningham, 2007).

This current study looked at how computer animations an interactive teaching mode could be used to enhance Senior High School students' academic achievement in rate of reactions. Though there are various literature which explain the difficulties students face in understanding rate of reactions and instructional strategies to improve students' understanding, as well as the important role of animation in education, none was found on how computer animations could be used to facilitate the teaching and learning of the identified difficult topic. There was, therefore, the need to conduct a study on how to use computer animations in teaching rate of reactions.

The outcome of this study will add up to the existing instructional strategies used in the teaching and learning of rate of reactions. There was also the need to conduct this study because it could help chemistry teachers to use computer animation as an alternate instructional strategy in teaching rate of reactions and this could make their lessons more interesting. In addition, this study could help curriculum developers to consider the use of computer animations in teaching other topics in chemistry.

1.2 Statement of the Problem

Form three General Science students of St. Margaret Mary Senior High School had difficulties in understanding rate of reactions. The performance of these students in a test on rate of reactions was not encouraging. This test was administered to the students after they were taught rate of reactions using the traditional method of teaching. The results of the test showed that 70% of the students who took part in the test performed poorly and 30% performed averagely. It was in view of this poor outcome that this study sought to improve students' understanding of rate of reactions that could help to improve their academic performance in chemistry in general.

1.3 Purpose of the Study

This study investigated how the use of computer animations could enhance Senior High School general science students' academic achievements in rate of reactions.

1.4 Objectives of the Study

This study sought to:

i. determine some misconceptions held by general science students about rate of reactions.

ii. use computer animations to help enhance general science students' academic achievements in rate of reactions.

iii. determine the perceptions students have about the use of computer animations in learning rate of reactions.

1.5 Research Questions

1. What would be some of the misconceptions that students have on rate of reactions?
2. What would be the effect of computer animation on students' academic achievement in learning of rate of reactions?
3. What would be the perceptions students have about the use of computer animation in learning rate of reactions?

1.6 Hypotheses

The following hypotheses were formulated:

H_{O1}: There is no statistically significant difference between the pre-test scores of students who were taught using computer animation and those taught using traditional method.

H_{O2}: There is no statistically significant difference between the post-test scores of students who were taught using computer animation and those taught using traditional method.

1.7 Significance of the Study

The study could help chemistry teachers to use an alternate instructional strategy such as animation in their teaching to make their lessons more interesting. This could also help build students' interest in learning chemistry and enhance conceptual change.

The findings of the study could help curriculum developers to consider the use of technological tools such as Computer animations in the teaching of some topics in chemistry which will help promote a better understanding of scientific concepts.

This study could help educational planners to formulate and implement policies that could be used in the teaching of rate of reactions in the Chemistry syllabus.

1.8 Limitations of the Study

Simon (2011) defined limitations in educational research as potential weakness in one's study that are not within their control. Ideally, this study should have involved all Senior High Schools in the Ablekuma West Municipal of the Greater Accra region for effectiveness of the research but due to time constraints, the researcher used two

Form Three general science classes from the two public senior high schools for the research.

1.9 Delimitations of the Study

According to Simon (2011), delimitations are characteristics that limit the scope and define the boundaries of a study. The delimitations are under the control of the researcher. Delimiting factors include the choice of objectives, the research questions, variables of interest, theoretical perspectives the researcher adopted and the population chosen to investigate (Simon & Goes, 2013). This study only looked at the misconceptions students have on rate of reactions, using computer animations to enhance students' academic achievements in rate of reactions and the perceptions students have about the use of computer animation in learning rate of reactions.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter provided the review of studies done by researchers that relate to and were found to be relevant to this study. It looked at the following areas:

a. Theoretical framework.
b. Misconceptions and difficulties in learning rate of reactions.
c. Instructional strategies used in teaching rate of reactions.
d. Animation as an educational tool in Science Education.
e. The role of animation in conceptual change and students' perceptions.

2.1 Theoretical Framework

The constructivism theory, Mayer's cognitive theory and the cognitive load theory are the theories that underpin the use of computer animation in teaching and learning. The constructivism theory says that people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences (Van Manen, 2015). According to the constructivist model, knowledge is constructed in the mind of the learner (Bodner, as cited in Karsli & Ayas, 2014). Spitery (2011) stated that according to constructivist's view, learning is a compounding process where each new piece of information is built on the last piece of information. Learning is seen as occurring when individuals interact in reality and construct knowledge separately from instruction (Duffy & Jonassen, as cited in Lainema, 2003).

Based on this idea, instruction does not involve disseminating knowledge but rather involves supporting learners in their construction of knowledge (Duffy & Cunningham, as cited in Lainema, 2003) and development of knowledge construction skills (Duffy & Jonassen, as cited in Lainema, 2003). Instruction also involves recognizing the value and importance of prior knowledge and incorporating learning tasks into realistic contexts to facilitate richer mental model and multiple perspectives (Lainema, 2003). Vygotsky argued that all cognitive functions originate in social interactions and that learning did not simply comprise the assimilation and accommodation of new knowledge by learners but it was the process by which learners get integrated into a knowledge community (Lynch, 2016).

Mayer (2001) proposed a cognitive theory model in order to explain the effects of multimedia materials on learning. This model was called Mayer's cognitive theory of multimedia learning. The principle known as the "multimedia principles", stated that people learn more deeply from words and pictures than from words alone (Mayer, 2001). Mayer's cognitive theory of multimedia learning proposed three main assumptions:

a. There are two separate channels for processing information. These two channels are audio and visual. This is sometimes called Dual-Coding system.
b. Each channel has a limited capacity. Humans can only process a finite amount of information in a channel at a time and they make sense of the information by actively creating mental representations.
c. Learning is an active process of filtering, selecting, organizing and integrating information based upon prior knowledge (Mayer, 2001, p. 44).

Mayer (2002) also discussed the role of three memory stores: sensory (which receives stimuli and stores it for a very short time), working (where we actively process information to create mental constructs or 'schema') and long-term (the repository of all things learned). Mayer's cognitive theory of multimedia learning presents the idea that the brain does not interpret a multimedia presentation of words, pictures and auditory information in mutually exclusive fashion; rather, these elements are selected and organised dynamically to produce logical mental constructs (Mayer, 2002). If animations use visual and auditory channels effectively, working memory is increased (Mayer, Heiser & Lonn, 2001). Similarly, overloading the learner with extraneous or confusing material in animation can inhibit short and long-term memory retention (O'Day, 2011).

Mayer's cognitive theory model also explained the effects of multimedia materials on learning. Based on his assumptions and supported with empirical evidence, Mayer carried on and made the following suggestions for an effective learning material:

a. Giving explanations or remarks next to an image instead of far away from the image.
b. Providing narration to animation simultaneously instead of successively.
c. Eliminate extraneous words, pictures and sounds.
d. Using pictures and words are better than words alone.
e. Animation with narration is better than animation with words.
f. Allowing students to have prerequisite knowledge about the objects in the animation at first is better than without such knowledge.
g. Telling students the summary or letting them know how the ideas were organized into a causal chain is better without that.

h. Presenting the words in conversational style is better than formal style (Mayer, 2002, p. 63).

Cognitive load theory is an instructional theory based on our knowledge of human cognition (Sweller, et al., 2011). Since its inception, the theory has used aspects of human cognitive architecture to generate experimental instructional effects (Sweller, 2011). According to the cognitive load theory, short term or working memory has limited capacity and can only handle so much information effectively at one time. If a person's working memory is overloaded, that person may not be able to process anything well, thus leading to poor understanding, retention and learning (Sweller, 2011; Mayer & Mareno, 2003).

There are three kinds of cognitive load: intrinsic (related to instructional context); germane (related to the activities that the students do) and extraneous (everything else) (Nguyen & Clark, as cited in Mestre, 2012). The load on working memory needs to be minimised in each of these areas so that people can process information more effectively and learn better (Mestre, 2012). This suggests that for instruction to be effective, care must be taken to design instruction in such a way as to not overload the mind's capacity for processing information. Mestre added that, rather than adding unnecessary "bells and whistles" to multimedia instruction, it is important to incorporate elements that contribute to instruction, but do not overload limited working memory.

2.2 Misconceptions and Difficulties in Learning Rate of Reactions.

Misconceptions and preconceptions are a constant battle for all teachers including science teachers (Ozmen, 2004). If a student develops a misconception, this can lead to compounded misconceptions with new information added (Spitery, 2011).

Research has shown that children bring to the classroom a lot of preexisting conceptions about scientific phenomena that can interfere with students' learning of correct scientific principles or concepts (Ozmen, 2004).

Children develop ideas and beliefs about the natural world through their everyday life experiences (Tüysüz, 2009). These include informal instructions like sensual experiences, language experiences, cultural background, peer groups, as well as formal instruction. Some students have an alternative understanding of concepts which are not consistent with the consensus of the scientific community (Mulford & Robinson, 2002; Taber, 2002). Every individual creates concepts according to his or her unique learning experience and matured pattern (Onder & Geban, 2006). Misconceptions obstruct the structuring of the acquired knowledge (Ozkan & Selcuk, 2013). Misconceptions are created by different sources. Cho, et al. (1985) stated that misconceptions may arise from textbooks, may arise from prior to formal instruction (Griffiths & Preston, as cited in Wu, et al., 2001), or as a result of interaction with teachers, physical and social world (Valanides, 2000).

Nyagaga'ia (as cited in Abanga, 2015) indicated that chemistry is one of the science subjects in which learners perform poorly. There are three levels of representations in chemistry: macroscopic, microscopic and symbolic levels (Gabel, Johnstone, as cited in Wu, et al., 2001). At the macroscopic level, chemical processes are observable such as burning of candles. At the microscopic level, chemical phenomena are explained by arrangement and motion of molecules, atoms or subatomic particles. Chemistry at the symbolic level is represented by symbols, numbers, formulas, equations and structures (Wu, et al., 2001). Wu, et al. (2001) also reported that many students have difficulties learning symbolic and molecular representation of chemistry. Other studies have shown that understanding microscopic and symbolic representations is especially difficult for students, because these representations are invisible and abstract and students' thinking relies heavily on sensory information (Ben-Zvi, et al., 1987; Ben-Zvi, et al., 1988; Griffiths & Preston, 1992, as cited in Wu, et al., 2001).

Chemical reaction rate or chemical kinetics has been found to be one of the most difficult chemistry topics to understand because it involves mathematical calculations and also because there are many factors influencing the rate of reactions (Justi, 2003). Cakmakci (2010) reported the difficulties students encounter in the learning of a topic such as chemical kinetics and the principles that underline it. Cakmakci (2010) added that the students encountered these difficulties because they were unable to differentiate between reaction rate and reaction time. He also added that students confused the chemical kinetics concepts with thermodynamic concepts.

Secken and Seyhan (2015) conducted a study that measured the basic knowledge and skills about rate of reactions of high school students attending the eleventh grade of four different Anatolian High Schools in Sivas, Turkey. In addition to this, the performance of the students regarding to the problems with or without graphics was analyzed and their anxiety level about the problems with graphics was determined. Secken and Seyhan used three measurement tools as data collection tools in solving chemistry problems. These were Achievement Test on Rates (RRAT), Graphical Test on Reaction Rates (RRGT) and Anxiety Scale on the Use of Graphics (ASUG). The findings of this study showed that students performed better in the RRAT than in RRGT. Most of the students reported that they did not have any interest in graphical themes under the unit of the rate of reactions and chemical equilibrium, and that they experienced anxiety when they had to draw or interpret graphics in the examinations due to fear of making mistakes.

Therefore, it was natural that the participants had higher scores in the RRAT, which did not include graphical problems. Students usually construct their own meaning of concepts from what they see in their environment (Irhasyuarna & Irhasyuama, 2017). Errors in construction of concepts can be briefly regarded as a misconception. According to Irhasyuarna and Irhasyuama (2017), misconceptions of rate of reactions that were experienced by high school learners were caused by preconception or early conception of learners, learner associate thinking, humanistic thinking, incomplete reasoning, wrong intuition, and the stage of cognitive development as well as learners' knowledge.

According to Ahiakwo and Isiguzo (2015), the nature of chemical reactions in chemical kinetics involving breaking and making of bonds and electron transfer is such that students can hardly conceptualise. This problem is recurrent as students progress from the secondary schools to the tertiary institutions. Ahiakwo and Isiguzo, (2015) investigated the conceptions and misconceptions in chemical kinetics of senior secondary school students and university chemistry students in River state, Nigeria. Their study showed that generally, students' performance in basic chemical kinetics and its calculation is poor and this is due to the fact that students can hardly conceptualize the kinetic principles involved in the process.

Chemical kinetics is an area of chemistry where mathematics is frequently used as the language of chemistry, requiring students to translate between mathematical representations and the physical meaning that they represent (Becker & Towns, 2012). The paucity of research in this area is especially troubling, as it has been noted that students have difficulty with the mathematics in physical chemistry, of which chemical kinetics is a subset (Thompson, et al., 2006; Bucy, et al., 2007; Christensen & Thompson, 2012; Hadfield & Wieman, 2010; Wemyss, et al., 2011; Becker & Towns, 2012). It has the power to provide insight into the nature of chemical reactions and processes, because it ties observable phenomenon with theoretical aspects of chemistry that are modeled mathematically (Çakmakci, et al., 2006).

Calik, et al. (2010) examined some previous studies and identified some problems encountered in learning the concept rate of reactions. Some of these problems are:

i. Inability to define the rate of reactions
ii. Misunderstanding or misinterpreting of the relationship between the rate of reactions and its influencing factors.
iii. Lack of understanding on how activation energy and enthalpy relate to the rate of reactions.

Calik and Kolomuc (2012) also explored the alternative conceptions generated by Turkish chemistry teachers and grade II students for the topic of rate of reactions. They found that chemistry teachers and students tended to have similar alternative conceptions, which may have been transmitted from the chemistry teachers. Examples of some of the alternative conceptions include:

i. Lack of understanding of the effect of enthalpy on the rate of reactions and mechanism of reactions.
ii. Misunderstanding of the relationship between temperature or concentration and the rate of reactions.

According to Kurt and Ayas (2012), learners have difficulty in understanding the relationships between rate of reactions and factors affecting it. They added that understanding many concepts in rate of reactions is difficult for learners and this makes it difficult for the learners to apply them in real life. Koç, et al. (2010) also reported that rate of reactions was found to be difficult for learners, mostly because it generally involves more complex mathematics, as well as qualitative explanations for both rate equations and the factors that affect the rate of reactions. They added that these difficulties make learning of the concept, rate of reactions, difficult. Taştan, et al. (2010) specifically studied tertiary students' understanding of reaction mechanism establishing that students did not recognize the slow step of the mechanism to be the rate-determining step. Rather, students typically used the net reaction equation when generating their rate expression.

Sözbilir, et al. (2010) investigated university students in Turkey to reveal their difficulties in determining the differences between chemical kinetics and thermodynamics concepts. A five-question open-ended diagnostic test was used to test students' ability to differentiate the concepts in each area. A subset of these participants was also interviewed to provide more in-depth explanations, clarifying written responses and probing conceptual understandings. The results showed that students struggled with conflating equilibrium and kinetics ideas, reporting that the equilibrium constant related (either directly or inversely) to the rate of reactions. Turányi and Tóth (2013) reported similar findings from their recent study in Hungary where students related the equilibrium constant to reaction rate.

2.3 Instructional Strategies used in Teaching Rate of Reactions

According to Aniaku (2013), teaching method or instructional strategy describes various ways information is presented to the students by specifying the nature of the activities in which the teacher and the learner will be involved during the teaching and learning processes. One of the reasons advanced for low achievement of students in chemistry and chemistry related courses at the Senior High School level is poor teaching methods used by chemistry teachers particularly, in teaching chemistry concepts classified by students as being difficult (Ekpo, 2006).

Learners demonstrate lack of understanding of what is taught because teachers often do most of the talking (Adams, 2013). However, this method of teaching does not achieve deep learning, because learners are passive and they quickly forget concepts as a result, perform poorly in examinations (Maftei & Popescus, 2012). Makgato and Mji (2006) reported that out dated teaching practices and lack of essential content knowledge has resulted in poor performance of students. Teachers should not be simply transmitters of knowledge but should facilitate the process of learning, to make learning easier (Jia, 2010). Teachers must therefore consider how to prepare learning environments which will make learners active and participate in classroom activities (Abdi, 2014).

Baah and Anthony-Krueger (2012) argued that, success in studying chemistry depends upon the familiarity of students with a few basic ideas, conventions, and methods upon which later studies are built. When a student has achieved mastery of them, further studies can be pursued with greater confidence. Modic (as cited in Abudu, 2020) added that without mastery of these concepts, students are likely to find higher levels of study in chemistry difficult.

Many researchers have worked to bring out some instructional strategies that will help to eliminate difficulties and misconceptions students have when it comes to rate of reactions. As students often enter the science classroom with misconceptions or alternative conceptions about science concepts, there must be a way for teachers to change these misconceptions (Hollister, 2019). To help students understand chemistry at the three levels of representations, researchers have suggested a variety of instructional approaches such as adapting teaching strategies based on the conceptual change model, integrating laboratory activities into class instruction, using concrete models and using technologies as learning tools (Wu, et al., 2001). To overcome students' misconceptions, a large amount of research has explored the effects of several instructional tools based on conceptual change approaches in science such as concept maps, conceptual change texts, cooperative learning strategy, computer assisted instruction, and analogies among others (Tekkaya, 2003; Sungur, et al., 2001; Basili & Sanford, 1991; Snir, et al., 2003; Bozkoyun, 2004, as cited in Kaya & Geban, 2012).

Among these approaches, using concrete models and technologies as learning tools seems promising (Wu, et al., 2001). Appropriate analogies help learners make connections between familiar knowledge and new science concepts (Treagust & Duit, 2009). Traditional based instruction emphasises the passive acquisition of knowledge and poor memorisation of concepts being taught (Zakaria & Iksan, 2007). Traditional based instruction is therefore not appropriate for effective conceptual understanding. Analogical teaching approaches can enhance learning and promote conceptual change (Harrison & Treagust, 2006). Using Dual coding theory, interactive instructional procedures was found to encourage referential processing which lead to deeper understanding of science principles (Paivio, 1990, cited in Chandler, 2004).

Two research–based approaches that have been found to increase students' engagement and learning in the science classroom are the 5E and Gather, Reason, Communicate instructional sequence (Moulding & Bybee, 2017). The 5E model means Engage, Explore, Explain, Elaborate and Evaluate. The 5E model is a constructivist approach to science teaching that uses inquiry to break down student misconceptions and teach desired conceptions of science concepts (Hollister, 2019). According to this study, each lesson contains components in which students will Gather, Reason and, or Communicate.

According to Bybee, et al. (2006), the 5E learning cycle involves the following steps:

i. Engagement – students are engaged in inquiry questions.
ii. Exploration – students plan, design, and carry out experiment and record the experimental data.
iii. Explanation – students give explanations from the experimental data to answer questions.
iv. Elaboration – students extend and apply their findings in a new context especially a daily life one.
v. Evaluation – students evaluate their experimental process and results in a variety of ways, such as an activity report, instructor observation during the activity and student presentations (pp. 76-80).

Karsli and Ayas (2014) suggested that laboratory activity based on 5E learning model combining different conceptual change methods can be used to overcome students' alternative conceptions and improve their science process skill. The study had some limitations in providing concrete evidence, because the study was not an experimental one.

Supasorn and Promarak (2015) conducted a study on the use of seven learning plan of 5E inquiry incorporated with an analogy learning approach to enhance students' understanding of rate of chemical reactions. In each of the learning plan, the students:

i. addressed a scientific question regarding rate of chemical reactions.
ii. explored evidence to answer the question by carrying out a corresponding experiment.
iii. drew explanations from collected evidence to answer the question.
iv. elaborated their understanding by studying the given analogy and the target.
v. evaluated their conceptual understandings by creating their own analogy and identifying similarities and differences of their analogies and targets.

The findings of the study indicated that the implementation of 5E inquiry incorporated with an analogy learning approach was an effective means to enhance and retain students' conceptual understanding of rate of chemical reactions.

Tsegaye, et al. (2020), investigated on the effect of analogical instruction as compared to the lecture approach. Tsegaye et al. (2020) used the six steps Teaching-With-Analogies (TWA) model developed by Glynm and the Focus-Action-Reflection (FAR) guide for systemic presentation of analogies. This model was proposed to maximise the benefits and minimise the problems encountered in analogy instruction. The six steps in the TWA models were used to:

a. introduce the target concept.
b. remind students of what they know of the analog.
c. identify relevant features.

d. connect (map) the similar features.

e. indicate the analogy between the features.

f. draw conclusions.

Findings of the study showed that the analogy-based learning was an effective means in enhancing students' achievement and attitudes towards the concept of the rate of reactions. The study was limited to the concepts of rate of a chemical reaction, specifically to the effect of the nature of reactants, surface area of reactants, concentration of reactants, and temperature of reactants and presence of catalysts on the rate of a chemical reaction.

Chairam, et al. (2009) investigated on the effect of inquiry-based learning activities on first year undergraduate science students' conceptual understanding of chemical kinetics in Thailand. They found that students were able to develop a good conceptual understanding of chemical kinetics from participation in this active and enjoyable teaching approach. Inquiry-based experiments or activities were proven to be effective means to help students overcome their alternative conceptions and change to more correct conceptions (Chairam et al., 2009).

Calik, et al. (2010) also investigated on the effects of conceptual change pedagogy on students' conceptions. They suggested that a combination of various conceptual change methods may be more effective for decreasing students' alternative conception. Calik and Ayas (2015) devised an analogy learning activity based on students' alternative conceptions about chemistry from their previous study to address students' present alternative conceptions. They found that alternative teaching method was generally successful; however, its applicability has not yet been investigated.

