University of Reading

Development of a Four-Tier Diagnostic Instrument in Chemical Kinetics (FTDICK) to Investigate First-Year Students' Understanding and Misconceptions in The Area

by

Habiddin

A thesis submitted to fulfill the requirements for the degree of Doctor of Philosophy

Supervisor: Prof. Elizabeth Page BSc, Ph.D, PGCE, CChem, FRSC, NTF, SFHEA

Department of Chemistry

School of Chemistry, Food and Pharmacy

University of Reading

February 2018

University of Reading

Declaration of original authorship

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Habiddin

ABSTRACT

Many undergraduate chemistry students harbour misconceptions in chemical kinetics and this can lead to further difficulty when embarking on more advanced studies in the area at the tertiary level. Chemistry educators are advised to identify misconceptions experienced by their students before they embark on new teaching. However, students' misconceptions cannot easily be identified by simple tests such as multiple-choice tests. Such misconceptions can only be investigated by specifically designed diagnostic instruments. This study was aimed to develop a Four-Tier Diagnostic Instrument in Chemical Kinetics (FTDICK) and to test it with students from universities in the UK and Indonesia to identify typical misconceptions in chemical kinetics.

The body of this study was conducted in three stages. The first stage (preliminary study) involved 591 chemistry students in the UK and Indonesia. The primary purpose of this stage was to collect students' misconceptions and lack of knowledge. Some typical students' misconceptions, lack of knowledge and other unscientific explanations have been uncovered. These findings were used as reason options in the "prototype of the FTDICK instrument." This prototype instrument was used in the next stage which was the pilot study.

In the pilot study, 271 first-year students in two Indonesian Universities participated. The primary purpose of this stage was to validate the prototype of the FTDICK. The reliability of the prototype of the FTDICK instrument is 0.85 and falls into the *excellent* category. Most items in the instrument were found to be valid with a 95% significance level. These results showed that this instrument is valid and reliable and could be used in the main study. However, some revisions were needed to improve the validity and the reliability of the instrument. The revised instrument which was produced at this stage was called "The FTDICK instrument."

The last stage (main study) involved first-year chemistry students in the UK and Indonesia and used in this stage was the final FTDICK instrument. The final FTDICK instrument showed a better validity and reliability rather than the prototype one with a reliability of 0.91. The validity indices of items for the FTDICK instrument are also higher than the indices of the prototype one. This implies the FTDICK instrument is of better quality than the prototype one. Several students' misunderstandings including *genuine* misconceptions, *spurious* misconceptions and confusion with chemical terminology were revealed in this study. Some of these misunderstandings confirm the results previously published in the literature. Some novel findings were also uncovered. Those misconceptions could be attributed to many factors including mathematical weaknesses, carelessness, and difficulty in interpreting diagrams. Suggestions for teaching practices to overcome these misconceptions are also discussed. This study also revealed that the use of a confidence rating on answer and reason responses is timely in order to avoid a misclassification of *spurious* misconceptions as *genuine* ones and vice versa. This study also found that students generally showed better ability in answering algorithmic questions over pictorial ones. As an additional aspect of this study the performance of UK and Indonesian students at equivalent levels was explored. The study showed that UK students' understanding of chemical kinetics is better than Indonesian students' on commencing further studies in chemical kinetics.

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to Prof. Elizabeth M. Page, my supervisor, for her patient guidance, enthusiastic encouragement and valuable and constructive suggestions for this research work.

I would like to thank the Directorate General of Higher Education, Ministry of Research, Technology and Higher Education, Republic of Indonesia for my PhD scholarship.

I would like to express my very great appreciation to my parents for everything they give to me, without them I am nothing. My wife, my son and my daughter, my sisters and all family members for their support morally and emotionally.

My sincere thanks goes to Indonesian students in the University of Reading, particularly my fellow PhD students for being my family during my study in Reading.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF APPENDICES

LIST OF ABBREVIATIONS

FTDICK	: Four-Tier Diagnostic Instrument in Chemical Kinetics
UM	: Universitas Negeri Malang/State University of Malang
UHO	: Universitas Haluoleo/ Haluoleo University
DL	: Difficulty Level
DI	: Discriminatory Index
A tier	: Answer tier
R tier	: Reason tier
B tier	: Both answer and reason tier
CR	: confidence rating
CR(TA)	: Confidence rating of Answer tier
CR(TR)	: Confidence rating of reason tier
CR(TB)	: Confidence rating of answer-reason tiers
CF	: Mean confidence
CFC	: Confidence of students when they gave correct answers
CFW	: Confidence of students when they gave wrong answers
CDQ	: The confidence discrimination quotient
UK	: United Kingdom
CA	: correct answer
PCA	: partially correct answer
WA	: wrong answer
Q	: Question
WACR	: Wrong answer- correct reason
CAWR	: Correct answer- wrong reason
WAWR	: Wrong answer- wrong reason
PISA	: Programme for International Student Assessment