They finally suggested that analogies supported students to clearly connect between the analogue and target concepts.

Doymuş and Karaçop (2011) investigated the effect of the jigsaw and animation techniques on students' understanding of concepts in electrochemistry. These researchers used first year undergraduate chemistry learners of Aturk University in Turkey. When the learning ability and understanding of concepts of the learners were tested, no significance difference was found between the jigsaw and animation group, but they had little improvement as compared to traditional method. Koç, et al. (2010) also investigated the effect of the jigsaw method on reaction rate with undergraduate students in Erzurum-Turkey. They found that jigsaw method of teaching was more effective than other traditional methods. According to them, the reason can be attributed to the difference in the application process of the techniques and to the fact that students were directed and encouraged to express their ideas in a warm atmosphere to convey and cooperate with their peers. Koç, et al. (2010) suggested that student-centered teaching should be implemented in the presence of an expert.

Kaya and Geban (2012) also conducted a study to find out the effects of demonstrations on eleventh grade students' understanding of rate of reactions concepts which was compared to traditionally designed chemistry instruction. The students were put into two groups which were an experimental group and a control group. Results of the study showed that the group of students in which demonstration was used which was the experimental group, had significantly better acquisition of scientific conceptions related to rate of reactions than the control group.

The use of demonstrations as a teaching strategy is based on cognitive conflict strategy which encourages students to engage in conceptual change (Baddock &

Bucat, 2008). Since chemical principles are emphasised during demonstration, students can learn basic definitions in chemistry and recall examples regarding these principles (Ophardt, et al., 2005).

For the past years, chemical educators have been advocating the use of Systematic Approach to Teaching and Learning (SATL) in preparing lesson delivery for chemical concepts including chemical kinetics (Fahmy & Lagowski, 2003; Nazir, et al., 2013). In SATL technique, the concepts are positioned in such a way that the relations between a series of ideas and issues are made logical (Ahiakwo & Isiguzo, 2015). They added that the basic goal of this approach is the achievement of meaningful (deep) learning by students. They continued that in preparing lessons based on this approach and other techniques, reference is made to the previous experience or what the learner already knows. SATL model seems to suggest that one way of teaching a learner is to use what is in the learners' memory.

Keller (2013) conducted a study to help learners to acquire science content knowledge to improve student knowledge in the processes of inquiry-based learning (IBL), and increase student engagement in appreciation of science. He found that IBL took a long time, and it was not possible to cover enough subject matter in the time. Some learners found the change to be too challenging because they felt lost and did not know what to do.

Ceylan and Geban (2010) investigated the effectiveness of the conceptual change-oriented instruction through demonstration over traditionally designed chemistry instruction on tenth grade learners' understanding of chemical reactions and energy concepts and their attitudes towards chemistry as a school subject. The participants were sixty-one tenth grade learners from two classes instructed by the same teacher.

One class was assigned as experimental group and instructed with the demonstrations supplying the conditions of conceptual change, while the other class was assigned as control group and instructed with the normal consistent chemistry teaching. In the study, concepts were explained through the use of demonstrations related to the concept of chemical change. A concept test and attitude scale test were administered as a pre-test and post-test. The results of the study showed that conceptual change-oriented instruction caused significantly better acquisition of the scientific conceptions related to chemical reactions and energy concepts than traditionally designed instruction.

2.4 Animation as an Educational Tool in Science Education

For years now, there have been studies to search for new ways to improve processes in which knowledge could be passed from one individual to another. Researchers found that humans take in information through multimedia learning, especially, when it is incorporated into traditionally textual courses (Shreesha & Tyagi, 2016). This is when animation-based learning comes in. According to Chang, et al. (2007), animations are effective aids for teaching concepts that involve motion in the molecular level. Animations are more realistic for showing change; they can demonstrate in action the systems to be taught and can show change in time, they are thought to be natural and effective for conveying change in time (Kim, et al., 2007). The use of dynamic visual models and visual representations of chemical processes help students to develop conceptual understanding and promote meaningful learning by creating dynamic mental models of particulate phenomena (Abanga, 2015). Tasker (2004) also stated that animations, like many other educational tools, need to be integrated into larger learning environment.

Animation-based learning is not all about visual materials but rather resources such as videos and info-graphics are used. The use of animated instructional material can help to present a complex concept in a simple form, create more interest about a subject, motivate the pupil for better learning, increase the accuracy of the message and play a crucial role in improving the students' academic performance. Shreesha and Tyagi (2016) assessed the efficacy of animation on different subjects (Mathematics, Language and Science) in primary education. The conclusion for this study was animation-based learning was a useful way to improve learning. Animations are good supplementary learning materials for students particularly for learning of complicated concepts and animations with close integration with extended readings, can be good in facilitating learning of a particular subject matter (Hwang, et al., 2012).

A study conducted by Spitery (2011) explored the role of computer animations in a secondary school chemistry classroom setting. This study examined the effects of animation among secondary school science students regarding chemical concepts and focused on the nature of matter, atomic structure and classes of chemical reactions. Results of the study showed that students benefited from the usage of animations coupled with lecture and they had positive impression of the student-created animations during laboratory activities.

Tasker and Dalton (2006) suggested that molecular-level animations could be a compelling and effective learning resource, but then they must be designed and presented with great care to encourage students to focus on the intended key features and to avoid generating or reinforcing misconceptions. Computer animation activities that demonstrate the dynamic processes allow students to be more interactive, learn from trial and error and repeat their trial over and over and none of which are possible with the illustration activity (Marbach-Ad, et al., 2008). Chang and Quintana (2006) reported that, with computer animation programs, students may build their own appropriate representations and use them to conduct higher-order thinking such as reasoning and interpretation.

Chacko, et al. (2015) determined the benefits of incorporating technology-based instruction on education and in increasing interest in science, technology, engineering and mathematics (STEM) fields. This study was conducted over the course of two years on a summer science program. The program was catered specifically towards bioengineering at high school level and the utilization of technology whenever possible. The courses comprised of four-week programmes that covered topics on diabetes, cancer, HIV/AIDS and individual research. The primary methods for learning were discussion, watching videos, completing hands-on laboratory activities, utilising case studies, topic related games or activities and lectures. It was found that in three of the four weeks, 100% of the students felt they understood the material after going through the learning segment (Chacko et al., 2015). In the other week, about 97% of the students felt they understood the topic. As for the interest in STEM, the percentage of students who claimed they would not pursue science decreased from about 13% to 0% after the four weeks. The percentage of students who said they had fun but were unsure about STEM increased after week one and then steadily decreased to about 12%. Lastly, those interested in pursuing a STEM career made up almost 90% of the class by the end.

Gryczka, et al. (2016) concluded from their study that utilising technology in the classroom can help students to be more conducive to learning because it improves their attitudes, thus allowing educators to teach more effectively. Gryczka et al.

indicated that the implementation of technology helps students to become more engaged with school work and it benefits teachers in the sense of keeping current with research and new teaching methods.

A study was conducted to analyse the effectiveness of blended learning using one such type of module known as Lab Lessons (Jihad, et al., 2018). Blended learning is said to address most, if not all types of learning styles, which is difficult to do with traditional teaching methods (Jihad et al., 2018). It involves the use of traditional methods, while also incorporating technology and online learning. Blended learning is seen as a bridge between traditional teaching and online learning and has been shown to be effective in the classroom. Jihad et al. (2018) were able to conclude from their study that blended learning is an effective tool. Not only does it spark interest in the students using simulations and visuals, but it also helps them to understand their mistakes.

Aksoy (2012) investigated on the effect of animation on academic achievement of students in the Human and Environment Unit lectured as part of the science and technology course of seventh grade in primary education. The findings of the study indicated that animation technique was more effective than the traditional teaching methods in terms of enhancing students' achievement.

Yang and Andre (2003) assessed the impact of computer animations that illustrated chemical reactions which occur inside a battery (electrochemistry) on students in a college chemistry course. The subjects were divided into a Computer Animation Group (CAG) who received the dynamic visualization while the second group, the Still Diagrams Group (SDG) received the same lecture but still diagrams replaced the dynamic animations. The analysis on post-test results showed the significant effect of the treatment. Animations, with parallel verbal narration provided by an instructor, allowed students to visually follow the movement of ions and electrons and thereby created a better understanding of the electrochemical processes.

A study was also conducted by Dasdemir, et al. (2008) to determine the effect of computer animations in teaching acid and base topics in chemistry and technology courses on the academic performance of primary school students and their opinions. The research was a quasi-experimental design. The animation group was taught by computer animations in acids and bases concepts while the control group was taught by the traditional method in same topic. After an examination, the findings showed that the mean score of the animation group was significantly better than the control group. Also, the animation group had positive opinions about teaching with the help of the animation instructional method.

Hays (1996) conducted a study on using three different media: animation, static graphs and textual material. In this study, students were to learn the movement of molecules, the effects of heat and pressure on molecules movement and how molecules diffused from different concentrations. The students were divided into groups of high and low spatial ability and they were asked to use the three different media to learn. A test was administered at the end to compare the learning performance of students in each group. The results of the study showed that animation was effective to help students who were low in spatial ability.

Concept cartoons enable the presentation of an example of an alternative conception in the class and make students see the topic from a different perspective (Kandil İngeç, 2008). Concept cartoons, which were created first in 1991, aimed to elicit learners' ideas and challenge their thinking and improving their understanding (Keogh

& Naylor, 1993, as cited in Ultay, 2015). As concept cartoons were used in learning environments, it was found that they affected learning positively (Naylor & Keogh, 2013). Concept cartoons, which are not designed for humor, present to students the opportunity to interpret and understand concepts (Sexton, 2010).

Ainsworth and Van Labeke (2004) made an important distinction between the terms dynamic representation and animation which are often mistaken as synonymous by many in the field of instruction. They proposed three methods of representing phenomena that change over time. They are time-persistent, time-implicit and time-singular representations. All three representations have different consequences for processing limitations with time persistent and time implicit representations usually being more complex than time singular representations. Using population density simulations, Ainsworth and Van Labeke (2004) explained that all three types of dynamic representation have distinct advantages over static representations. The implications of this work raise issues that hopefully will be addressed in future research. For example, which types of dynamic representations best support learners and how can they be combined to result in enhanced understanding of dynamic visualizations? It is clear from the above discussion that the design of dynamic visualizations requires an appreciation of the cognitive mechanisms that underlie complex thought.

Lowe (2004) allowed learners to utilize a very flexible interactive facility to more closely examine changes in complex weather pattern systems. However, domain novice users found the ability of the facility to interact with and interrogate animations quite unhelpful. Since the learners did not have sufficient background to know what aspects of the animation required further interrogation, they engaged in unsophisticated interactions with the animation and did not extract essential thematic information. Lowe concluded that animations need to be carefully designed to address processing considerations if meaningful learning is to occur.

Zacharia's work on a comparison of real and virtual experiments as he termed them showed that there was a great improvement in the learners when they used a combination of both interactive computer simulations and real laboratory experiments (Zacharia & Olympiou, 2011).

According to Williams, et al. (2017), students enjoyed using technological tools for learning because of the ease of access for research. It was a challenge, yet enjoyable, to learn how to properly conduct research and present in unique ways as part of the inquiry process. Collaborative tools, such as Google Docs, where students can edit and share with each other were found to be useful. Although some would rather be taught through traditional teaching, the inquiry process was also said to be enjoyable compared to traditional teaching methods. From this process, the students were able to learn science topics and inquiry-based skills, such as problem solving, collecting, analysing data, and discussing.

2.5 Role of Animations in Conceptual Change and Students' Perceptions

Many studies have been conducted on conceptual change in science education (Artun & Costu, 2013). Conceptual change refers to alterations in knowledge and understanding of topics over a period of learning (Hollister, 2019).The conceptual change model is one of the effective methods for coping with misconceptions and for understanding concepts (Kaya & Geban, 2012). The conceptual change model which is based on constructivist notion claims that learning is a process of knowledge construction (Cobern, 1996). Nzewi (2002) noted that effective teaching makes learning meaningful, while poor teaching leads to poor learning and result in poor performance. The use of animation as one of the effective tools of information technology in education has increased recently and it is highly recommended to use animation to enhance learning of individuals with special needs in addition to individuals with typical development (Baglama, et al., 2018).

Dynamic concepts are difficult to explain in traditional animation media such as slides. Animations seem to have the advantage of delivering better representations of these concepts (Hwang, et al., 2012). O'Day (2011) reported in a study that animations can be useful for communicating dynamic events and processes but only when specific rules are followed. There are unlimited ways to lose a students' attention and the study discussed fundamental components that should be included in a meaningful animation (O'Day, 2011). These essential components discussed by O'Day were apprehension, coherence effect, spatial contiguity effect, multimedia effect, personalization, interactivity, visual cues, and attention cueing. The study indicated that learning from animations and graphics differs between males and females. O'Day concluded that most studies on animations focused on college and university students and it is important to determine the value of animations in teaching high school students.

Lowe (2004) suggested that animations have the potential to serve both affective function and cognitive function. Affective function refers to portraying things in a humorous, spectacular or bizarre way so that learners will be attracted to pay additional attention on the learning materials and be motivated to learn (Hwang, et al., 2012). Cognitive function refers to the clear presentation of dynamic matters (which might be abstract and difficult) that can allow learners to understand in an easier way

(Hwang, et al., 2012). Lowe (2004) added that increasing the level of interactivity of animations stimulates engagement and motivation of learners.

According to Ismail, et al. (2017), video animation enhances students' imagination and visualizations. Ismail et al. added that animated videos assisted students in understanding difficult topics. They concluded that text, graphics, animation, audio and video were able to increase the motivation of students and make learning process interesting. It has been suggested that with the use of animation in education, there is a significant increase in the attitudes and academic achievement of the students in a positive way (Lai, et al., 2009).

Computer animation, in particular, is a new educational tool that fosters long-term learning by calling attention to objects during the early steps of instruction (Gagne, 1985; Rieber, 1994). Weiss, et al. (2002) discussed five functions of instructional animation and these are:

a. Cosmetic functions that make instruction attractive to learners.
b. Attention gaining functions that signal salient points of a topic.
c. Motivation functions that provide feedback to reinforce a correct response.
d. Presentation functions that provide concrete reference and a visual context for ideas.
e. Clarification functions that clarify relationships through visual means.

Wu, et al. (2001) investigated on how students develop their understanding of chemical representations with the aid of a computer-based visualising tool, eChem, which allowed them to build molecular models and view multiple representations simultaneously. Multiple sources of the data were collected with the participation of eleventh graders at a small public high school over a six-week period. The results of the study showed that students' understanding of chemical representations improved substantially when eChem was used in teaching. Analysis of the study also revealed that the several features in eChem helped students to construct models and translate representations. From these, Wu, et al. (2001) suggested that computerised models could serve as a vehicle for students to generate mental images.

Sanger, et al. (2001) also found that college students who viewed animations of diffusion of perfume molecules and osmosis of water molecules had better understanding of random and constant movement of particles than students who did not view the animations. Similarly, a study comparing students' responses to a prediction question before and after viewing computer animation found that students did learn a lot and were able to make favorable predictions from viewing animations (Hegarty, et al., 2003).

Lidwell, et al. (2003) indicated that aesthetic and attractiveness of animated particles influenced students' attitude towards using animations. They added that, when learners find an interface to be attractive and aesthetic, they tend to perceive the system as being effective. Addressing these perceptions, help learners to use animations more easily and more readily. Doymus, et al. (2009) investigated the effects of computer animations and cooperative learning on students' comprehension of chemistry topics at the macro, micro and symbolic levels. They enrolled university students in three general chemistry course classes and indicated the classes as cooperative group, animation group and control group. Their achievements were evaluated in an experimental design by post-test scores. The results of the study showed that students in the animation and cooperative groups had significantly better results than the traditional group in microscopic level representations. There were no significant differences in terms of understanding at non-micro level (macro and symbolic). The maximum efficiency was achieved when both computer animations and cooperative learning methods were used.

Interactive learning plays a very important role in assisting students in learning processes (Nusir, et al., 2011). It has possibility to enhance the early education system with multimedia technologies (Islam, et al., 2014). They also noted that the positive impact of the developed programme on students' abilities is to understand new knowledge or skills. Islam et al. added that multimedia education offers an alternative to traditional education that can enhance the current methods.

Lowe and Mason (2017) stated that the understanding and application of the interaction of movement, sound, time and visual communication within the animation in the education process will give the best results for educational communication. Educational animations contain motivating and entertaining features of computer and education and can be used as an alternative, complement and enrichment of other teaching methods for instructional or educational purposes (Baglama, et al., 2018). The characteristics of learning with animation are as follows:

i. It is an educational course that students follow visually.
ii. There can be many kinds of educational animation games and video animation.
iii. For each content, students can offer a wide range of animation by combining different types of animation with different learning methods.
iv. Educational animations provide hidden learning.

v. The students play with or watch the animation with joy and when it finishes they realise what he or she has.

vi. Educational animations can be combined with other learning methods and provide complete learning (Mayer & Anderson, 1992; Lowe, 2003; Dalgarno & Lee, 2010, as cited in, Baglama, et al., 2018)

Baglama, Yucesoy and Yikmis (2018) explained that animations and digital maps make it easier to understand abstract concepts and ensure that learning is permanent. Animations are the process of animating graphics in a certain scenario and they should be regarded as alternative teaching ways in order to visualise knowledge (Pekdag, 2010, as cited in Baglama, et al., 2018).

Çalık, et al. (2010) preferred the use of animations for several reasons:

i. to make abstract concepts or phenomena 'concrete',
ii. to promote individual learning and
iii. to provide a better student engagement with the learning of science.

Sanger and Greenbowe (2000) suggested that computer animations give students the opportunity to imagine how complex or abstract dynamic processes occur at the sub-microscopic level.

2.6 Summary of Literature Review

The chapter reviewed literature on the key words in the topic guided by the objectives of the study. The literature review began with the theories that relate to the use of animation in science education. These theories were the constructivism theory, Mayer's cognitive theory of multimedia learning and the cognitive load theory. The review revealed the misconceptions and difficulties students encountered when learning rate of reactions as well as the instructional strategies used in teaching rate of reactions. The instructional strategies in most studies included the 5E model with Gather, Reason and Communicate instructional sequence, analogical instructions, laboratory activities with 5E model, Systematic Approach to Teaching and Learning (SATL) technique as well as Inquiry-Based Learning (IBL). Other instructional strategies discussed were demonstrations, and jigsaw technique. This chapter also reviewed most studies conducted on the use of animations in teaching chemistry and science as a whole. These studies showed that animation helped to improve students' understanding as well as their academic performance. Finally, this chapter discussed the various studies conducted on the role of computer animation on conceptual change. Though there are various literature which explain the difficulties students face in understanding rate of reactions and instructional strategies to improve students' understanding, as well as the important role of animation in education, none was found on how computer animations could be used to facilitate the teaching and learning of the identified difficult topic. There was, therefore, the need to conduct a study on how to use computer animations in teaching rate of reactions in two public schools in Ablekuma West Municipal of Greater Accra Region.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter describes the profile of the study area, research design and population of the study. The chapter further discusses in details, the sampling and sampling technique, validity and reliability of instruments, data collection instruments, administration of instruments, data collection procedure and data analysis of the study. Finally, the chapter discusses the ethical considerations in the study.

3.1 Study Area

The study was conducted in Ablekuma West Municipal in the Greater Accra Region of Ghana. Ablekuma West Municipal is among 26 Metropolitan, Municipal and District Assemblies (MMDA) in the Greater Accra Region, which was recently carved out of the Accra Metropolitan Assembly. Ablekuma West Municipal covers the districts of Dansoman, Sahara, Gbegbeyise, Agege, Glefe, Opetekwe and Shiabu. Currently, there are five public and private Senior High Schools in the municipal of which two are public and three are private. For the purpose of this study, only the two public Senior High Schools were involved. The schools were St. Margaret Mary Senior High Technical School (SHTS) and Ebenezer Senior High School (SHS), all in Dansoman district.

3.2 Research Approach

Research approaches are plans and the procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis (Creswell & Creswell, 2018). This study adopted a quantitative approach, in order to achieve the objectives of the study. Cohen, et al. (2013) explained that, quantitative research typically explores specific and clearly defined questions that examine the relationships between two events. Quantitative research was used to examine the cause and effect of relationships between variables (Jeridah, 2019). This method was adopted as the study compared the influence of a treatment between two groups. This approach was also used to find the misconceptions students have about rate of reactions.

3.3 Research Design

Creswell and Creswell (2018) defined research design as the types of inquiry within qualitative, quantitative and mixed methods approaches that provide specific direction for procedures in a research study. The research design for this study was the quasi-experimental research design. Quasi- experimental design is a form of experimental research in which individuals are not randomly assigned to groups (Creswell & Creswell, 2018). Quasi- experimental design also involves selecting groups, upon which a variable is tested, without any random pre-selection processes (Cohen, et al, 2013). Nonequivalent (pre-test and post-test) control group design was used for the quasi-experiment. Two intact science classes of two schools, which were, St. Margaret Mary SHTS and Ebenezer SHS were engaged. One science class of St. Margaret Mary SHTS was the experimental group and one science class of Ebenezer SHS was the control group. The experimental group was taught rate of reactions using computer animation by the researcher. The control group was taught rate of reactions using the traditional method by a colleague teacher trained by the researcher.