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

1.1.1. Previous research related to chemistry undergraduate students' understanding in various subject areas

Research into school students' understanding of many fundamental chemistry concepts has been conducted for decades, while similar research related to undergraduate students is still limited. As stated by Sozbilir and Bennett (2007), a number of studies into students' understanding of chemical ideas have focused on school students, with less emphasis on university students. In fact, several published studies reported that undergraduate students have many difficulties in understanding chemistry concepts as described below.

Sozbilir and Bennett (2007), reported that some university students hold limited or incorrect ideas in several fundamental concepts in chemistry such as entropy and interpreting mathematical equations in thermodynamics. Furthermore, Sreenivasulu and Subramaniam (2013) have revealed several university students' misconceptions in the field of chemical thermodynamics. They found that many students believe that an endothermic reversible reaction with a negative entropy change is spontaneous in the reverse direction at all temperatures since the forward reaction is always non-spontaneous. Carson and Watson (2002) reported a number of students' alternative concepts in this topic, for instance assuming that entropy is a form of energy and confusion between the system and surroundings. Bain, Moon, Mack, and Towns (2014) provided a comprehensive review of students' misconceptions, difficulties and limited understandings in specific topics in thermodynamics that had been reported by earlier researchers and also synthesized some valuable recommendations for chemistry educators teaching chemical thermodynamics.

It can be argued that students' difficulties in understanding chemical thermodynamics are not unexpected because this topic is thought to be much more difficult than many other chemistry topics. Becker and Towns (2012) stated that to master thermodynamics, students have to be proficient in basic calculus, using mathematical equations, and relating physical variables such as pressure and temperature to more abstract concepts such as Gibbs energy, entropy and others. Furthermore, Carson and Watson (2002) emphasized that the abstract nature of some concepts in this topic requires high cognitive ability in processing the new information properly.

University students' difficulties have been reported in various chemistry topics. Pinarbasi and Canpolat (2003) revealed that students assumed undissolved solute to be a component of a solution, Adadan and Savasci (2012) found that students always associated the concept of solution as the dissolution of any solid substance in a liquid phase (commonly water); Smith and Villarreal (2015) found some students did not realize that the particles in a liquid move around within the entire volume occupied by the liquid; Smith and Nakhleh (2011) showed students' confuse bonding concepts in the processes of melting and dissolving; Burrows and Mooring (2015) found misconceptions in the concept of electronegativity within some international students. One of the misconceptions they found was that the number of electrons surrounding an atom has a prominent role in its electronegativity. Cartrette and Mayo (2011) revealed students' poor understanding of acids and bases, Kousathana and Tsaparlis (2002) investigated ideas surrounding chemical equilibrium, (Guzel & Adadan, 2013) the structure of matter, (Benson, Wittrock, & Baur, 1993) gases and others.

1.1.1.1 The role of students' prior knowledge/preconceptions

The existing knowledge of students' chemical concepts when they start class is described as prior knowledge or pre-concepts. Students' prior knowledge has a significant role in determining the success of teaching and learning. Nakhleh (1992) stated that students' interpretations of new information gained are affected by the current information held. However, students generally harboured their own perceptions of scientific phenomena which disagree with the actual scientific concepts (Barke, Hazari, & Yitbarek, 2009) and this disagreement can cause the new material to be misinterpreted (Campbell & Campbell, 2009).

The influence of chemistry undergraduate students' prior knowledge in the effectiveness of general chemistry courses has been uncovered by Hailikari and Nevgi (2010), Seery (2009) and others. However, several general chemistry classes are conducted without first identifying undergraduate students' preconceptions. Some lecturers assume that their students have mastered some basic chemistry concepts because they have completed the subject of chemistry in their secondary schools. In fact, students continue to harbour some lack of understandings and misconceptions as reported in earlier studies. This mismatch of teaching staff assumptions to students' prior knowledge leads to a teaching and learning barrier (Carson & Watson, 2002). In addition, lecturers have a limited time to identify students' preconceptions comprehensively. Furthermore, Treagust (2002) emphasized the considerable importance of research in university chemistry students' prior knowledge because, even though these students have completed chemistry lessons in their high schools, they still harbour some alternative concepts. Furthermore, he concluded that these alternative concepts will contribute to ineffective learning in their university classes.