3.4 Research Population

Population is defined as a group of people from which the sample can be drawn (Burger & Silima, 2006). The target population of the study included all general science students in St. Margaret Mary Senior High Technical School and Ebenezer Senior High School. The target population comprised about three hundred and fifty (350) general science students. The estimated accessible population of the study was one hundred and eighty (180) form three general science students.

3.5 Sample and Sampling Technique

The sample size was 85 Form Three general science students from two science classes of St Margaret Mary SHTS and Ebenezer SHS. The sampling technique that the researcher used was purposive sampling technique. Purposive sampling is a non-random sampling technique that utilises a specific criterion or purpose to select particular sample. This was done to collect in depth information from the right respondents.

3.6 Instrumentation

Instrumentation is the process where two or more tools of data collections are used in order to confirm the findings of each other (Creswell, 2014). The instruments used for data collection were pre-test, post-test and questionnaire developed by the researcher. The pre-test and post-test comprised 20 multiple-choice questions and 10 closed-ended questions for students to answer. Each item in the multiple-choice questions had four options from which students were to select the correct answers.

A structured questionnaire was used for the study. The questionnaire was designed based on the third research question that sought to determine the perceptions students have on the use of computer animation in learning rate of reactions. Questionnaires are straight forward written questions which require answers by ticking the appropriate box and this is an efficient way of collecting facts (Hannan, 2007). Questionnaires are employed as a tool to gather information about people's opinion through asking the respondents to indicate how strongly they agree or disagree with a statement given (Bawa, 2014). Most of the items on the questionnaire were closed-ended type questions. Likert- scale type was used because it is easy to construct and more reliable than other scales (Tittle & Hill, 1967 cited in Baidoo, 2015). The scale also provided the researcher the opportunity to use frequency and percentage as well as finding the central tendency scores in computing the data. The questionnaire was composed of three main sections. The first section was concerned with the bio data of the respondent. This contained information on sex and class. The second section was concerned with the benefits of using computer animation in learning rate of reactions. The third section was concerned with the challenges involved in using animations in learning rate of reactions.

3.7 Validity and Reliability of the instruments

According to O'Donoghue and Punch (2003) validity is concerned with the study's success at measuring what the researcher sets out to measure, while reliability is concerned with the consistency of the actual measuring instrument or procedure. Face validity of test items and the questionnaire was done by colleague chemistry teachers. Face validity is the degree to which a measure appears to be related to a specific construct, in the judgment of non-experts such as test takers and representatives of the legal system (Taherdoost, 2016). That is, a test has face validity if its content simply looks relevant to the person taking the test. The content validity of the questionnaire was checked by experts in the field of Chemistry Education. Taherdoost (2016) explained content validity as the extent that measurement instrument items are relevant and representative of the target construct. Content validity is defined as the degree to which items in an instrument reflect the content universe to which the instrument will be generalized (Straub, et al., 2004). The comments and suggested changes made from the review were corrected before the administration of the instruments.

Testing for reliability is important as it refers to the consistency across the parts of a measuring instrument (Huck, 2007). To ensure there was no ambiguity in the questions and to enhance the reliability of the instruments, the test questions and questionnaire was trial tested using a small sample of the students who were not involved in the study. Test-retest reliability was used to assess the degree to which test scores are consistent from one test administration to the next. Pearson's correlation coefficient was used to find out if the first test scores correlated with the second test scores or not. The statistic found for Pearson's correlation coefficient was $r = 0.81$. This means that the two test scores were consistent and highly reliable for the study. The purpose of the trial testing was to identify any difficulties in responding to the questions in the pre-test, post-test and questionnaires. The Cronbach's alpha reliability statistic was used to assess the internal consistency of the questionnaire. The Cronbach alpha internal consistency reliability coefficient for the questionnaire using data from the trial test was found to be 0.76 and this was considered significantly reliable for the study (Baidoo, 2015).

3.8 Data Collection Procedure

The data were collected from the pre-test and post-test written by the control group and the experimental group. This study was conducted within four weeks. The same pre-test was administered to both students in the experimental group and control group before employing computer animation for the experimental group. The results from the pre-test of students helped the researcher to identify the misconceptions students have about rate of reactions.

This was followed by a two-week instruction for the experimental group using computer animation and the control group using the traditional approach. Based on the students' misconceptions, the computer animation-based instruction was divided into three sessions within a week. Each session lasted for 40 minutes. While the experimental group received their lessons through computer animated visualizations on projected screen, the control group received their lesson through the traditional method.

The post-test was administered to both the experimental group and the control group in the fourth week to check for any differences in the performance of the two groups after the implementation of the treatment. Cohen, et al. (2013) indicated that the period between the pre-test and post-test should not be made too long, since the situational factors may change, and also not too short that the participants will remember the first test. In view of this, the post-test was administered a week after the treatment.

3.9 Pre-treatment Activities

The researcher used pre-test questions to identify the misconceptions and difficulties students have about rate of reactions. Pre-test questions were administered to the form three general science students of the two schools on a pre-determined day. An allocated time of forty minutes was given to students to finish answering the questions individually. After which the papers were taken from them.

3.10 Treatment Activities

One hundred and twenty minutes of instructional time within a week was designed for both the experimental group and the control group. The participants from the control group were traditionally taught by the teacher, who explained the concepts of rate of reactions to the students. The areas addressed by the teacher were definition of rate of reactions, how to calculate rate of a given reaction, collision theory and activation energy, rate law questions and order of the reactions and factors that affect the rate of reactions. Afterwards, the students prepared themselves for the post-test at school.

For the experimental group, their lessons were divided into three sessions, where the students watched animated videos of the areas in rate of reactions. The lesson plan designed is showed in Table 1.

Table 1: Allocated Areas in each Session

Session 1	Session 2	Session 3
• Definition of rate of reactions. • Collision theory and activation energy.	• Factors that affect the rate of reactions.	• Rate law equations • Graphical representations

Session 1

This session was designed by the researcher to help students understand the meaning of rate of reactions and calculate the rate of given reactions. The rate of a chemical reaction was explained to students as the change in concentration of reactants or products per unit time. Mathematically, rate of reactions is given by:

$$\text{Rate of a chemical reaction} = \frac{-Change\ in\ concentration\ of\ reactants}{Time}$$

$$\text{Rate of a chemical reaction} = \frac{+\ Change\ in\ concentration\ of\ products}{Time}$$

Negative sign is placed in front of the change in concentration of the reactants because reactants are consumed during chemical reactions.

Positive sign is placed in front of the change in concentration of the products because products are formed during chemical reactions.

Rate of reactions has the unit mol/dm^3/s

This session was also used to help students state each postulate of the collision theory and explain the activation energy. Figure 1 shows how molecules collide to bring about chemical reactions.

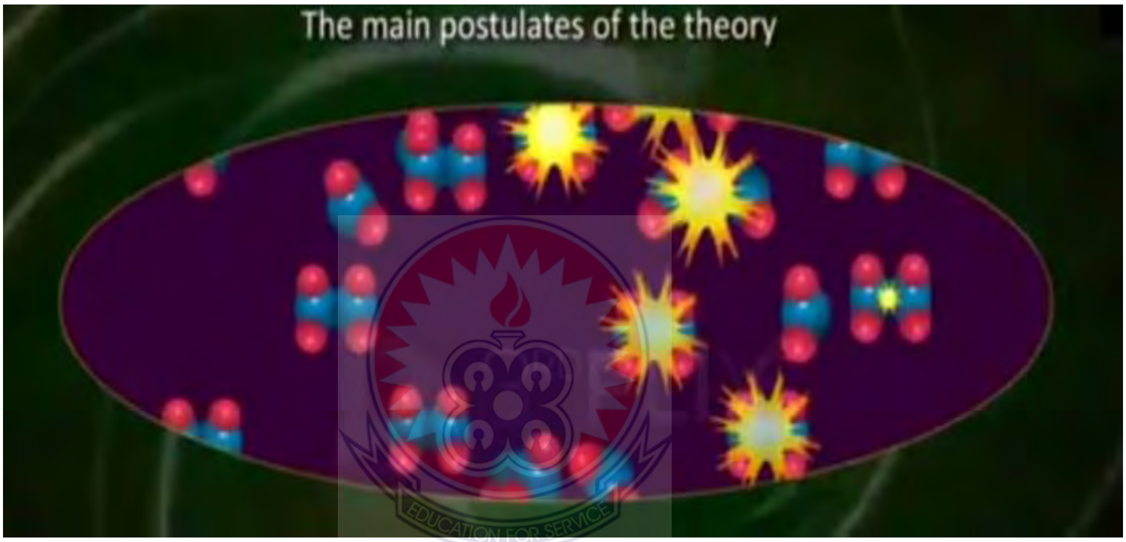

Figure 1: Animation showing how molecules collide to bring about chemical reactions

The researcher explained concepts to students as they watched the animated videos on a screen using a projector. The researcher explained the postulates of the collision theory as follows:

- Particles are in constant rapid motion which results in many collisions. Chemical reactions therefore occur as a result of collisions between reactant molecules.

- Only a small fraction of the collisions lead to chemical reactions and these collisions are called effective collisions.
- Only the most energetic molecules undergo reactions as a result of effective collisions.
- The probability of a collision resulting in a chemical reaction depends on the orientation of the colliding molecules.

Figure 2 was used to explain the types of collisions and the orientations of the colliding molecules that can bring about chemical reactions.

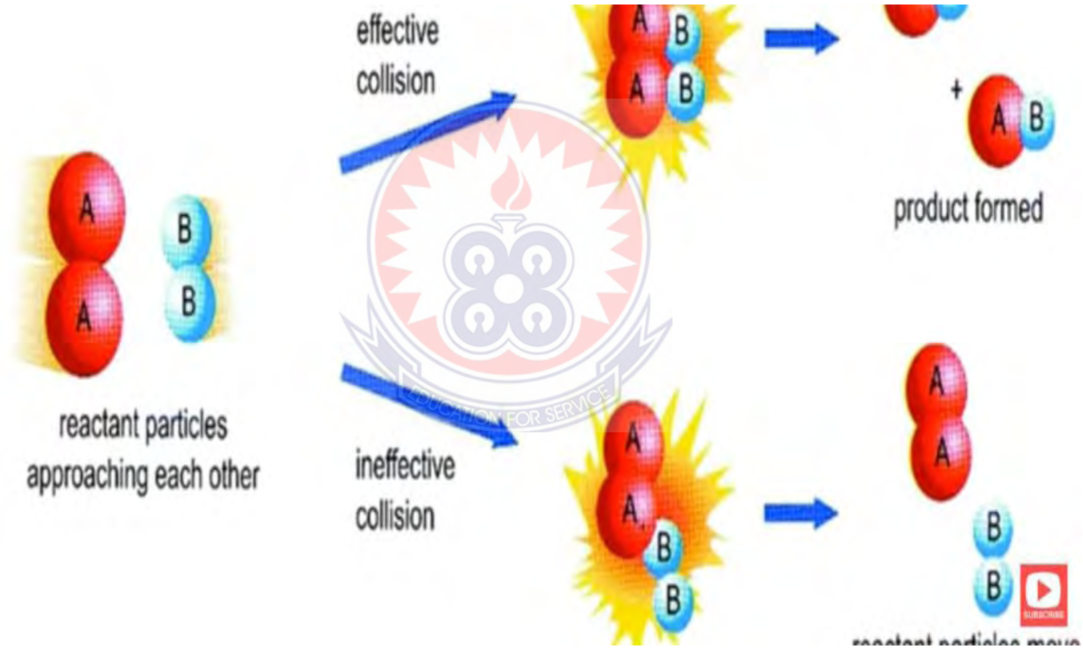

Figure 2: Animations showing the orientation of colliding molecules that can bring about effective collision and ineffective collision.

The researcher further explained activation energy to students as the minimum amount of energy needed by reactants to bring about a chemical reaction.

Students were put in groups after watching the videos to discuss what they had learnt. Students were allowed to ask questions for clearer explanations. At the end of the session, questions were posed to the students by the researcher to find out what they have learnt.

Session 2

Session 2 of the treatment activities took place in another chemistry lesson. This session was designed by the researcher to help students explain the factors that affect the rate of reactions. Using the projected animations on a screen, the researcher explained how temperature, concentration, addition of suitable catalyst and nature of particles could affect the rate of chemical reactions.

Using the animation in Figure 3, it was explained to students that, increase in concentration, increases the number of particles per unit volume. This increases the number of collisions as well as the number of effective collisions per unit time and the rate of the reactions also increases. Decrease in concentration, decreases the number of particles per unit volume. As there are few particles present, the number of collisions caused by these particles will be less and the number of effective collisions per unit time will decrease. The rate of the reaction will also decrease.

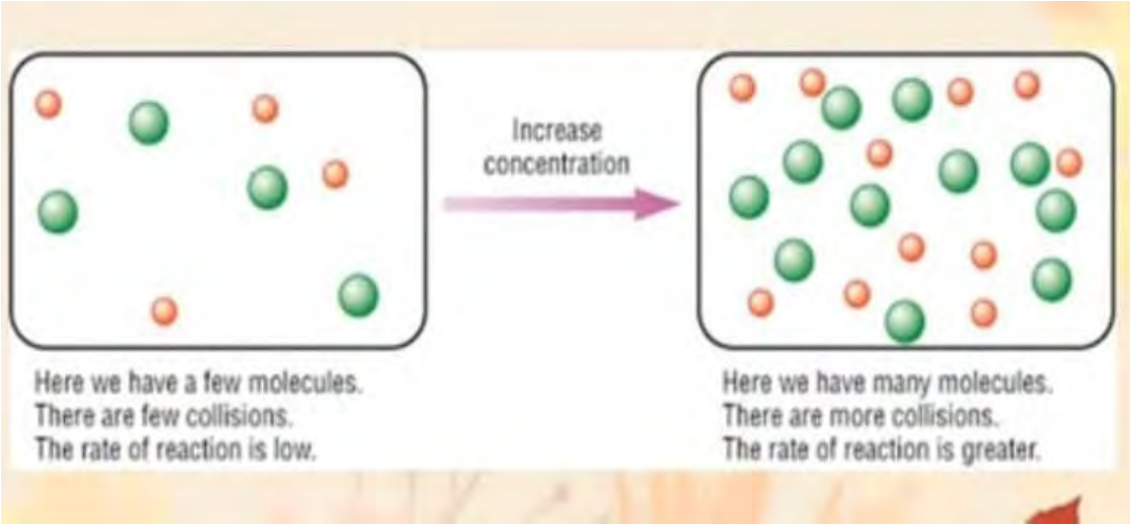

Figure 3: Animation showing the effect of concentration on the rate of reactions

Using the animation in Figure 4, it was explained to students that, an increase in temperature of the reacting molecules, increases the kinetic energy of the reacting molecules. This increases the number of collisions per unit time as well as the number of effective collisions and the rate of the reactions increases. Decrease in temperature of the reacting molecules, decreases the kinetic energy of the reacting molecules. This decreases the number of collisions as well as the number of effective collisions per unit time and the rate of the reactions decreases.

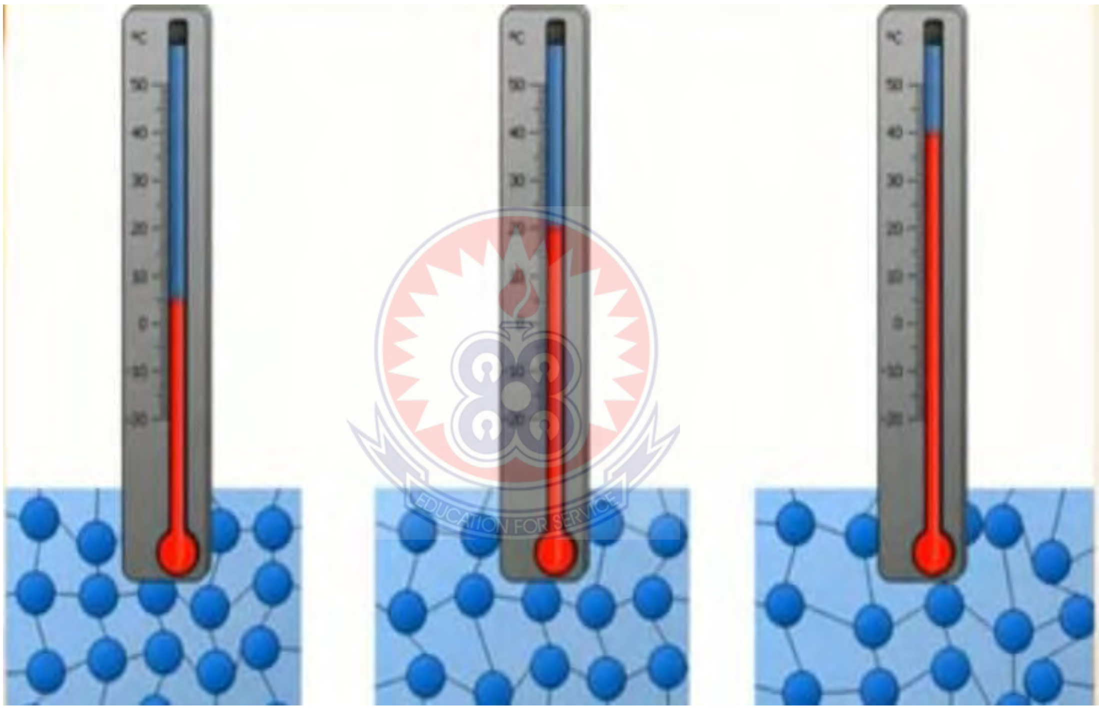

Figure 4: Animation showing how decrease and increase in temperature affect the rate of reactions.

The researcher used Figure 5 to explain how nature of particles affect the rate of reactions.

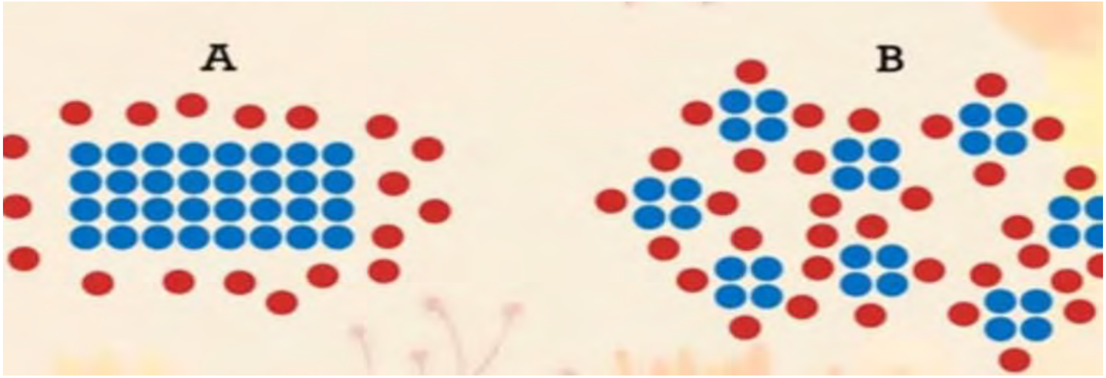

Figure 5: Animation showing how the nature of particles can affect the rate of reactions.

The particles in A in the animation in Figure 5 represent particles in a solid and particles in B represent particles in a liquid. Solids have smaller surface area and only particles at the surface can partake in reactions, resulting in a smaller number of collisions and slow rate of reactions. Breaking the solid reactant into smaller pieces as shown in B, increases the surface area and more particles are exposed. This results in an increased frequency of collisions and therefore a faster rate of reactions.

The effect of suitable catalyst on rate of reactions was also explained. A catalyst is a substance that speeds up a reaction, but is not used up in the process. It provides a new reaction pathway which reduces the activation energy of a reaction. A catalyst does not increase the frequency of collisions but increases the likelihood that each collision will be successful and this increases the rate of reactions. Students were put in groups after watching the videos to discuss what they have learnt. After which students asked questions for better understanding.

Session 3

In session 3, the researcher used animated diagrams to explain the rate determining step of reactions and guided students to write the rate law equations for the given reactions. The researcher also guided the students to determine the order of these given reactions. Students worked more examples related to the concept to help improve their understanding. The animations were also used to explain the types of order using graphical representations.

Rate law equation is an expression or an equation that relates the rate of a reaction to the concentration of reactants raised to their corresponding powers. The rate law equation is derived from the rate determining step of a reaction. Rate determining step of a reaction is the slowest step among a series of reactions that complete the main reaction.

Example: If the reaction, $X + 2Y + Z \rightarrow Q + P$ is a rate determining step, the rate law equation will be given as $R = K[X]\,[Y]^2\,[Z]$

Where R = the rate of the reaction

K = specific rate constant

[X] = concentration of reactant X

[Y] = concentration of reactant Y

[Z] = concentration of reactant Z

The specific rate constant, K, is defined as the constant of proportionality in any rate law equation.

Order of reaction with respect to a particular species is equal to the power to which the concentration of this species must be raised in the rate expression. From the rate law equation, R = K[X] $[Y]^2$ [Z], the order of the reaction with respect to each reactant will be:

Order of the reaction with respect to reactant X is 1

Order of the reaction with respect to reactant Y is 2

Order of the reaction with respect to reactant Z is 1

The overall order of a reaction is the sum of the powers to which the concentrations of the reactants in a rate law equation are raised.

Therefore the overall order of the reaction X + 2Y + Z → Q + P is calculated as:

Order of the reaction = order of reactant X + order of reactant Y + order of reactant Z

= 1 + 2 + 1 = 4

Deducing the rate law equations from an experimental data

When the reactions given are not Rate Determining Step, the orders of the respective reactants are deduced from given experimental data.

Example: The following data were obtained in an experiment to determine the rate of the reaction, A + 2B → 2C + D under various conditions. Table 2 shows the experimental data for the reaction, A + 2B → 2C + D.

Table 2: An Experimental Data.

Experiment	Concentration of A / $\mathbf{mol\ dm^{-3}}$	Concentration of B / $\mathbf{mol\ dm^{-3}}$	Rate/ $\mathbf{mol\ dm^{-3}s^{-1}}$
1	0.10	0.10	7.6×10^{-3}
2	0.10	0.20	1.52×10^{-2}
3	0.20	0.10	1.52×10^{-2}

Let the order of the reaction with respect to A and B be x and y respectively.

The rate law equation will be written as $R = K [A]^x[B]^y$ since the equation given is not a rate determining step.

$$\frac{\text{Exp 2}}{\text{Exp 1}} = \frac{1.52 \times 10^{-2}}{7.6 \times 10^{-3}} = \frac{K (0.10)^x (0.20)^y}{K (0.10)^x (0.10)^y}$$

$$2 = 2^y$$

$$y = 1$$

$$\frac{\text{Exp 3}}{\text{Exp 1}} = \frac{1.52 \times 10^{-2}}{7.6 \times 10^{-3}} = \frac{K (0.20)^x (0.10)^y}{K (0.10)^x (0.10)^y}$$

$$2 = 2^x$$

$$x = 1$$

The order of the reaction with respect to A and B is 1 and 1 respectively.

The rate law equation will therefore be $R = K [A] [B]$

The overall order of the reaction = order of the reaction with respect to A + order of the reaction with respect B = 1 + 1= 2

Graphical representations of the orders of reactions

Considering the reaction: A→ Products

- If the order of the reaction with respect to A is zero, then the rate law equation is given as $R =K [A]^0$. The plot of rate against concentration of A gives a straight horizontal line represented in diagram A in Figure 6.
- If the order of the reaction with respect to A is 1, then the rate law equation is given as $R =K [A]$. A plot of rate against concentration of A gives a straight line that passes through the origin represented in diagram B in Figure 6.
- If the order of the reaction is 2, the rate law equation is given as $R = K [A]^2$.

A plot of rate against concentration of A gives a curve as represented in diagram C in Figure 6.

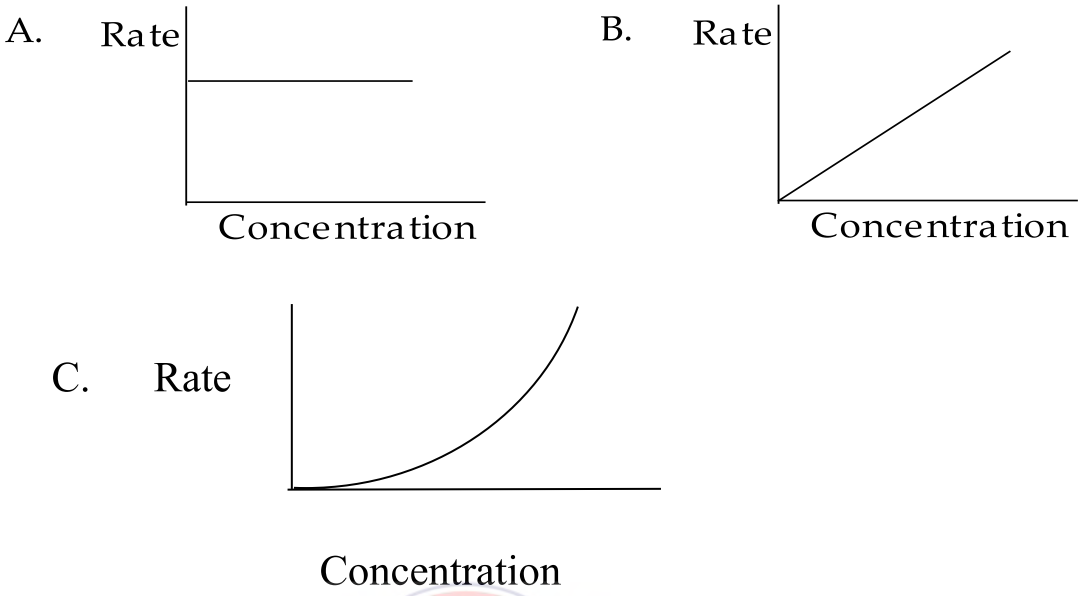

Figure 6: Graphical representation of zero order, first order and second order of reactions

After the three sessions, the animated videos were put on the computers in the school's ICT laboratory, for students to watch at their leisure time during school hours. This was done under the supervision of the ICT teacher and the researcher. Questionnaires were given to the participants in the experimental group to fill to find out the perceptions students have about the use of computer animation in learning of rate of reactions.

3.11 Data Analysis

The questionnaires were analysed to find out the perceptions students have on the use of computer animation. The data collected from both the pre-test and post-test exercises were analysed using descriptive statistics. A t-test was used for the hypothesis testing to find if there was a significant difference or not between the academic achievements of students who were taught using animations and students who were taught using the traditional approach. A p-value, which is the significance (p) value is compared to the prior alpha level (level of significance for the statistic) and a determination is made as to reject ($p < \alpha$) or retain ($p > \alpha$) the null hypothesis (Hair, et al., 2010). A p-value less than 0.05 is considered significant while a p-value greater than 0.05 is considered insignificant.

3.12 Ethical Consideration

There is the need for ethical consideration in any research that involves people. The following ethical issues were observed when conducting this research: informed consent, confidentiality, anonymity, respect and discontinuance.

3.12.1 Informed consent

Informed consent seeks to incorporate the rights of autonomous individuals through self-determination. Individuals can make informed decisions in order to participate in the research voluntarily, only if they have information on the possible risks and benefits of the research before the research begins (Fouka & Mantzorou, 2011). The head teachers of the two schools and the participants were informed of the purpose of the research, expected duration and procedures of the research.

3.12.2 Discontinuance

Participants' right to decline to participate or to withdraw from the research was made clear to the participants. The participants were told of their freedom to withdraw at any time without giving any reason or being penalised. The researcher ensured that the participants knew their rights to withdraw. The participants had the rights to withdraw retrospectively, and to require that their own data, including recordings, be destroyed.

3.12.3 Confidentiality

Confidentiality relates to the protection of data gathered. It is the management of private information by the researcher in order to protect the subject's identity (Maclean & Poole, 2010). Participants in science research have the rights to expect that the information they provide will be treated confidentially and if published, will not be identifiable as theirs (Jeridah, 2019). The researcher informed the participants about the methods which would be used to protect anonymity and confidentiality.

3.12.4 Anonymity

Making data anonymous means that the contributors' names are not disclosed in order to protect participant's identity. Anonymity is protected when participant's identity cannot be with personal response (Fouka & Mantzorou, 2011).

All research data collected in this study remained confidential and the identity of the participants was protected throughout the study. No student's names have been mentioned or was published in any reports of this study. The researcher took as much precaution as possible to protect anonymity and gave advice on any special action the participants should take, to avoid risk.

3.12.5 Respect

The principle of respect requires the researcher to avoid discrimination against colleagues or learners on basis of sex, race, gender, ethnicity or other factors that are not related to their scientific competence and integrity (David & Resnic, 2011). In this study, all students taking part were treated equally irrespective of their gender, social, economic and religious differences.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents the analysis of data and findings of the study obtained from the pre-test, post-test and questionnaire from the experimental group and the control group. The analysis and discussions were in light of the research questions. Descriptive statistics of the test scores were calculated to determine the difference between the variables of the two groups. The descriptive statistics included frequency of the number of boys and girls who participated in the study, means and standard deviations. An independent t-test was further applied to see whether a statistically significant difference existed among the mean values at a 0.05 alpha level.

4.1 Demographic Characteristics of the Students

This section presents the statistical data on the number of boys and girls who took part in the study. Figure 7 shows a bar chart indicating the percentage number of boys and girls who participated in the study.

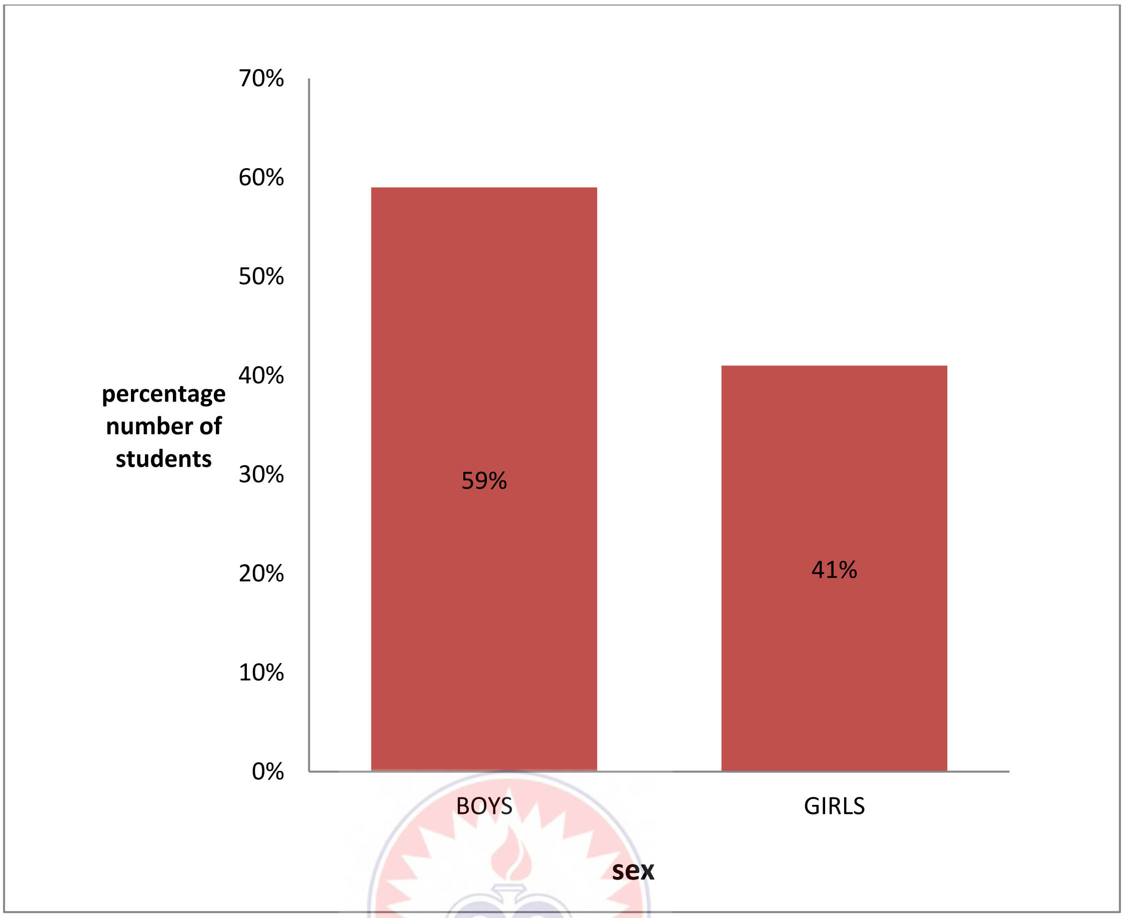

Figure 7: A bar chart of the percentage number of boys and girls who participated in the study

Figure 7 revealed that 59% of the students were boys and 41% of them were girls. This implies that the study was dominated by boys; however, the dominance of the boys in the study is not supposed to skew the results of the study.

4.2 Presentation of the Results from Research Questions

Research Question One: What would be some of the misconceptions general science students have on rate of reactions?

The first research question of the study sought to find out the misconceptions students have on rate of reactions. The pre-test scores were used to identify some of these misconceptions. The Table 3 shows the pre-test scores for each student in the experimental and control groups.

Table 3: Pre-test Scores (in Percentages) for Experimental Group and Control Groups

Learner number	Experimental group: Scores for each learner (%)	Control group: Scores for each learner (%)	Learner number	Experimental group: Scores for each learner (%)	Control group: Scores for each learner (%)
1.	58	50	25.	33	60
2.	38	53	26.	28	35
3.	38	48	27.	38	38
4.	25	40	28.	58	30
5.	38	28	29.	13	53
6.	35	18	30.	33	58
7.	15	48	31.	18	38
8.	23	20	32.	30	33
9.	23	18	33.	38	65
10.	65	20	34.	20	20
11.	33	33	35.	25	30
12.	40	48	36.	21	35
13.	30	35	37.	40	48
14.	53	33	38.	33	45
15.	65	30	39.	30	28
16.	18	35	40.	23	30
17.	70	25	41.	33	
18.	65	35	42.	20	
19.	35	23	43.	18	
20.	40	50	44.	32	
21.	58	30	45.	28	
22.	53	28			
23.	65	45			
24.	48	28			

From Table 3, the pre-test scores showed that most of the students in both the experimental and control groups scored below 50%which was a poor performance in the pre-test exercise. It was also seen that few of the students from both groups scored above 50%. Scoring below 50% indicated that most of the students had wrong answers for most questions in the pre-test and this was due to misunderstanding of the concepts.

Table 4 was used to identify some of the misconceptions students have on rate of reactions. Table 4 shows the results for the test items, the number of participating students who worked each item correctly and wrongly and their corresponding percentages in the pre-test exercises.

Table 4: Results of Students' Performance in the Pre-test Presented as Figures and Percentages

Question number	Total number of students	Number of students with correct answers	Percentage (%)	Number of students with wrong answers	Percentage (%)
1.	85	20	24	65	76
2.	85	50	59	35	41
3.	85	21	25	64	75
4.	85	37	44	48	56
5.	85	75	88	10	12
6.	85	23	27	62	73
7.	85	66	78	19	22
8.	85	64	75	21	25
9.	85	11	13	74	87
10.	85	23	27	62	73
11.	85	30	35	55	65
12.	85	70	82	15	18
13.	85	26	31	59	69
14.	85	32	38	53	62
15.	85	20	24	65	76
16.	85	40	47	45	53
17.	85	17	20	68	80
18.	85	40	47	45	53
19.	85	19	22	66	78
20.	85	21	25	64	75
21.	85	59	69	26	31
22.	85	68	80	17	20
23.	85	65	76	20	24
24.	85	75	88	10	12
25.	85	5	6	80	94
26.	85	9	11	76	89
27.	85	25	29	60	71
28.	85	23	27	62	73
29.	85	24	29	61	71
30.	85	20	24	65	76

Table 4 indicated that, some students had some questions correctly and others had some questions wrong. This helped the researcher to identify some of the misconceptions from the wrong answers.

Table 5 is the specification table of the pre-test which shows the various areas in rate of reactions that students were tested on and the corresponding test items.

Table 5: Specification Table of the Pre-test

Areas in rate of reactions tested on	Item Number	Total items
1. Definition of terms	5, 21, 22, 23	4
2. Collision theory	8, 18, 25	3
3. Rate law equation	4, 11, 15, 28, 30	5
4. Order of reactions	1, 9, 17, 27, 29	5
5. Graphs on rate of reactions	6, 7, 13, 19	4
6. Factors that affect rate of reactions	2, 3, 10, 12, 14, 16, 20, 24, 26	9
Total	**30 items**	**30 items**

From Table 5, test items 5, 21, 22 and 23 of the pre-test were used to identify the misconceptions students have on the definitions of rate of reactions, activation energy, order of a reaction and the rate law. From Table 4, 88% of the students were able to define activation energy and 12% possess misconceptions because of their wrong choice of answer for item 5. Table 4 also revealed that the percentage of students who had item 21 correct was 69% and those who had it wrong was 31%. This indicated that most students were able to define rate of reactions. For items 22 and 23, the percentage of students who had correct answers were 80% and 76% respectively. This shows that the majority of the students could define the order of a reaction and the rate law.

Test items 8, 18 and 25 of the pre-test from Table 5 were intended to identify the misconceptions students have on the collision theory. Table 4 showed that 75% of the students were able to select the correct option for item 8 when they were asked to choose the correct postulate of the collision theory from others which were not. However, when a similar question was asked in item 18, only 47% of the students chose the correct answer and 53% of them chose wrong answers. This is an indication that the students did not know all the postulates in the collision theory. This misconception that students have about the collision theory was confirmed when only 6% out of the 85 students who took the test were able to state all the postulates of the collision theory while 94% could not in item 25.

The most prevalent misconceptions the students had were observed in items 4, 11, 15, 28, and 30. From Table 5, these test items were used to identify the misconceptions students have in writing the rate law equations. Observations from Table 4 showed that 44% of the students chose the correct factor to which the rate of the reaction will be increased to when the reactants in the given rate law equation, $R = K [X]^2 [Y]$ were doubled and 56% of them had the same item 4 wrong. 35% of the students chose the correct factor for item 11 and 65% of them chose the wrong factors when the concentrations of different reactants were used and the powers, to which the reactants were raised to, were also changed.

For item 15, about 76% of the students chose the wrong option while 24% chose the correct number of times that the rate of the given reaction, $2A + 2B + C \rightarrow D$, would increase when all the reactants in the rate law equation $R = K [A]^2[B]^2[C]$ are doubled.

The experimental data from Table 6 for the reaction, A + 2B → 2C + D was provided for students to deduce the rate law equation.

Table 6: Experimental data for the reaction, A + B → 2C + D

Experiment	Concentration of A / **mol dm^{-3}**	Concentration of B / **mol dm^{-3}**	Rate/ **mol dm^{-3}s^{-1}**
1	0.10	0.10	7.6×10^{-3}
2	0.10	0.20	1.52×10^{-2}
3	0.20	0.10	1.52×10^{-2}

Only 27% of the total students were able to write the correct rate law equation for the experimental data in Table 6 for item 28 while 73% of them were not able to write the rate law equation. For item 30, students were then asked to calculate the specific rate constant of the reaction using the experimental data provided in item 28, but only 24% of them could calculate the specific rate constant and provided the correct units.

Items 1, 9, 17, 26, 27 and 29 as displayed in Table 5 were used to identify the misconceptions that students have about finding the order of reactions. From Table 4, 24% of the students were able to choose the correct answer which was the third order while 76% of them chose the wrong answer for item one when they were asked to provide the order of the reaction, A + 2B → D, which was the rate determining step for the reaction, 2A + 3B → 3C. About 13% of the students were able to calculate the overall order of the reaction, 3A + 2B → C + D for item nine when the rate of the reaction was doubled as the concentration of A was doubled and quadruples as concentration of B was doubled.

For item 17, students were asked to select the correct rate law of the reaction, $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$ which was found to be first order with respect to the reactants. Out of the 85 students who participated in the test, 20% of them selected the correct option and 80% of them selected the wrong option. Analysing item 27, 29% of the students successfully determined the order of the reaction with respect to the reactants in the given experimental data but 71% had difficulties determining the orders. For item 29, those who answered this item correctly were 29% and those who had difficulties were 71% when they were asked to calculate the overall order of the given reactions.

Items 6, 7, 13 and 19 as shown in Table 5 were used to assess students' ability to interpret graphs on rate of reactions. Table 4 showed that majority of the students representing 78% were able to select the presence of catalyst as the correct option when they were asked to find the factor responsible for the activation energy, E_2 in an energy profile diagram provided in item seven. This indicated that few of the students representing 22% had difficulties in interpreting the energy profile diagram. For items 6, 13 and 19, low percentage was recorded for students who could interpret the various graphs provided. This shows that the majority of the students had difficulties in interpreting given graphs.

From Table 5, items 2, 3, 10, 12, 14, 16, 20, 24 and 26 were used to identify the misconceptions students had on the factors that affect the rate of reactions. Table 4 showed that a high percentage of students answered items 2, 12, and 24 correctly. These are indications that most students could state the factors that affect the rate of reactions. From Table 4, there were low percent of students who answered items 3, 10, 14, 16, 20 and 26 correctly. These showed that most students could not explain how temperature, concentration, nature of particles, addition of suitable catalyst and pressure could affect the rate of reactions.

Testing of Hypothesis

H_{O1}: There is no statistically significant difference between the pre-test scores of students who were taught using computer animation and those taught using traditional method.

A t-test was applied to the pre-test results of the experimental group and control group to see whether a statistically significant difference existed among the mean values.

Table 7 shows outcomes of the t-test results between the experimental group and the control group before the treatment was employed.

Table 7: The t-test results of the experimental and control groups' pre-test scores (significant at $p < 0.05$)

Groups	N	M	SD	Df	t	p
Experimental group	45	36.51	15.43	83	-0.05	0.96
Control group	40	36.68	12.18			

Table 7 reports the outcomes of the independent t-test for the overall mean scores for the experimental group and the control group. The standard deviations of the pre-test scores for the experimental and control groups were 15.43 and 12.18 respectively. The mean of the pre-test scores for the experimental group was 36.51 and the mean for the control group was 36.68. The mean of the control group was slightly higher than the mean of the experimental group, but this small difference is not statistically significant. Analysis from Table 7 shows that the t-statistic was -0.05 and the p-value was 0.96. The results indicated that the p-value was greater than the alpha value, 0.05 ($p > 0.05$). There was, therefore, no statistically significant difference between the pre-test scores of the experimental and control groups. Therefore, we fail to reject the null hypothesis. This indicates that the students in the experimental group and control group were at the same level of understanding at the beginning before the treatment was employed.

Research Question Two: What would be the effect of computer animation on students' academic achievements in learning rate of reactions?

The second research question sought to find the effect of computer animation on students' academic achievements in learning rate of reactions. The post-test results showed whether the academic achievement of the students improved or not after the experimental group was taught using computer animation. Table 8 shows the post-test scores for each student in the experimental and control groups.