Research results suggest the importance of investigating students' understanding before and after they learn new concepts. Tastan, Yalçinkaya, and Boz (2010) suggested that knowing students' alternative concepts may help chemistry teachers at schools or at universities to design their lessons. Similarly, Sozbilir and Bennett (2007) recommended a principal review and reform of teaching strategies at the tertiary level of education. On the other hand, identifying students' understandings after learning is necessary to measure the effectiveness of teaching and learning and to get feedback for the next learning.

1.1.1.2 The triplet representation of chemistry concepts

A chemical representation displays information of a chemical entity including its structure and function (Gegios, Salta, & Koinis, 2017). Graphs, diagrams, photographs, tables and mathematical formulae are inscriptions which are generally used to present and communicate a scientific concept including chemical concepts. Studies in scientific laboratories confirm that these inscriptions are essential to scientific practice (Bowen & Roth, 2002). The complex nature of chemistry, including chemical kinetics, can be described by the triplet representation of chemistry concepts (Gabel, 1999; Gegios et al., 2017). Gilbert and Treagust (2009) define the triplet representation in chemistry as The First or Phenomenological Type, The Second or Model Type, and The Third or Symbolic Type. Actually, there are several terms used by authors in describing the triplet representation of chemistry as summarized by Gilbert and Treagust (2009). Because macroscopic, microscopic and symbolic are the terms most commonly used, these terms are preferred in this study. Portraying chemical representation in an appropriate manner is essential because it can stimulate students' thinking, facilitate students' memory, and help students to process information (Gegios et al., 2017).

The macroscopic level relates to characteristic properties that can be observed in the human sense. The macroscopic level is the world of experiment and observation in chemistry (Kotz, Treichel, & Townsend, 2012) which is tangible and visible (Johnstone, 1991). Properties such as volume, concentration, pH, mass, colour change, temperature, density are observable in chemistry laboratories and in daily life and are therefore measurable (Gegios et al., 2017; Gilbert & Treagust, 2009; Treagust, Chittleborough, & Mamiala, 2003). The macroscopic representation is not a challenge for most chemistry students. Meanwhile, the world of chemistry generally occurs at the microscopic level, involving atoms, molecules, electrons, particles, free radicals and ions that are invisible and accessible only by imagination or visualisation using models (Bucat & Mocerino, 2009; Gegios et al., 2017; Gilbert & Treagust, 2009; Kotz et al., 2012; Treagust et al., 2003). As stated by Wu (2003), chemistry is a microscopic science in which chemical processes are generally represented by molecules and interpreted from a microscopic view. Microscopic entities are commonly visualized as models such as space-filling or ball-and-stick. The symbolic level involves the use of symbols, letter, signs, subscripts, equations such as $H_2O(g)$, Cu^{2+}, CH_3COOH (Gilbert & Treagust, 2009). Furthermore, Taber (2009) claimed the symbolic level as the language of chemistry that connects between the macroscopic and microscopic level. Finally, Kotz et al. (2012), Wu (2003) & Treagust et al. (2003) stated that chemistry experiments occur at the macroscopic level, but these are explained at the microscopic level and written as symbols.

Many researchers emphasize the importance of students' understanding of the three levels in order to meaningfully understand chemistry. A good understanding of chemistry demands a good ability to cross between the boundaries of the triplet representation (Johnstone, 1991; Treagust et al, 2003). Kozma and Russell (1997) argue that students' ability in interpreting an invisible and untouchable chemical phenomenon is notably important in understanding chemical concepts. Generally, chemical concepts are abstract, invisible and untouchable. Therefore, Bucat and Mocerino (2009) stressed the importance of using imagination to visualise these abstract concepts. According to Sanger (2000), microscopic representation of chemical concepts should be provided in learning, because this representation will help students to understand some questions given in conceptual format. Also, Tan, Goh, Chia, and Treagust (2009) underlined that to help students in understanding chemical reactions in experimental qualitative analysis, teachers are advised to design an activity that provides an opportunity for students to experience the reaction (at the macroscopic level), explain the relevant reactions with chemical equations (at the symbolic level) and use analogy and/or multimedia animations to describe what happens in the reactions (at the sub-microscopic level). Therefore, Guzel and Adadan (2013) recommended the application of multiple representational tasks combined with discussion and collaborative activities to aid pre-service chemistry teachers in building their scientific knowledge.