Table 8: Post-test scores (in Percentages) for Experimental Group and Control Group

Learner number	Experimental group: Learner scores (%)	Control group: Learner scores (%)	Learner number	Experimental group: Learner scores (%)	Control group: Learner scores (%)
1.	85	51	24.	70	42
2.	65	55	25.	68	62
3.	60	50	26.	58	46
4.	63	42	27.	65	40
5.	68	48	28.	90	45
6.	65	47	29.	62	54
7.	65	48	30.	63	58
8.	63	42	31.	60	49
9.	68	44	32.	70	50
10.	88	41	33.	75	66
11.	74	46	34.	71	45
12.	70	50	35.	75	42
13.	65	42	36.	68	40
14.	75	43	37.	71	50
15.	85	40	38.	70	49
16.	63	40	39.	69	40
17.	92	43	40.	69	40
18.	68	48	41.	75	
19.	65	43	42.	70	
20.	78	51	43.	55	
21.	84	53	44.	81	
22.	80	58	45.	63	
23.	82	50			

From Table 8, it was observed that the majority of the students in the experimental group scored above 50%. This is an indication that the students in the experimental group performed better in the post-test than the pre-test. The majority of the students in the control group scored below 50% in the post-test as observed in Table 8. This showed that there was no improvement in the performance of the students in the control group after the treatment. From these observations, it was concluded that the academic performance of the students in the experimental group was enhanced after they were taught rate of reactions using computer animation.

Testing of Hypothesis

H_{O2}: There is no statistically significant difference between the post-test scores of students who were taught using computer animation and those taught using traditional method.

A t-test analysis was further applied to compare the results of the post-tests scores for the experimental group and control group. The t-test results are shown in Table 9.

Table 9: The t-test results of the Experimental and Control Groups' Post-test Scores (Significant at $p < 0.05$)

Groups	N	M	SD	Df	t	p
Experimental group	45	70.87	10.58	83	13.96	0.00
Control group	40	47.33	11.09			

Table 9 shows statistical differences in the means of the post-test scores of the experimental group and control group. The means of the post-test scores for control group and experimental group were 47.33 and 70.87 respectively. The mean of the experimental group was higher than the mean of the control group in the post-test scores. When t-test was used to analyze this comparison, it was found that the t-statistic was 13.96 and the p-value was 0.00. The p-value was less than the 0.05 alpha value and this shows that there was a statistically significant difference in the post-test scores between the experimental group and the control group after the treatment. Based on the data provided in Table 9, it could be concluded that the treatment used in teaching the experimental group enhanced learners' understanding of rate of reactions and they performed better than those in the control group that were taught using the traditional method. The null hypothesis was rejected as there was statistically significant difference between the academic achievements of students who were taught using computer animation and students who were taught using the traditional method.

Research Question Three: What would be the perceptions students have about the use of computer animation in learning rate of reactions?

The third research question sought to find the perceptions students have on the use of computer animation in learning rate of reactions. These perceptions were determined from the analysis of responses of respondents from the questionnaire given. The perceptions looked at were the benefits that students derived from using computer animation in the learning of rate of reactions and the challenges students faced when using computer animation in learning rate of reactions. The results of the analysis were presented in frequency and percentages. Table 10 presents the analysis of the responses on the benefits and challenges of using computer animation in learning rate of reactions.

Table 10: Responses of Students on the Benefits and Challenges of Using Computer Animation in Learning Rate of Reactions.

Benefits and challenges of using computer animation in learning rate of reactions	D	%	NS	%	A	%
1. Computer animation deepens my understanding in rate of reactions much more than traditional diagrams	5	11.1	2	4.4	38	84.4
2. I find the use of computer animation as an interactive tool for learning rate of reactions	6	13.3	0	0	39	86.7
3. Too many graphics in animation can be annoying	10	22.2	2	4.4	33	73.3
4. The use of animation for learning rate of reactions is very interesting to me	2	4.4	1	2.2	42	93.3
5. Excessive colours in animation can be distractive	15	33.3	3	6.7	27	60
6. Animation makes complex information in rate of reactions simple for me	5	11.1	2	4.4	38	84.4
7. I discover that animation has the power of creating and bringing things alive as it appears in real life.	2	4.4	3	6.7	40	88.9
8. It is difficult to understand rate of reactions when using animation	42	93.3	1	2.2	2	4.4
9. The use of animation in learning rate of reactions adds fun to my learning	3	6.7	2	4.4	40	88.9
10. Animation makes rate of reactions more complicated to learn	40	88.9	3	6.7	2	4.4
11. Animation can hold my attention in learning	5	11.1	7	15.6	33	73.3
12. It is boring to learn rate of reactions using animation	40	88.9	2	4.4	3	6.7
13. Animation builds interest in me and motivates me to learn more	2	4.4	3	6.7	40	88.9

D= strongly disagree/ disagree NS= not sure A= strongly agree/ agree

From Table 10, about 84.4% of the students generally agreed that computer animation deepens understanding in rate of reactions much more than traditional diagrams while only 11.1% of students disagreed to the assertion and 4.4% of students were indecisive. The results also showed that the majority of the students representing 86.7% agreed that the use of computer animation is an interactive tool for learning rate of reactions. This statement was, however, disagreed with by 13.3% of the students while none of the students was unsure about their responses.

Out of the 45 students representing 100% who responded to the statement of whether the use of animation for learning rate of reactions is very interesting or not, 93.3% of the students were in agreement with the assertion whilst 4.4% of the students disagreed, and only 2.2% of the students were unsure. The results also showed that 84.4% of the students agreed to the statement that animation makes complex information in rate of reactions simple. In addition to that, 11.1% of the students disagreed to the assertion and 4.4% of the students were unsure.

With regards to the statement, animation has the power of creating and bringing things alive as it appears in real life, 88.9% of the students were in agreement with the statement while 4.4% of the students disagreed with the statement. Additionally, 88.9% of the students also indicated their agreement with the statement, the use of animation in learning rate of reactions adds fun to learning. The result also revealed that 6.7% and 4.4% of the students disagreed and were uncertain about the response. In terms of whether animation can hold students' attention or not, 73.3% of the students agreed with the statement while 11.1% of the students disagreed and 15.6% of students were unsure about the statement.

Out of the total number of students who responded to the statement that animation builds interest in students and motivate them to learn more, 88.9% of them agreed with the assertion while 4.4% of them disagreed.

Table 10 also presents the analysis of the responses on the challenges students face when using computer animation in learning rate of reactions. The results revealed that the students had some challenges when it came to using computer animation in learning rate of reactions. One of such a challenge was seen when 73.3% of the students agreed to the statement that too many graphics in animation can be annoying and 22.2% disagreed, with 4.4% of them who were not sure of the statement.

Another challenge identified was that excessive colours in animation can be distractive. This was noticed when majority of the students representing 60% agreed with the statement item two. 33% disagreed with the same statement and 6.7% of them were unsure. A higher percentage of the students disagreed with the following statements; learning rate of reaction using animation is boring, understanding rate of reactions using animation is difficult and animation makes rate of reactions more complicated to learn.

4.3 Discussion of Results in Relation to Research Questions

4.3.1 Research Question 1:

What would be some of the misconceptions general science students have on rate of reactions?

From the responses of the students in Table 4 for the pre-test exercise before the treatment, the following misconceptions were also identified as vernacular and conceptual misunderstandings:

1. Most students had poor understanding of the collision theory and how to use the theory to explain the factors that affect rate of reactions.
2. Most students could not draw graphs for the various orders of reactions and as such could not interpret those graphs.
3. Most students had difficulties in calculating orders of reactions and writing rate law equations from experimental data.

All these misconceptions are in line with the findings of Irhasyuarna and Irhasyuarna (2017), Secken and Seyhan (2015), and Ahiakwo and Isiguzo (2015). Irhasyuarna and Irhasyuarna reported that students in their study had misconceptions on the order of reactions and how temperature, concentration and pressure affect the rate of reactions. Secken and Seyhan found that most of the participants in their study did not have any interest in graphical themes under rate of reactions and chemical equilibrium and that they had anxiety in drawing or interpreting graphs in exams due to making mistakes. Ahiakwo and Isiguzo also found that secondary students had misconceptions related to the factors that affect rate of reactions and they also reported that students' performance in basic calculations in rate of reactions was poor with the mean scores less than one point.

4.3.2 Research Question 2:

What would be the effect of computer animation on students' academic achievements in learning rate of reactions?

From the responses of the students in the post-test exercise after the treatment, it was noticed that the experimental group performed better than the control group. This was observed from Table 8, when students in the experimental group scored above 50% and the majority of students in the control group still had scores below 50%. From this analysis, it was concluded that the use of computer animation in teaching rate of reactions helped enhanced students' academic achievements.

This section also presents the t-test analysis between the post-test scores of the experimental group and control group. The rationale was to find the effect of computer animation on the academic achievements of students in the experimental group in their learning of rate of reactions. The results of the t-test analysis in Table 9 showed that the p-value was 0.00 which was less than the alpha level 0.05. This shows that there was statistically significant difference between the post-test scores of the experimental group and control group. This indicates that the means of the experimental group and the control group were not equal and the mean of the experimental group was higher than the control group. This also shows that the academic achievements of the students in the experimental group increased when they were taught using computer animations.

In congruence to these results of the study, Ismail, et al. (2017) pointed out that video animation enhanced students' imagination and visualizations and assisted students in understanding difficult topics. The results of this study are also in agreement with the findings of Gryczka, et al., (2016) study that suggested that utilising technology in the classroom could help students to be more conductive to learning because it improves their attitudes, thus allowing educators to teach more effectively. They added that implementation of technology helps students to become more engaged with school work and it benefits teachers in the sense of keeping current with research and new teaching methods.

Aksoy (2012) investigated the effect of animation on the academic achievement of students in the human and environment unit lectured as part of the science and technology course of seventh grade in primary education. The findings of the study indicated that the animation technique was more effective than the traditional teaching methods in terms of enhancing students' achievement. Also in congruence to these results of the study, Ikwuka and Samuel (2017) revealed that computer animation chemistry instruction had significant effect on students' academic achievement in chemistry. They suggested that the use of animation in teaching adds real value to chemistry concepts and concluded that the use of computer animation in teaching abstract chemistry concepts enhanced the efficiency of teaching and learning and assimilation of information. Lai, et al., (2009) reported that the use of animation in teaching is significant in increasing the attitudes and academic achievement of the students.

4.3.3 Research Question 3:

What would be the perceptions students have about the use of computer animations in learning rate of reactions?

This section presents the analysis of responses of respondents from the questionnaire given. This was to look at the benefits that students derived from using computer animation in the learning of rate of reactions and the challenges students faced using computer animation in learning rate of reactions. From the analysis as shown in Table 10, it was found that most of the students agreed to the statements that, computer animation was an interesting and interactive tool that had the power of creating and bringing things alive. A higher percentage of the students also agreed that the use of computer animation made complex information simple and deepened understanding of rate of reactions. Majority of them also agreed that computer animation can hold students' attention, build their interest and motivate them to learn more.

From the analysis as indicated in Table 10, it was revealed that students had some challenges when it came to using computer animation in learning rate of reactions. Most of the students agreed that too many graphics and excessive colours in animation can be distractive during teaching.

In support of these findings of the study, Baglama, et al. (2018) pointed out that educational animations contain motivating and entertaining features that can be used as an enrichment of other teaching methods for instructional or educational purposes. Ismail, et al. (2017) concluded that text, graphics, animation, audio and video were able to increase the motivation of students and make learning process interesting. Hwang, et al. (2012) also revealed that animation explains contents more explicitly to students.

In line with these findings, O'Day (2011) reported that there are unlimited ways to lose a student's attention and he also discussed the fundamental components that should be included in a meaningful animation. These essential components discussed were apprehension, coherence effect, spatial contiguity effect, multimedia effect, personalization, interactivity, visual cues, and attention cueing.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

The chapter presents the summary of the findings of the study on which conclusions are drawn. It also includes recommendations and suggestions for further studies. The purpose of the study was to find out how the use of computer animation could help to improve Senior High School general science students' academic achievement in learning rate of reactions.

5.1 Summary of Main Findings

The first research question sought to find the misconceptions students have on rate of reactions. Analysis of the pre-test scores presented in Table 4 showed that students had poor understanding of the collision theory and this made it difficult for them to state all the postulates of the collision theory. It was also noticed that students could not write the rate law equation correctly, calculate the order of given reactions and interpret graphs. The most prevalent of these misconceptions was observed when most students were able to state the factors that affect the rate of reactions (concentrations, temperature, nature of particles and addition of suitable catalyst) but could not explain how these factors affect the rate of reactions.

The identified misconceptions were found to belong to the class of vernacular and conceptual misunderstanding. Vernacular misconceptions arose from the students' interpretations of what collision means in our everyday life and what it means in the postulates of the collision theory. The conceptual misunderstanding stemmed from the way they were taught in their previous class.

The second research question sought to find the effect of computer animation on students' academic achievements in rate of reactions. The t-test analysis provided evidence that the traditional instruction was not as effective as the computer animated instruction in enhancing conceptual understanding about rate of reactions. The post-test scores were statistically significant at 5% since the p-value, 0.00 was less than the alpha level of 0.05. This showed that the mean of the experimental group was greater than the mean of the control group with 83 degrees of freedom. Therefore, the academic achievement of the experimental group improved more than the control group. It was also observed that, even with illustrations and explanations given during the treatment, students in the control group retained some resistance to change their misconceptions.

The third research question sought to find out the perceptions students have on the use of computer animation in learning rate of reactions. The responses of students from the questionnaire revealed that they perceived that computer animation deepened their understanding more than the traditional method and also simplified complex information. The use of animation in learning rate of reactions was an interesting and interactive tool that had the power of creating and bringing things alive as observed in real life. The students further perceived that animation added fun to learning, held students' attention and motivated students to learn more. The students added that too many graphics and excessive colours in animations distracted them during instructions.

The null hypothesis 1 stated that there is no statistically significant difference between the pre-test scores of students who were taught using computer animation and those taught using traditional method. Table 7 revealed that the students in the experimental group and the control group were at the same level of understanding before the treatment was employed since the p-value after the t-test analysis was 0.96 which was greater than the alpha value of 0.05.

The null hypothesis 2 stated that there is no statistically significant difference between the post-test scores of students who were taught using computer animation and those taught using traditional method. This null hypothesis was rejected, as the findings of the study revealed that the experimental group where computer animation was used performed better after the treatment than the control group where the traditional method was used.

5.2 Conclusions

Based on the findings, it was concluded that the use of computer animations assisted Form Three general science students of St. Margaret Mary Senior High Technical School to better understand the various sub-topics under rate of reactions. This explains why the academic performance of the experimental group improved more than the control group in their post-test scores.

The study also concluded that animation stimulates mental model building abilities of the students. This explains why the form three general science students in the experimental group were able to explain the collision theory and used this theory to explain how temperature, concentration, nature of particles and catalyst affected the rate of reactions. They were also able to calculate the order of reactions and interpret graphs representing the zero order, first order and second order as indicated in their post-test.

The representational models in animation allowed students to realize their existing conceptions, became dissatisfied with these conceptions and accepted better explanations. This helped students to eliminate their misconceptions. Computer animation provided better understanding of abstract concepts by serving as a bridge between the real-life examples and misunderstood concepts.

Finally, the study concluded that, although animation enhanced conceptual understanding and stimulated the interest of the students, too many graphics and excessive colours used in animation could distract students during instructional periods.

5.3 Recommendation

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

- Science teachers especially chemistry teachers in St. Margaret Mary Senior High Technical School and Ebenezer Senior High School in Ablekuma West Municipal should incorporate computer animation in teaching abstract concepts for easy conceptual changes and for better understanding.
- Chemistry teachers in St. Margaret Mary Senior High Technical School and Ebenezer Senior High School in Ablekuma West Municipal should make sure not to include many graphics and excessive colours when designing or selecting computer animations for instructions.
- Heads of St. Margaret Mary Senior High Technical School and Ebenezer Senior High School in Ablekuma West district should make projectors and other equipment needed for computer animated instructions available for teachers to use.

5.4 Suggestions

The following suggestions were made from the study:

- Curriculum designers for Senior High Schools should include the use of computer animation as an instructional approach for teaching complicated topics in the science curriculum.
- The Ghana Education Service directorate should organize in-service training and workshops for Senior High School science teachers in the various districts to train them on the use of animation for teaching.
- The Ghana Education Service directorate should also make computers, projectors and other equipment needed for computer animated instructions available in Senior High Schools.

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APPENDIX "A"

PRE-TEST

PART I

Answer all questions in this part.

1. The rate determining step for a reaction
   $2A + 3B \rightarrow 3C$ is $A + 2B \rightarrow D$. Therefore the reaction is of the
   A. first order. B. second order.
   C. third order. D. zero order

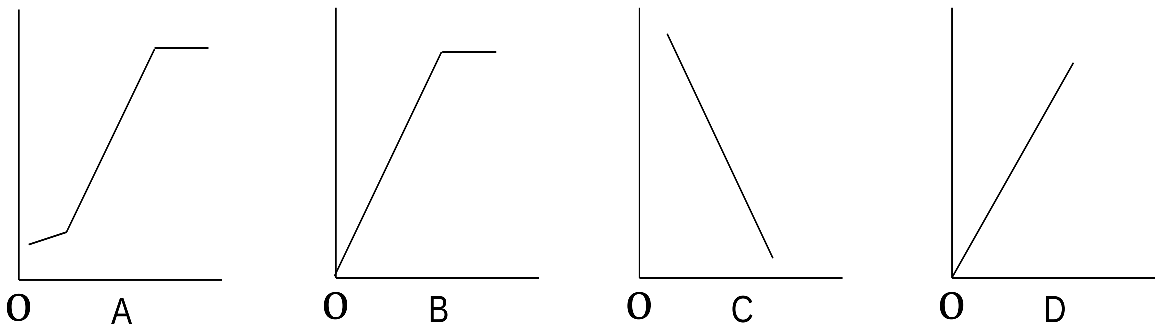
2. Chemical reactions tend to occur at higher rate at a higher temperature because
   A. masses of the reacting particles become lower at a higher temperature.
   B. the activation energy of the reaction becomes lower at a higher temperature.
   C. the number of effective collisions is higher at a higher temperature.
   D. the mechanism of the reaction at a higher temperature is different from that at a lower temperature.

3. Consider the reaction represented by the following equation: $2KClO_3 \rightarrow KCl + 3O_2$.
   Which of the following factors would increase the rate of the reaction?
   A. Increasing the volume of oxygen. B. Decreasing the temperature.
   C. Decreasing the quantity of reactant. D. Addition of MnO_2.

4. The rate equation of a reaction is $R = K [X]^2 [Y]$. By what factor would the rate of the reaction increase if the concentrations of X and Y are both doubled?
   A.16 B. 8 C. 4 D. 2

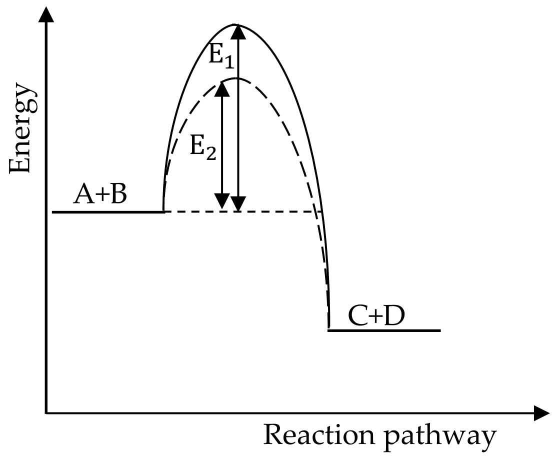
5. The activation energy of a reaction is the
   A. energy given out as the reaction proceeds.
   B. energy used up by the reactants.
   C. minimum energy that must be possessed by reactants to enable them react.
   D. energy absorbed as the reaction proceeds.

Use the graphs ***A, B, C*** *and* ***D*** *to answer Questions* **6.** *In each graph, O is the origin.*



6. Which of the graphs shows the variation of the rate of evolution of a gas from a given length of magnesium ribbon (**y-axis**) with increase in the concentration of acid added (**x-axis**).

7. In the diagram below, which of the following factors is responsible forE_2?



A. Low temperature B. High pressure
C. Presence of catalyst D. Increased concentration of reactants

8. The collision theory proposes that
   A. reactants collide to bring about the destruction of molecules.
   B. all collisions are fruitful.
   C. reactants must collide with a certain minimum amount of energy to form products.
   D. the harder the collisions the faster the reaction.

9. The rate of the reaction $\mathbf{3A + 2B \rightarrow C + D}$ is doubled when the concentration of **A** is doubled and quadrupled when the concentration of **B** is doubled. Calculate The overall order of the reaction.
   A. 5 B. 4 C. 3 D. 2

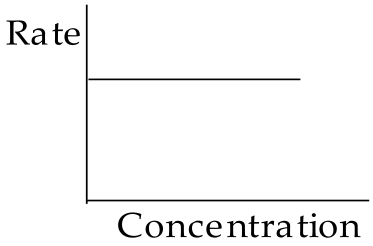
10. Increase in temperature of a reaction leads to an increase in the reaction rate by
   A. increasing the concentration of the reactants.
   B. lowering the activation energy of the reactants.
   C. increasing the number of molecules of reactants having the activation energy.
   D. providing an alternative reaction path with low activation energy.

11. The rate equation of a reaction is $R = K[A][B]^2$. By what factor will the reaction rate change if the concentrations of both **A** and **B** are doubled?
   A. 4 times B. 8 times C. 27 times D. 64 times

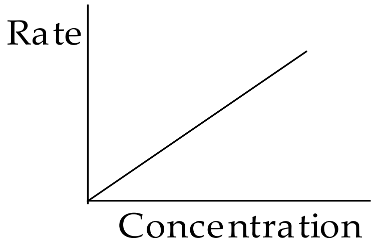
12. Which of the following parameters affects the rate of chemical reactions?
   I. State of reactants II. Temperature III. Catalyst
   A. I only B. I and II only C. I, II and III D. I and III only

13. Which of the following graphs represents a first order reaction?

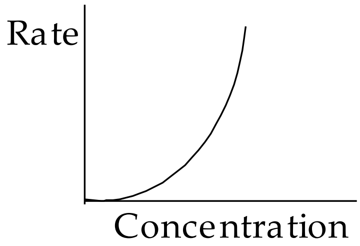
A.



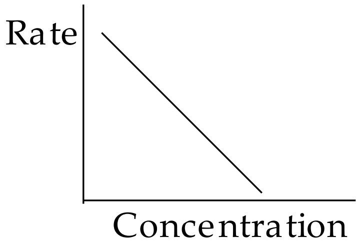
B.



C.



D.



14. Which of the following statements is **true** about the rate of a chemical reaction? The rate

A. depends on the size of the containing vessel.

B. decreases with increasing temperature.

C. depends on the concentration of the reactants.

D. increases with increasing activation energy.

15. Consider the reaction: $2A + 2B + C \rightarrow D$. The rate of the reaction is given by $R = k[A]^2[B]^2[C]$. By how many times will the rate increase, if the concentration of all reactants are doubled?

A. 4 B. 8 C. 16 D. 32

16. A catalyst alters the rate of a chemical reaction by ……………………………….

A. providing an alternative pathway with lower activation energy

B. changing the enthalpy of reaction.

C. changing the frequency of collision between molecules

D. always providing a surface on which molecules react

17. The reaction, $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ was found to be first order with respect to each of the reactants. The rate law should therefore be written as

A. rate $= k[NO]^2[O_2]$ B. rate $= k[NO][O_2]$

C. rate $= k[NO]^2\,[O_2]^2$ D. rate $= k[[NO]\,[O_2]^2$

18. The collision theory proposes that ....

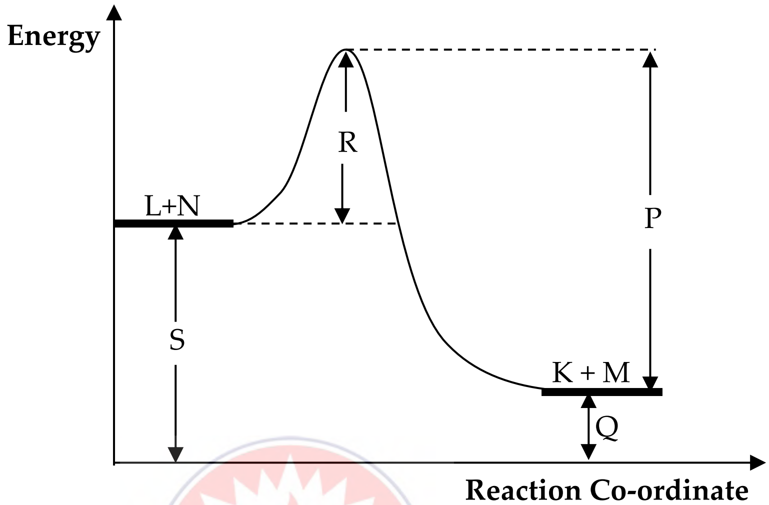
A. reactants collide to bring about the destruction of molecules.

B. all collisions result in the formation of products

C. reactants collide with a minimum amount of energy.

D. the more frequent the collisions, the more stable the product.

19.



In the energy profile diagram above, the activation energy for the reverse reaction is represented by

A. **P**. B. **Q**. C. **R**. D. **S**.

20. Equal masses of $CaSO_3$, were added to equal volumes of $HCl(aq)$. In which of the following reactions will the rate be slowest?

A. Lumps of $CaSO_3$ and 1.0 mol dm^{-3} HCl

B. Lumps of $CaSO_3$ and 0.1 mol dm^{-3} HCl

C. Powdered $CaSO_3$ and 1.0 mol dm^{-3} HCl

D. Powdered $CaSO_3$ and 0.1 mol dm^{-3} HCl

PART II

Provide the appropriate answer for each of the following questions.

21. What is meant by the rate of a chemical reaction?

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22. Explain what is meant by the rate law of a reaction.

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23. What is meant by the order of a reaction?

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24. List three factors that may affect the rate of a chemical reaction.

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25. State the collision theory of rate of reactions.

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26. Show how the collision theory explains one of the factors listed in (a) above.

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Use the information below to answer questions 27-30.

The following data were obtained in an experiment to determine the rate of the reaction **A** + **2B** →**2C** + **D** under various conditions.

Experiment	*Concentration* of **A** / mol dm^{-3}	*Concentration* of **B** / mol dm^{-3}	*Rate/* mol $dm^{-3}s^{-1}$
1	0.10	0.10	7.6×10^{-3}
2	0.10	0.20	1.52×10^{-2}
3	0.20	0.10	1.52×10^{-2}

27. Determine the order of the reaction with respect to **A** and **B.**

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28. Write the rate law equation for the reaction.

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29. Write the overall order of the reaction.

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30. Calculate the specific rate constant of the reaction and give its units.

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APPENDIX ‘’B’’

MARKING SCHEME OF PRE-TEST QUESTIONS

PART I

1. C	11. B
2. C	12. C
3. D	13. B
4. B	14. C
5. C	15. D
6. D	16. A
7. C	17. B
8. C	18. C
9. C	19. A
10. C	20. B

Total marks for Part I= 20 marks

PART II

21. The rate of a chemical reaction is the change in concentration of reactants per unit time or the change in concentration of products per unit time. (1 mark)

22. The rate law equation of a reaction is the chemical equation that relates the rate of a reaction to the concentration of reactants raised to their corresponding powers. (1 mark)

23. Order of a reaction is the sum of the powers to which the concentrations of the reactants in a rate law equation are raised. (1mark)

24. Concentration, temperature, surface area or nature of particles, addition of suitable catalyst and pressure. (Any 3 for 3 marks)

25. The collision theory states that:

a. Particles are in constant rapid motion and this results in many collisions. Chemical reactions therefore occurs as a results of collisions between the reactant molecules.

b. Only a small fraction of the collisions lead to chemical reactions. These collisions are called effective collisions.

c. Only the most energetic molecules undergo reaction as a result of effective collisions.

d. the probability of a collision resulting in a chemical reaction depends on the orientation of the colliding molecules. (4 marks)

26. a. Increase in temperature increases the kinetic energy of the reactant molecules and so the number of collisions as well as effective collisions per unit time increases. The greater the number of collisions per unit time, the higher the rate of reactions.

b. Addition of suitable catalyst provides a new reaction pathway with a lowered activation energy such that more reactants molecules will now have their kinetic energy to be greater than the activation energy of the reaction. The greater the fraction of the reactant molecules with kinetic energy greater than the activation energy, the higher the rate of reactions.

c. Increase in concentration of reactant molecules increases the number of particles per unit volume of the reaction vessel. The number of collisions and hence effective collisions per unit time increases and so the rate of reactions increases.

(Any 1 for 2 marks)

27. Let the order of the reaction with respect to A and B be x and y respectively.

The rate law equation will be written as $R = K [A]^x[B]^y$ since the equation given is not a rate determining step.

$$\frac{\text{Exp 2}}{\text{Exp 1}} = \frac{1.52 \times 10^{-2}}{7.6 \times 10^{-3}} = \frac{K\,(0.10)^x\,(0.20)^y}{K\,(0.10)^x\,(0.10)^y}$$

$$2 = 2^y$$

$$y = 1$$

$$\frac{\text{Exp 3}}{\text{Exp 1}} = \frac{1.52 \times 10^{-2}}{7.6 \times 10^{-3}} = \frac{K\,(0.20)^x\,(0.10)^y}{K\,(0.10)^x\,(0.10)^y}$$

$$2 = 2^x$$

$$x = 1$$

The order of the reaction with respect to A and B is 1 and 1 respectively. (5 marks)

28. The rate law equation will therefore be R = K [A] [B] (1 mark)

29. The overall order of the reaction = order of the reaction with respect to A + order of the reaction with respect to B = 1 + 1 = 2 (1 mark)

30. R = K [A] [B]

$K = \frac{R}{[A][B]} = 0.76$ mol/dm^3/s (2 marks)

Total marks for Part II = 20 marks

APPENDIX "C"

PRE-TEST RESULTS FOR STUDENTS

STUDENT 'A'

38%

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF CHEMISTRY EDUCATION

PRE-TEST DURATION: 40 MINUTES

PART I

Answer all questions in this part.

1. The rate determining step for a reaction
   2A + 3B → 3C is A + 2B → D. Therefore the reaction is of the
   A. first order. B. second order.
   C. third order. D. zero order.

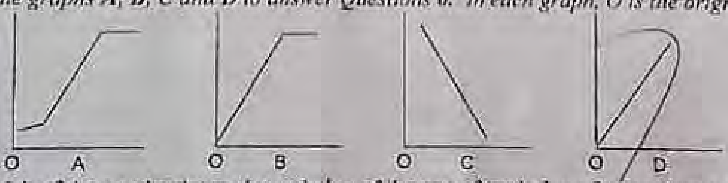
2. Chemical reactions tend to occur at higher rate at a higher temperature because
   A. masses of the reacting particles become lower at a higher temperature.
   B. the activation energy of the reaction becomes lower at a higher temperature.
   C. the number of effective collisions is higher at a higher temperature.
   D. the mechanism of the reaction at a higher temperature is different from that at a lower temperature.

3. Consider the reaction represented by the following equation: $2KClO_3 \rightarrow KCl + 3O_2$.
   Which of the following factors would increase the rate of the reaction?
   A. Increasing the volume of oxygen. B. Decreasing the temperature.
   C. Decreasing the quantity of reactant. D. Addition of MnO_2.

4. The rate equation of a reaction is $R = K[X]^2[Y]$. By what factor would the rate of the reaction increase if the concentrations of X and Y are both doubled?
   A. 16 B. 8 C. 4 D. 2

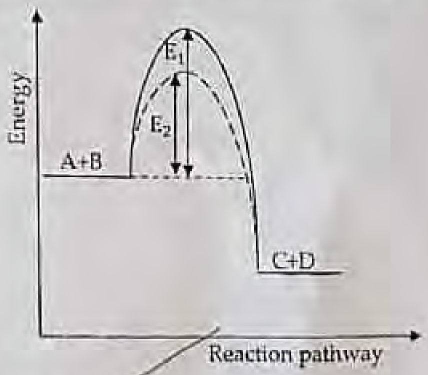
5. The activation energy of a reaction is the
   A. energy given out as the reaction proceeds.
   B. energy used up by the reactants.
   C. minimum energy that must be possessed by reactants to enable them react.
   D. energy absorbed as the reaction proceeds.

Use the graphs A, B, C and D to answer Questions 6. In each graph, O is the origin.



6. Which of the graphs shows the variation of the rate of evolution of a gas from a given length of magnesium ribbon (y-axis) with increase in the concentration of acid added (x-axis).

7. In the diagram below, which of the following factors is responsible for E_2?



A. Low temperature
B. High pressure
C. Presence of catalyst
D. Increased concentration of reactors

8. The collision theory proposes that
A. reactants collide to bring about the destruction of molecules.
B. all collisions are fruitful.
C. reactants must collide with a certain minimum amount of energy to form products.
D. the harder the collisions the faster the reaction.

9. The rate of the reaction $3A + 2B \rightarrow C + D$ is doubled when the concentration of A is doubled and quadrupled when the concentration of B is doubled. Calculate the overall order of the reaction.
A. 5
B. 4
C. 3
D. 2

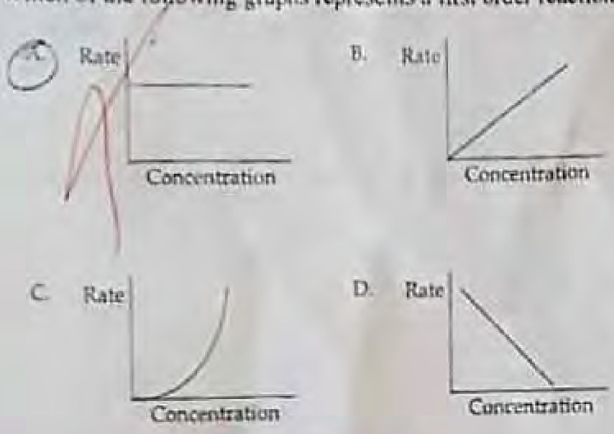
10. Increase in temperature of a reaction leads to an increase in the reaction rate by
A. increasing the concentration of the reactants.
B. lowering the activation energy of the reactants.
C. increasing the number of molecules of reactants having the activation energy.
D. providing an alternative reaction path with low activation energy.

11. The rate equation of a reaction is $R = K[A][B]^2$. By what factor will the reaction rate change if the concentrations of both A and B are doubled?
A. 4 times
B. 8 times
C. 27 times
D. 64 times

12. Which of the following parameters affects the rate of chemical reactions?
I. State of reactants
II. Temperature
III. Catalyst

A. I only
B. I and II only
C. I, II and III
D. I and III only

13. Which of the following graphs represents a first order reaction?



14. Which of the following statements is **true** about the rate of a chemical reaction? The rate
   A. depends on the size of the containing vessel.
   B. decreases with increasing temperature.
   C. depends on the concentration of the reactants.
   D. increases with increasing activation energy.

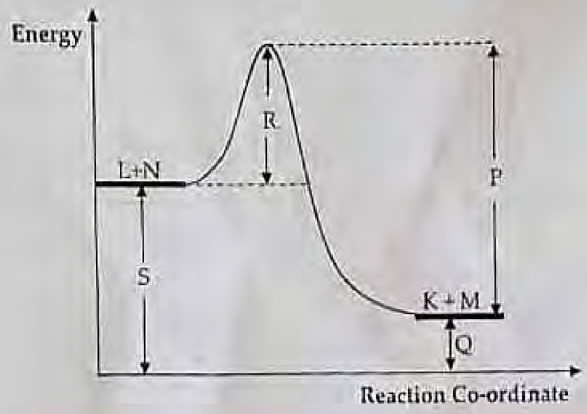
15. Consider the reaction $2A + 2B + C \rightarrow D$. The rate of the reaction is given by $R = k[A]^2[B]^2[C]$. By how many times will the rate increase, if the concentration of all reactants are doubled?
   A. 4 B. 8 C. 16 D. 32

16. A catalyst alters the rate of a chemical reaction by
   A. providing an alternative pathway with lower activation energy
   B. changing the enthalpy of reaction.
   C. changing the frequency of collision between molecules
   D. always providing a surface on which molecules react

17. The reaction $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ was found to be first order with respect to each of the reactants. The rate law should therefore be written as
   A. rate = $k[NO]^2[O_2]$
   B. rate = $k[NO][O_2]$
   C. rate = $k[NO]^2[O_2]^2$
   D. rate = $k[[NO][O_2]]^2$

18. The collision theory proposes that
   A. reactants collide to bring about the destruction of molecules.
   B. all collisions result in the formation of products
   C. reactants collide with a minimum amount of energy.
   D. the more frequent the collisions, the more stable the product.

19.



In the energy profile diagram above, the activation energy for the reverse reaction is represented by

A. P. B. Q. C. R. D. S.

20. Equal masses of $CaSO_3$, were added to equal volumes of HCl(aq). In which of the following reaction, will the rate be slowest?
A. Lumps of $CaSO_3$ and 1.0 mol dm^{-3} HCl
B. Lumps of $CaSO_3$ and 0.1 mol dm^{-3} HCl
C. Powdered $CaSO_3$ and 1.0 mol dm^{-3} HCl
D. Powdered $CaSO_3$ and 0.1 mol dm^{-3} HCl

10

PART II

Provide the appropriate answer for each of the following question.

21. What is meant by the rate of a chemical reaction?

Rate of chemical reaction is the change in the concentration of reactants and product per unit time.

22. Explain what is meant by the rate law of a reaction.

Rate law is an equation that relates the rate of reaction to the concentration of reactants which are raised to their corresponding powers.

23. What is meant by the order of a reaction?

Order of reaction is sum of the powers of the concentration per unit time

24. List three factors that may affect the rate of a chemical reaction.

i. temperature ii. Catalyst
iii. Concentration

25. State the collision theory of rate of reactions.

An increase in temperature increases the rate of reaction

26. Show how the collision theory explains one of the factors listed in (a) above.

The following data were obtained in an experiment to determine the rate of the reaction $A + 2B \rightarrow 2C + D$ under various conditions.

Experiment	*Concentration of* A / mol dm^{-3}	*Concentration of* B / mol dm^{-3}	*Rate/* mol dm^{-3}s^{-1}
1	0.10	0.10	7.6×10^{-3}
2	0.10	0.20	1.52×10^{-2}
3	0.20	0.10	1.52×10^{-2}

27. Determine the order of the reaction with respect to **A** and **B**.

28. Write the rate law equation for the reaction.

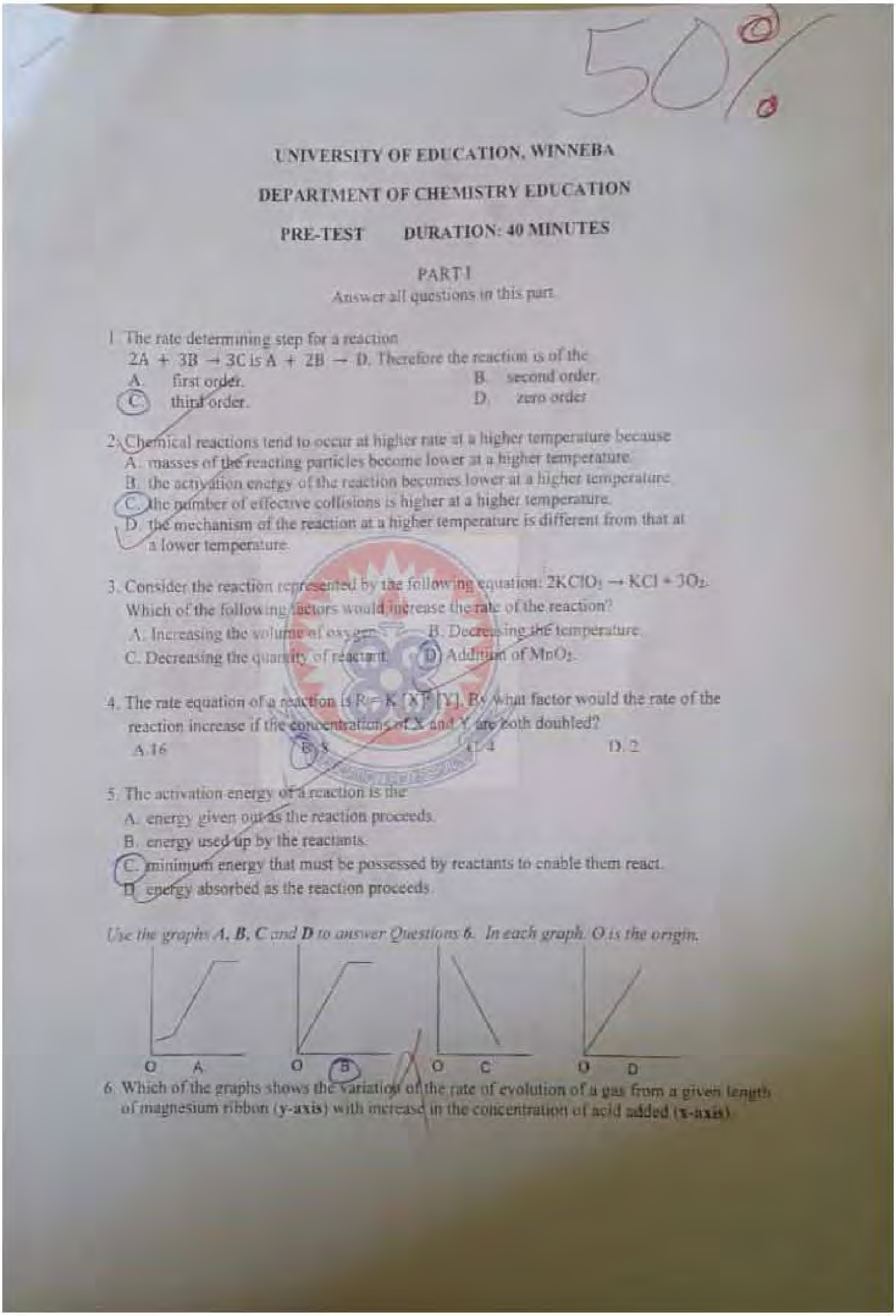
29. Write the overall order of the reaction.

30. Calculate the specific rate constant of the reaction and give its units.

5

15/40

STUDENT 'B'


50%

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF CHEMISTRY EDUCATION

PRE-TEST DURATION: 40 MINUTES

PART I

Answer all questions in this part

1. The rate determining step for a reaction $2A + 3B \rightarrow 3C$ is $A + 2B \rightarrow D$. Therefore the reaction is of the
   A. first order. B. second order.
   C. third order. D. zero order

2. Chemical reactions tend to occur at higher rate at a higher temperature because
   A. masses of the reacting particles become lower at a higher temperature.
   B. the activation energy of the reaction becomes lower at a higher temperature.
   C. the number of effective collisions is higher at a higher temperature.
   D. the mechanism of the reaction at a higher temperature is different from that at a lower temperature.

3. Consider the reaction represented by the following equation: $2KClO_3 \rightarrow KCl + 3O_2$.
   Which of the following factors would increase the rate of the reaction?
   A. Increasing the volume of oxygen B. Decreasing the temperature.
   C. Decreasing the quantity of reactant D. Addition of MnO_2.

4. The rate equation of a reaction is $R = K[X]^2[Y]$. By what factor would the rate of the reaction increase if the concentrations of X and Y are both doubled?
   A. 16 B. 8 C. 4 D. 2

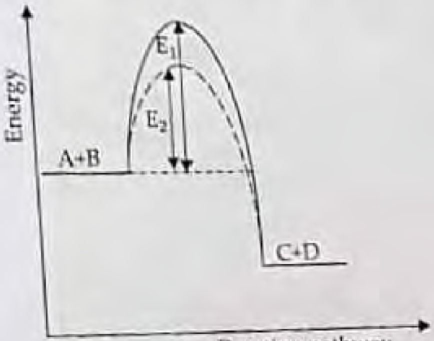
5. The activation energy of a reaction is the
   A. energy given out as the reaction proceeds.
   B. energy used up by the reactants.
   C. minimum energy that must be possessed by reactants to enable them react.
   D. energy absorbed as the reaction proceeds.

*Use the graphs **A, B, C** and **D** to answer Questions 6. In each graph, O is the origin.*

O A O B O C O D

6. Which of the graphs shows the variation of the rate of evolution of a gas from a given length of magnesium ribbon (**y-axis**) with increase in the concentration of acid added (**x-axis**).

7. In the diagram below, which of the following factors is responsible for E_2?



A. Low temperature
B. High pressure
C. Presence of catalyst
D. Increased concentration of reactors

8. The collision theory proposes that
A. reactants collide to bring about the destruction of molecules.
B. all collisions are fruitful.
C. reactants must collide with a certain minimum amount of energy to form products.
D. the harder the collisions the faster the reaction.

9. The rate of the reaction $3A + 2B \rightarrow C + D$ is doubled when the concentration of A is doubled and quadrupled when the concentration of B is doubled. Calculate the overall order of the reaction.
A. 5
B. 4
C. 3
D. 2

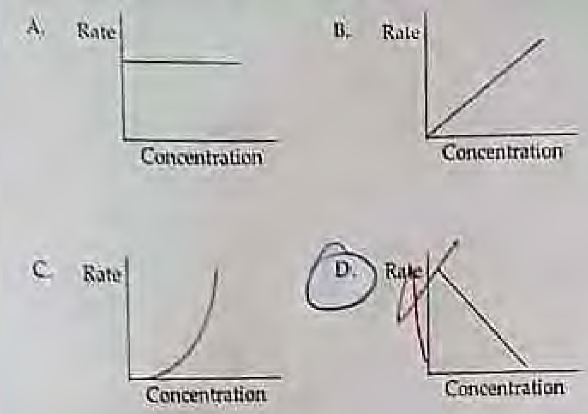
10. Increase in temperature of a reaction leads to an increase in the reaction rate by
A. increasing the concentration of the reactants.
B. lowering the activation energy of the reactants.
C. increasing the number of molecules of reactants having the activation energy.
D. providing an alternative reaction path with low activation energy.

11. The rate equation of a reaction is $R = K[A][B]^2$. By what factor will the reaction rate change if the concentrations of both A and B are doubled?
A. 4 times
B. 8 times
C. 27 times
D. 64 times

12. Which of the following parameters affects the rate of chemical reactions?
I. State of reactants
II. Temperature
III. Catalyst

A. I only
B. I and II only
C. I, II and III
D. I and III only

13. Which of the following graphs represents a first order reaction?



14. Which of the following statements is **true** about the rate of a chemical reaction? The rate
    A. depends on the size of the containing vessel.
    B. decreases with increasing temperature.
    C. depends on the concentration of the reactants.
    D. increases with increasing activation energy.

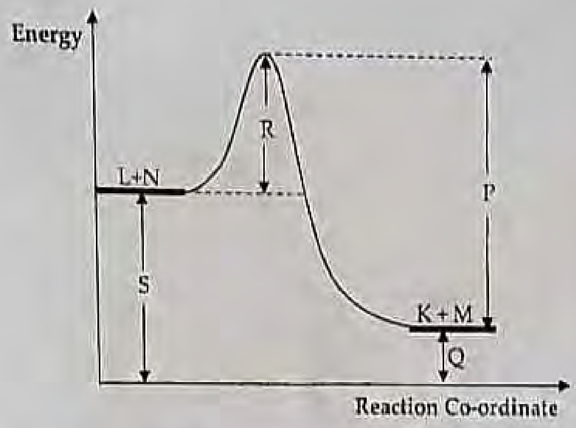
15. Consider the reaction: $2A + 2B + C \rightarrow D$. The rate of the reaction is given by $R = k[A]^2[B]^2[C]$. By how many times will the rate increase, if the concentration of all reactants are doubled?
    A. 4 B. 8 C. 6 D. 32

16. A catalyst alters the rate of a chemical reaction by
    A. providing an alternative pathway with lower activation energy
    B. changing the enthalpy of reaction.
    C. changing the frequency of collision between molecules
    D. always providing a surface on which molecules react

17. The reaction $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ was found to be first order with respect to each of the reactants. The rate law should therefore be written as
    A. rate $= k[NO]^2[O_2]$ B. rate $= k[NO][O_2]$
    C. rate $= k[NO]^2\,[O_2]^2$ D. rate $= k[[NO]\,[O_2]]^2$

18. The collision theory proposes that
    A. reactants collide to bring about the destruction of molecules.
    B. all collisions result in the formation of products
    C. reactants collide with a minimum amount of energy.
    D. the more frequent the collisions, the more stable the product.

19.



In the energy profile diagram above, the activation energy for the reverse reaction is represented by

A. P. B. Q. C. R. D. S.

20. Equal masses of $CaSO_3$, were added to equal volumes of HCl(aq). In which of the following reactions will the rate be slowest?

A. Lumps of $CaSO_3$ and 1.0 mol dm^{-3} HCl

B. Lumps of $CaSO_3$ and 0.1 mol dm^{-3} HCl

C. Powdered $CaSO_3$ and 1.0 mol dm^{-3} HCl

D. Powdered $CaSO_3$ and 0.1 mol dm^{-3} HCl

11

PART II

Provide the appropriate answer for each of the following question.

21. What is meant by the rate of a chemical reaction?

The rate of a chemical reaction is the ~~Chen~~ change in concentration of reactants per unit time

22. Explain what is meant by the rate law of a reaction.

The rate law equation of a reaction is the Chemical equation that relates the the rate of a reaction to the concentration of reactants raised to their corresponding power

23. What is meant by the order of a reaction?

Order of a reaction is the sum of the power to which the concentrations of the reactants in a rate law equation are ~~can~~ raised

24. List three factors that may affect the rate of a chemical reaction.

Concentration, pressure and Catalyst

25. State the collision theory of rate of reactions.

1. Particles are in constant rapid motion and this results in many collisions
2. Only a small fraction of the collisions lead to chemical reaction. These collisions are effective collisions.
3. ?

26. Show how the collision theory explains one of the factors listed in (a) above.

When temperature is increased, the molecules move faster because the kinetic energy is increased and this increased the collisions ?

The following data were obtained in an experiment to determine the rate of the reaction $A + 2B \rightarrow 2C + D$ under various conditions.

Experiment	*Concentration of* A / mol dm^{-3}	*Concentration of* B / mol dm^{-3}	*Rate/* mol dm^{-3} s^{-1}
1	0.10	0.10	7.6×10^{-3}
2	0.10	0.20	1.52×10^{-2}
3	0.20	0.10	1.52×10^{-2}

27. Determine the order of the reaction with respect to A and B.

$R = [A]^2[B]^1$

28. Write the rate law equation for the reaction.

$R = [A]^2[B]^1$

29. Write the overall order of the reaction.

$A + B = 4$

30. Calculate the specific rate constant of the reaction and give its units.

mol/dm^3

9

20/40

APPENNDIX "D"

POST-TEST

Answer all questions in part I and part II

PART I

1. The rate of chemical reactions generally increases with increasing temperature because

   A. the activation energy of the reaction decreases at a higher temperature

   B. masses of the reacting particles decrease at higher temperature

   C. the reaction at a higher temperature differs from that at a lower temperature

   D. the number of effective collisions is higher at a higher temperature

2. The rate equation of a reaction is $R = K [X]^2 [Y]^2$. By what factor would the rate of the reaction increase if the concentrations of X and Y are both doubled?

   A.16   B. 8   C. 4   D. 2

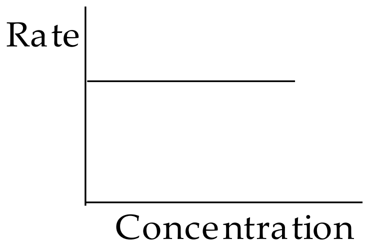
3. The rate determining step for a reaction, $2A + 3B \rightarrow 3C$ is $A + B \rightarrow D$. Therefore the reaction is of the ………………………………

   A. first order.   B. second order.

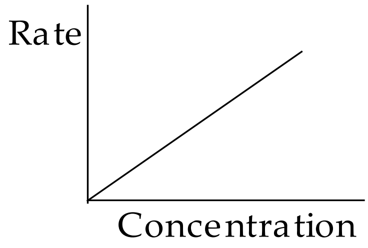
   C. third order.   D. zero order

4. Which of the following graphs represents a zero order reaction?

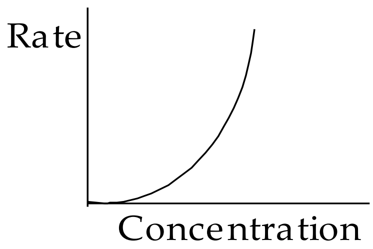
A.



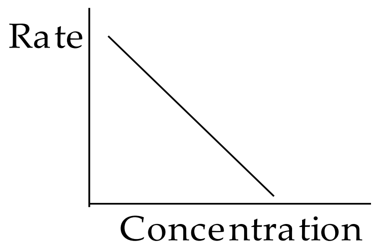
B.



C.



D.



5. A catalyst alters the rate of a chemical reaction by..............

A. providing an alternative pathway with lower activation energy

B. changing the enthalpy of reaction

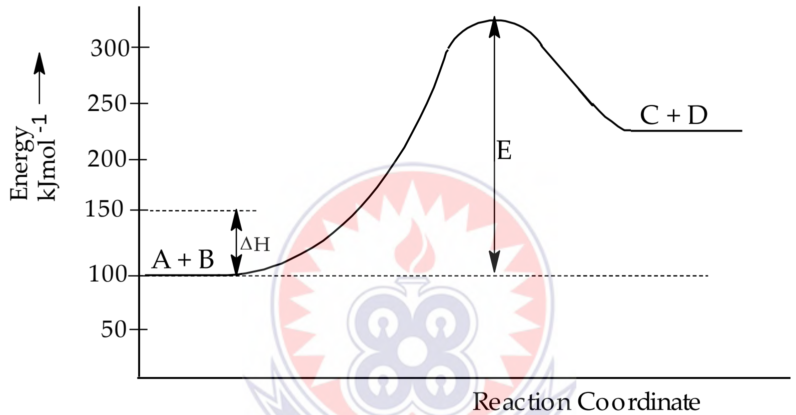
C. changing the frequency of collision between molecules

D. always providing a surface on which molecules react

6. The rate equation of a reaction is $R = K[A][B]^2$. By what factor will the reaction rate change if the concentrations of both **A** and **B** are doubled?

A. 4 times B. 8 times C. 27 times D. 64 times

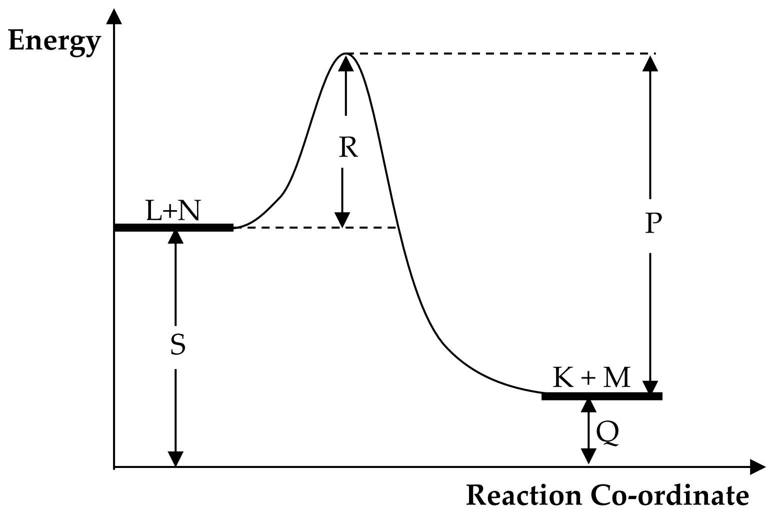
Use the diagram above to answer Questions **7**



7. What is the value of the activation energy?

A. 100kJmol^{-1} B. 150kJmol^{-1} C. 200kJmol^{-1} D. 300kJmol^{-1}

8.



In the energy profile diagram above, the activation energy for the forward reaction is represented by

A. **P**. B. **Q**. C. **R**. D. **S**.

9. The collision theory proposes that ……………………………………………..

A. reactants collide to bring about the destruction of molecules.

B. not all collisions result in the formation of products.

C. reactants collide with a maximum amount of energy.

D. the more frequent collisions, the more stable the product.

10. Consider the reaction equation: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$The rate of the reaction can be increased by ……………………………..

A. using more zinc lumps instead of zinc powder. B. diluting the acid with water

C. removing some of the zinc granules D. warming the reaction mixture

11. The reaction, $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ was found to be second order with respect to each of the reactants. The rate law should therefore be written as

A. rate $= k[NO]^2[O_2]$ B. rate $= k[NO][O_2]$

C. rate $= k[NO]^2\,[O_2]^2$ D. rate $= k[[NO]\,[O_2]^2$

12. Which of the following parameters affects the rate of chemical reactions?

I. concentration II. size of particles III. Catalyst

A. I only B. I and II only C. I, II and III D. I and III only

13. Which of the following statements is **false** about the rate of a chemical reaction? The rate ……………………….

I. depends on the size of the containing vessel.

II. decreases with increasing temperature.

III. depends on the concentration of the reactants.

IV. increases with increasing activation energy.

A. III and IV B. I, II and III C. I, II and IV D. III only

14. The rate equation of a reaction is $\mathbf{R=K\,[A]^3[B]^3}$. By what factor will the reaction rate change if the concentrations of both **A** and **B** are doubled?

A. 4 B. 8 C. 27 D. 64

15. Which of the following statements are postulates of the collision theory of gases?

I. The pressure exerted by a gas is due to the collision of the molecules with each other.

II. Chemical reactions occur as a result of the collision between molecules.

III. Only a fraction of the collision leads to chemical reaction.

IV. The probability of a collision to result in a chemical reaction depends on the orientation of the colliding molecules

A. I and III only B. II and IV only C. I, II and III only D. II, III and IV only

16. The rate of the reaction $3A + 2B \rightarrow C + D$ is doubled when the concentration of **A** is doubled and quadrupled when the concentration of **B** is doubled. Calculate the overall order of the reaction.

A. 5 B. 4 C. 3 D. 2

17. Addition of catalyst to a reaction leads to an increase in the reaction rate by ……

A. increasing the concentration of the reactants.

B. lowering the activation energy of the reactants.

C. increasing the number of molecules of reactants having the activation energy.

D. providing an alternative reaction path with low activation energy.

The following data were obtained in an experiment to determine the rate of the reaction X + 2Y →2W + Z under various conditions.

Experiment	*Concentration* of **X** / mol dm^{-3}	*Concentration* of **Y** / mol dm^{-3}	*Rate/* mol dm^{-3}s^{-1}
1	0.10	0.10	7.6×10^{-3}
2	0.10	0.20	1.52×10^{-2}
3	0.20	0.10	1.52×10^{-2}

18. The order of the reaction with respect to **X** and Y are ……………..
A. 1 and 2 B. 1 and 1 C. 3 and 1 D. 3 and 2

19. What is the overall order of the reaction?
A. 1 B. 2 C. 3 D. 4

20. Which of the following statement about rate of reactions is true?
A. Rate of a reaction is an expression that explains the powers of reactants.
B. Rate of a reaction is the sum of the powers to which the concentrations are raised to.
C. Rate of a reaction is the change in the concentration of reaction products per time.
D. Rate of reactions is the order of the reaction with respect to the reactants.

PART II

Provide the appropriate answer for each of the following question.

21. Calculate the rate of a chemical reaction with initial concentration of 1.0 mol/dm^3 and final concentration 0.2 mol/dm^3 at time 3s?

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Consider the hypothetical reaction: $\mathbf{X} + \mathbf{Y} + \mathbf{Z} \rightarrow \mathbf{Q} + \mathbf{P}$.
The rate law was found to be:Rate $=$ k[**X**][**Y**]^2

22. What is the order of the reaction with respect to **each** of **X, Y** and **Z**?

…………………………………………………………………………………………
…………………………………………………………………………………………
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23. Determine the overall order of the reaction.

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

24. Show how the rate changes if the concentration of **Y** is doubled while that of X and Z remains constant.

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25. List one factor that may affect the rate of a chemical reaction.

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

26. State three postulates of the collision theory of reaction rates.

…………………………………………………………………………………………
…………………………………………………………………………………………
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Use the information below to answer questions 27-30.

Using the collision theory, explain how the following factors affect the rate of chemical reaction:

27. Increase in concentration of reactants;

………………………………………………………………………………………

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28. Increase in temperature.

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29. Addition of suitable catalyst

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30. Nature of particles

………………………………………………………………………………………

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APPENDIX ''E''

MARKING SCHEME OF POST-TEST QUESTIONS

PART I

1. D
2. A
3. B
4. A
5. A
6. B
7. C
8. C
9. B
10. D
11. C
12. C
13. C
14. D
15. D
16. C
17. D
18. B
19. B
20. C

Total marks of Part I = 20 marks

PART II

21. Rate = $\frac{\Delta C}{\Delta t}$, R = $\frac{0.20-1.0}{3}$ = -0.267mol/dm^3/s (1 mark)

22. Order of the reaction with respect to reactants X, Y and Z are 1, 2 and 0 respectively. (3 marks)

23. Overall order = 1 + 2 + 0 = 3 (1 mark)

24. 4R = R_1, where R_1 is the rate when concentration of Y is doubled while concentration of X and Z remain constant. (2 marks)

25. Concentration, temperature, surface area or nature of particles, addition of suitable catalyst and pressure. (Any 1 for 1 mark)

26. The collision theory states that:

a. Particles are in constant rapid motion and this results in many collisions. Chemical reactions therefore occurs as a results of collisions between the reactant molecules.

b. Only a small fraction of the collisions lead to chemical reactions. These collisions are called effective collisions.

c. Only the most energetic molecules undergo reaction as a result of effective collisions.

d. the probability of a collision resulting in a chemical reaction depends on the orientation of the colliding molecules. (Any 3 for 3 marks)

27. Increase in concentration of reactant molecules increases the number of particles per unit volume of the reaction vessel. The number of collisions and hence effective collisions per unit time increases and so the rate of reactions increases. (2 marks)

28. Increase in temperature increases the kinetic energy of the reactant molecules and so the number of collisions as well as effective collisions per unit time increases. The greater the number of collisions per unit time, the higher the rate of reactions. (2 marks)

29. Addition of suitable catalyst provides a new reaction pathway with a lowered activation energy such that more reactants molecules will now have their kinetic energy to be greater than the activation energy of the reaction. The greater the fraction of the reactant molecules with kinetic energy greater than the activation energy, the higher the rate of reactions. (2 marks)

30. The greater the surface area of reactants, the greater the number of collisions and the effective collisions and the higher the rate of a reaction. The surface area of reactants depend on the nature of the reactants. Gaseous reactants move into any available space and so have the greatest surface area. Liquid reactants also have

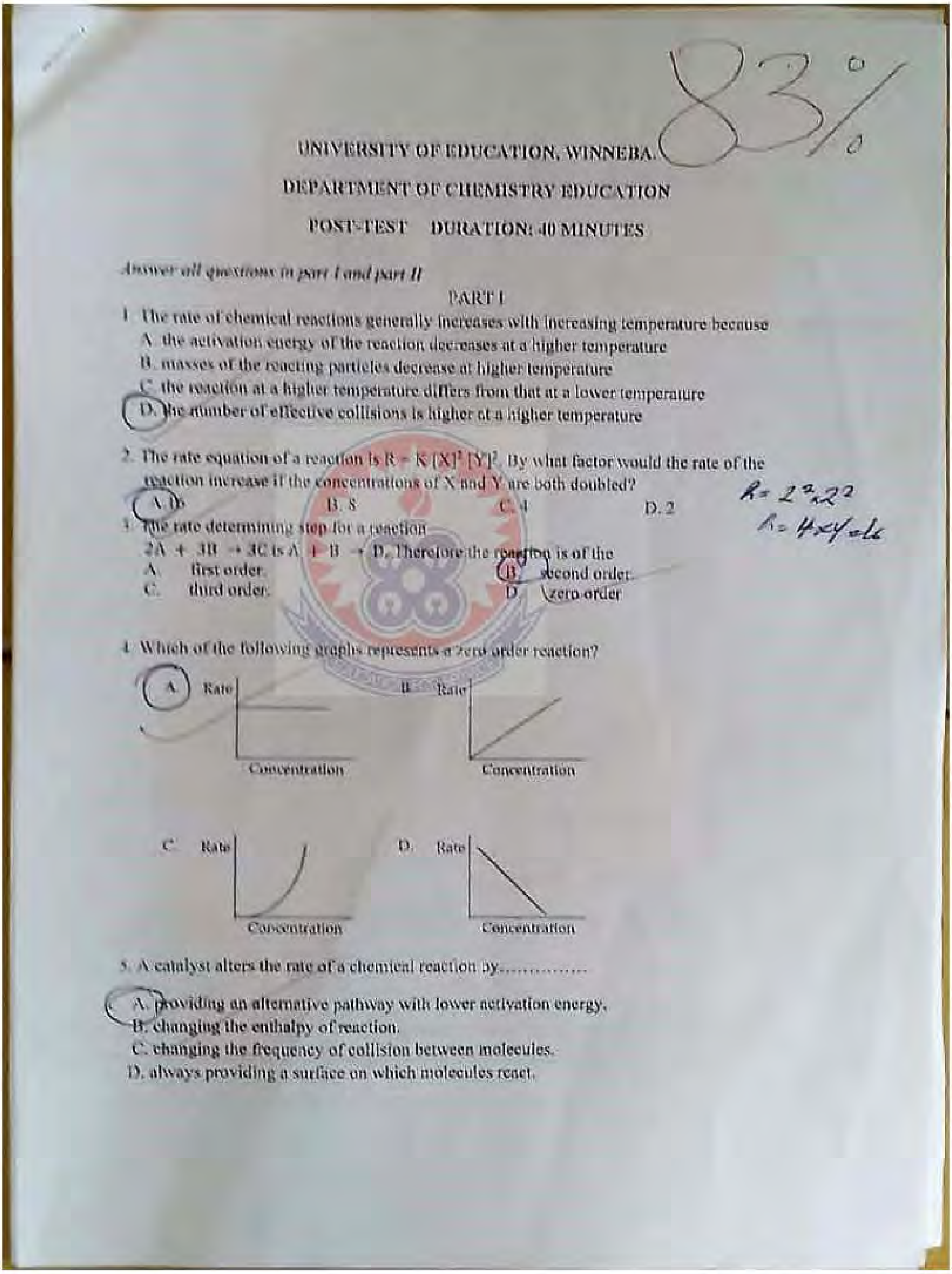
greater surface area than powdered solids and powdered solids than lumpy solids.(2 marks)

Total marks for Part II = 20 marks

APPENDIX "F"

POST-TEST RESULTS FOR STUDENTS

STUDENT 'A'



83%

UNIVERSITY OF EDUCATION, WINNEBA.

DEPARTMENT OF CHEMISTRY EDUCATION

POST-TEST DURATION: 40 MINUTES

Answer all questions in part I and part II

PART I

1. The rate of chemical reactions generally increases with increasing temperature because
   A. the activation energy of the reaction decreases at a higher temperature
   B. masses of the reacting particles decrease at higher temperature
   C. the reaction at a higher temperature differs from that at a lower temperature
   D. the number of effective collisions is higher at a higher temperature

2. The rate equation of a reaction is $R = K[X]^2[Y]^2$. By what factor would the rate of the reaction increase if the concentrations of X and Y are both doubled?
   A. 16 B. 8 C. 4 D. 2

   $R = 2^2 \times 2^2$
   $R = 4 \times 4 = 16$

3. The rate determining step for a reaction $2A + 3B \rightarrow 3C$ is $A + B \rightarrow D$. Therefore the reaction is of the
   A. first order. B. second order.
   C. third order. D. zero order

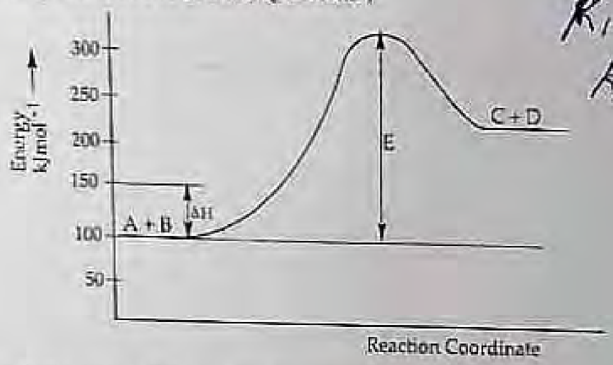
4. Which of the following graphs represents a zero order reaction?

5. A catalyst alters the rate of a chemical reaction by...............
   A. providing an alternative pathway with lower activation energy.
   B. changing the enthalpy of reaction.
   C. changing the frequency of collision between molecules.
   D. always providing a surface on which molecules react.

6. The rate equation of a reaction is $R = K[A][B]^2$. By what factor will the reaction rate change if the concentrations of both A and B are doubled?

A. 4 times B. 8 times C. 27 times D. 64 times

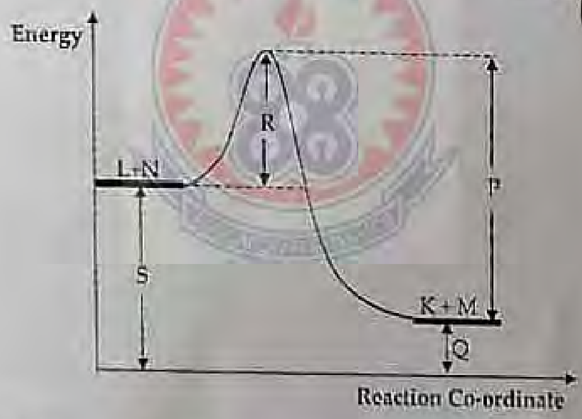
Use the diagram above to answer Questions 7



7. What is the value of the activation energy?

A. $100kJmol^{-1}$ B. $150kJmol^{-1}$ C. $200kJmol^{-1}$ D. $300kJmol^{-1}$

8.



In the energy profile diagram above, the activation energy for the forward reaction is represented by

A. P. B. Q. C. R. D. S.

9. The collision theory proposes that ....

A. reactants collide to bring about the destruction of molecules.

B. not all collisions result in the formation of products.

C. reactants collide with a maximum amount of energy.

D. the more frequent collisions, the more stable the product.

10. Consider the reaction equation: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$The rate of the reaction can be increased by ....

A. Using more zinc lumps instead of zinc powder.
B. diluting the acid with water.
C. removing some of the zinc granules.
D. warming the reaction mixture.

11. The reaction,$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ was found to be second order with respect to each of the reactants. The rate law should therefore be written as

A. rate $= k[NO]^2[O_2]$
B. rate $= k[NO][O_2]$
C. rate $= k[NO]^2[O_2]^2$
D. rate $= k[[NO][O_2]^2$

12. Which of the following parameters affects the rate of chemical reactions?

I. concentration
II. size of particles
III. Catalyst

A. I only
B. I and II only
C. I, II and III
D. I and III only

13. Which of the following statements is false about the rate of a chemical reaction? The rate

I. depends on the size of the containing vessel.
II. decreases with increasing temperature.
III. depends on the concentration of the reactants.
IV. increases with increasing activation energy.

A. III and IV
B. I, II and III
C. I, II and IV
D. III only

14. The rate equation of a reaction is $R=K[A]^3[B]^3$. By what factor will the reaction rate change if the concentrations of both A and B are doubled?

A. 4
B. 8
C. 27
D. 64

15. Which of the following statements are postulates of the collision theory of gases?

I. The pressure exerted by a gas is due to the collision of the molecules with each other.
II. Chemical reactions occur as a result of the collision between molecules.
III. Only a fraction of the collision leads to chemical reaction.
IV. The probability of a collision to result in a chemical reaction depends on the orientation of the colliding molecules

A. I and III only
B. II and IV only
C. I, II and III only
D. II, III and IV only

16. The rate of the reaction $3A + 2B \rightarrow C + D$ is doubled when the concentration of A is doubled and quadrupled when the concentration of B is doubled. Calculate the overall order of the reaction.

A. 5
B. 4
C. 3
D. 2

17. Addition of catalyst to a reaction leads to an increase in the reaction rate by
A. increasing the concentration of the reactants.
B. lowering the activation energy of the reactants.
C. increasing the number of molecules of reactants having the activation energy.
D. providing an alternative reaction path with low activation energy.

The following data were obtained in an experiment to determine the rate of the reaction $X + 2Y \rightarrow 2W + Z$ under various conditions.

Experiment	Concentration of $X / mol\ dm^{-3}$	Concentration of $Y / mol\ dm^{-3}$	Rate/ $mol\ dm^{-3}s^{-1}$
1	0.10	0.10	7.6×10^{-3}
2	0.10	0.20	1.52×10^{-2}
3	0.20	0.10	1.52×10^{-2}

18. The order of the reaction with respect to X and Y are
A. 1 and 2 B. 1 and 1 C. 3 and 1 D. 3 and 2

19. What is the overall order of the reaction?
A. 1 B. 2 C. 3 D. 4

20. Which of the following statement about rate of reactions is true?
A. Rate of a reaction is an expression that explains the powers of reactants.
B. Rate of a reaction is the sum of the powers to which the concentrations are raised to.
C. Rate of a reaction is the change in the concentration of reaction products per time.
D. Rate of reactions is the order of the reaction with respect to the reactants.

PART II

Provide the appropriate answer for each of the following question.

21. Calculate the rate of a chemical reaction with initial concentration of 1.0 mol/dm³ and final concentration 0.2 mol/dm³ at time 3s?

Consider the hypothetical reaction: $X + Y + Z \rightarrow Q + P$.

The rate law was found to be: $Rate = k[X][Y]^2$

22. What is the order of the reaction with respect to each of X, Y and Z?

Order of the reaction with respect to X = 1
Order of the reaction with respect to Y = 2
Order of the reaction with respect to Z = 0

23. Determine the overall order of the reaction.

Overall order of the reaction = 1+2+0 = 3

24. Show how the rate changes if the concentration of Y is doubled while that of X and Z remains constant.

$R = K[X][Y]^2$

$R_1 = K[X][2Y]^2$

$R_1 = 2^2 K[X][Y]$

$\frac{R_1}{R} = \frac{4K[X][Y]^2}{K[X][Y]^2}$

$R_1 = 4R$

25. List one factor that may affect the rate of a chemical reaction.

Concentration

26. State three postulates of the collision theory of reaction rates.

1. Particles are in constant rapid motion which may lead to many collisions.
2. Only a small fraction of these collisions can bring about chemical reaction which are called effective collisions.
3. Only the most energetic molecules can bring about effective collisions.

Using the collision theory, explain how the following factors affect the rate of chemical reaction:

27. Increase in concentration of reactants;

Increasing the concentration of reactants increases the number of particles per unit volume and the number of collisions as well as effective collision also increases. Increasing the rate of reaction. 2

28. Increase in temperature.

Increase in temperature increases the kinetic energy of the molecules. So the number of collisions as well as effective collisions also increases and rate of reaction increases. 2

29. Addition of suitable catalyst

When a catalyst is added, it provides a new reaction pathway which decreases or lowers the activation energy. Rate of reaction increases. 1

30. Nature of particles

Nature of particles increases as rate of reaction increases. Given have a larger surface area so it has a greater rate of reaction. 1

17

33/40

STUDENT 'B'

80%

UNIVERSITY OF EDUCATION, WINNEBA.

DEPARTMENT OF CHEMISTRY EDUCATION

POST-TEST DURATION: 40 MINUTES

Answer all questions in part I and part II

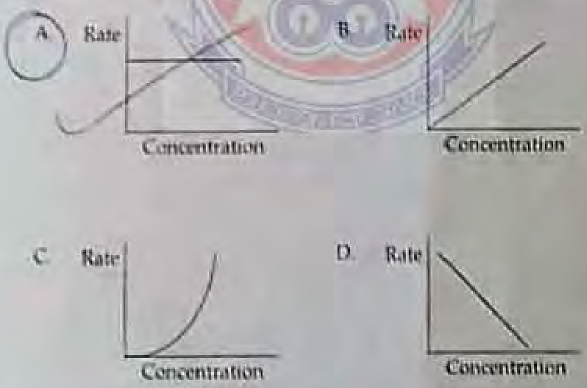
PART I

1. The rate of chemical reactions generally increases with increasing temperature because
   A. the activation energy of the reaction decreases at a higher temperature
   B. masses of the reacting particles decrease at higher temperature
   C. the reaction at a higher temperature differs from that at a lower temperature
   D. the number of effective collisions is higher at a higher temperature

2. The rate equation of a reaction is $R = K [X]^2 [Y]^2$. By what factor would the rate of the reaction increase if the concentrations of X and Y are both doubled?
   A. 16 B. 8 C. 4 D. 2

3. The rate determining step for a reaction
   $2A + 3B \rightarrow 3C$ is $A + B \rightarrow D$. Therefore the reaction is of the
   A. first order. B. second order.
   C. third order. D. zero order

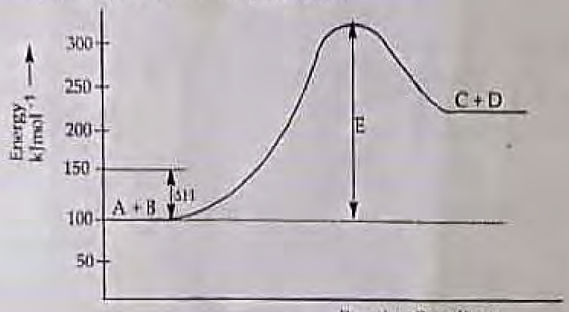
4. Which of the following graphs represents a zero order reaction?



5. A catalyst alters the rate of a chemical reaction by...............
   A. providing an alternative pathway with lower activation energy.
   B. changing the enthalpy of reaction.
   C. changing the frequency of collision between molecules.
   D. always providing a surface on which molecules react.

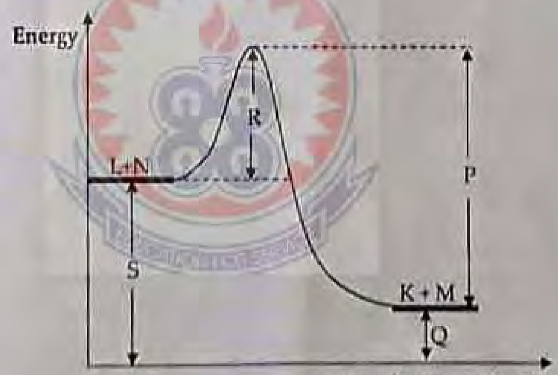
6. The rate equation of a reaction is $R = K[A][B]^2$. By what factor will the reaction rate change if the concentrations of both A and B are doubled?
A. 4 times B. 8 times C. 27 times D. 64 times

Use the diagram above to answer Questions 7



7. What is the value of the activation energy?
A. 100kJmol^{-1} B. 150kJmol^{-1} C. 200kJmol^{-1} D. 300kJmol^{-1}

8.



In the energy profile diagram above, the activation energy for the forward reaction is represented by
A. P. B. Q. C. R. D. S.

9. The collision theory proposes that ....
A. reactants collide to bring about the destruction of molecules.
B. not all collisions result in the formation of products.
C. reactants collide with a maximum amount of energy.
D. the more frequent collisions, the more stable the product.

10. Consider the reaction equation: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$ The rate of the reaction can be increased by ....

A. Using more zinc lumps instead of zinc powder. B. diluting the acid with water.
C. removing some of the zinc granules. D. warming the reaction mixture.

11. The reaction, $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ was found to be second order with respect to each of the reactants. The rate law should therefore be written as

A. rate $= k[NO]^2[O_2]$ B. rate $= k[NO][O_2]$
C. rate $= k[NO]^2[O_2]^2$ D. rate $= k[[NO][O_2]^2$

12. Which of the following parameters affects the rate of chemical reactions?

I. concentration II. size of particles III. Catalyst

A. I only B. I and II only C. I, II and III D. I and III only

13. Which of the following statements is **false** about the rate of a chemical reaction? The rate

I. depends on the size of the containing vessel.
II. decreases with increasing temperature.
III. depends on the concentration of the reactants.
IV. increases with increasing activation energy.

A. III and IV B. I, II and III C. I, II and IV D. III only

14. The rate equation of a reaction is $R=K[A]^3[B]^3$. By what factor will the reaction rate change if the concentrations of both A and B are doubled?

A. 4 B. 8 C. 27 D. 64

$R_1 = K[2A]^3[2B]^3$
$R_1 = 2^3 \times 2^3 K[A][B]$
$R_1 = 64$

15. Which of the following statements are postulates of the collision theory of gases?

I. The pressure exerted by a gas is due to the collision of the molecules with each other.
II. Chemical reactions occur as a result of the collision between molecules.
III. Only a fraction of the collision leads to chemical reaction.
IV. The probability of a collision to result in a chemical reaction depends on the orientation of the colliding molecules

A. I and III only B. II and IV only C. I, II and III only D. II, III and IV only

16. The rate of the reaction $3A + 2B \rightarrow C + D$ is doubled when the concentration of A is doubled and quadrupled when the concentration of B is doubled. Calculate the overall order of the reaction.

A. 5 B. 4 C. 3 D. 2

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B. lowering the activation energy of the reactants.
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PART II

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Consider the hypothetical reaction: X + Y + Z → Q + P.
The rate law was found to be: Rate $= k[X][Y]^2$

22. What is the order of the reaction with respect to each of X, Y and Z?

Order of reaction of X is 1
Order of reaction of Y is 2
order of reaction of Z is 1

23. Determine the overall order of the reaction.

Overall order of reaction = 1 + 2 = 3

24. Show how the rate changes if the concentration of Y is doubled while that of X and Z remains constant.

$R = K[X][Y]^2$
Let R_1 be the rate of reaction
$R_1 = K[X][Y]^2$
$R_1 = K[X][2Y]^2$
$R_1 = 2^2 K[X][Y]^2$
$R_1 = 4K[X][Y]^2$
$\frac{R_1}{R} = \frac{4K[X][Y]^2}{K[X][Y]^2}$
$4R = R_1$

25. List one factor that may affect the rate of a chemical reaction.

temperature

26. State three postulates of the collision theory of reaction rates.

i. Particles are always in constant rapid motion resulting in many collisions
ii. Only small fraction of collisions result in chemical reactions
(iii) Only the most energetic molecules undergo chemical reaction as a result of effective collision

Using the collision theory, explain how the following factors affect the rate of chemical reaction:

27. Increase in concentration of reactants;

An increase in concentration increase the frequency of collision between molecules increasing the number of collisions. Hence an increase in the rate of chemical reaction 2

28. Increase in temperature.

An increase in temperature increases the kinetic energy of the reacting molecules. The number of collisions increases as well as the the number effective collision. Hence an increase in the rate of chemical reaction

29. Addition of suitable catalyst

When catalyst is added it creates a new pathway for reactants and decreases the activation energy. Hence the rate of reaction decreases

30. Nature of particles

2

1.5

32/40

APPENDIX "G"

QUESTIONNAIRE

UNIVERSITY OF EDUCATION, WINNEBA
DEPARTMENT OF CHEMISTRY EDUCATION
MASTER OF PHILOSOPHY IN CHEMISTRY EDUCATION

Dear Respondent,
This questionnaire seeks to find out perceptions students have on the use of computer animations in teaching rate of reactions. Please as much as possible, kindly complete this questionnaire as accurately and honestly as you can. Any information gathered will be treated confidentially.

SECTION A – Background Information
Instructions: Please, tick the brackets provided that appropriately corresponds to the best answer. Please provide written answer where applicable.
1. Gender   Female [ ]   Male [ ]
2. Class ……………………………………………

SECTION B: Benefits of using computer animation in the learning of rate of reactions.
Instructions: This section presents some statements on the benefits of using of computer animations in learning rate of reactions. You are expected to indicate your knowledge about the statements by ticking the numbers in the boxes provided below the option that best describe your responses.
Keys: 1- Strongly disagree (very untrue) 2- Disagree (untrue) 3- Not sure (unaware) 4-Agree (true) 5- Strongly agree (very true)

Benefits of using computer animation	Responses				
3. Computer animation deepens my understanding in rate of reactions much more than traditional diagrams	1	2	3	4	5
4. I find the use of computer animation is an interactive tool for learning rate of reactions	1	2	3	4	5
5. The use of animation for learning rate of reactions is very interesting to me	1	2	3	4	5
6. Animation makes complex information in rate of reactions simple to me	1	2	3	4	5
7. Animation has the power of creating and bringing things alive as it appears in real life.	1	2	3	4	5

8. The use of animation in learning rate of reactions adds fun to my learning	1	2	3	4	5
9. Animation can hold my attention in class	1	2	3	4	5
10. Animation builds interest in me and motivate me to learn more	1	2	3	4	5

SECTION C: The challenges in using computer animations for learning rate of reactions.

Instructions: This section presents statements that look at the challenges students' face in using computer animations for learning rate of reactions. Respondents are required to tick the appropriate response that best describes their agreement or disagreement to the statements provided.

Keys: 1- Strongly disagree (very untrue) 2- Disagree (untrue) 3- Not sure (unaware) 4-Agree (true) 5- Strongly agree (very true)

Challenges in using computer animation for learning rate of reactions	Responses				
11. It is boring to learn rate of reactions using animation	1	2	3	4	5
12. Too many graphics in animation can be annoying	1	2	3	4	5
13. Excessive colours in animation can be distractive	1	2	3	4	5
14. It is difficult to understand rate of reactions when using animation	1	2	3	4	5
15. Animation makes rate of reactions more complicated to learn	1	2	3	4	5

Thank you for your cooperation