1.1.1.3 The effect of lack of understanding in the triplet representation of chemistry

Some studies have uncovered the link between students' understanding of some chemistry concepts to their ability in interpreting the triplet representation of chemistry. Kozma and Russell (1997) investigated how expert groups (faculty members and graduate chemistry students) use their understanding of the triplet representation to explain chemical phenomena. At the same time, novice groups (students taking general chemistry) were given the same task as the previous group. The experts explained chemical phenomena by appropriate transformation from one level to another level (Kozma & Russell, 1997). In contrast, the novices only used surface entities such as colour, motion, labels in explaining chemical phenomena because they generally got into difficulty linking the different levels. This difficulty contributes to their poor understanding as well (Gabel, 1999; Kozma & Russell, 1997; Tan et al., 2009). As reported by Cakmakci, Leach, and Donnelly (2006) even though students gave a correct scientific reasoning for the change of reaction rate with time, they failed when depicting this relationship graphically. This fact shows how students struggle across the different representational levels of chemistry. This difficulty strengthens the research results published by Kozma (2003). Therefore, Johnstone in Treagust et al. (2003) criticized the teachers who assume that students can link one level of representation to another level. Regardless of the teacher’s intention to help his/her students, students do not always recognize the role of the microscopic and symbolic representations. Substantial research in enhancing students’ ability to link and distinguish between the triplet representations has been conducted (Talanquer, 2011). However, similar research, particularly on the topic of chemical kinetics at the university level is still limited. For this reason, this study investigated undergraduate students’ understandings in chemical kinetics with an emphasis on the microscopic level. This emphasis was implemented by providing some questions in the form of pictorial questions.

1.1.2. Students’ misunderstanding of chemical kinetics

At the university level, chemical kinetics is taught as one topic in a basic/general/fundamental chemistry module. Chemical kinetics is also a separate module in the area of physical chemistry. Chemical kinetics, in particular, is one chemistry topic which has been of concern to chemical education researchers at the undergraduate level in the last decade. According to many students as well as some senior lecturers, physical chemistry modules including chemical kinetics are difficult (Nicoll & Francisco, 2001). This is a difficult topic for many students (Yan &

Subramaniam, 2016). A number of published studies revealed students' misunderstandings on this topic.

1.1.2.1 Students' misconceptions

Plenty of studies in the area of chemistry education have shown that many students develop different ideas from those that are scientifically correct and approved by the scientific community (Gegios et al., 2017). Those students' unscientific ideas are named misconceptions. Students' misconceptions should be overcome as they can deter the subsequent learning (Garnett, Garnett, & Hackling, 1995). Several different terms have been used in the scientific literature to describe the incorrect concept held by any particular person, including; "misconception", "alternative conception", "erroneous concepts", "misunderstanding", "erroneous ideas", "alternative frameworks", "misinterpretation", "wrong knowledge" and "oversimplifications". In agreement with Treagust (1988), Gunstone (2008), Nakhleh (1992), Schmidt (1997), Taber (2000), Barke et al. (2009) and others, the term 'misconception' is preferred in this study because it is more widely used than the others.

A number of university students' misconceptions in chemical kinetics have been uncovered and published (Yalçınkaya, Taştan-Kırık, Boz, & Yıldıran, 2012). Turányi and Tóth (2013) found that first and second-year Hungarian students of chemistry, environmental science, biology and pharmacy have similar misunderstandings in thermodynamics and chemical kinetics to the misunderstandings reported in earlier research. They reported that students assume that the order of reaction is directly obtained from the coefficient of each reactant in the stoichiometric equation and the rate of reaction is always a linear function of concentration. In addition, almost one in four students investigated by Voska and Heikkinen (2000) claimed that a catalyst only increases the rate of the forward reaction.

Cakmakci (2010) listed several misconceptions of first and third year university students as follows: confusing the rate of reaction with the time of reaction, the assumption that reaction rate increases with time, increase in temperature does not affect an exothermic reaction, an endothermic reaction is slower than an exothermic reaction, a catalyst does not affect the reaction mechanism, and a catalyst multiplies the percentage of products. Correspondingly, Kolomuç and Tekin (2011) uncovered many chemistry teachers' misconceptions such as that reaction rate refers to the time needed for the reaction to occur; reaction rate can increase or decrease, therefore it remains constant at the end; the increase of a reactant concentration always increases the reaction rate; reaction always takes place in a single step; in a reaction with higher activation energy, the frequency of collisions decreases.

Some students' misconceptions are rooted by a lack of knowledge. Lack of knowledge refers to the partial or total inability of students in mastering a certain concept. The lack of students' knowledge of this particular topic can be observed clearly based on several empirical results below. Students' assumptions that the order of reaction is directly related to the coefficient of a reactant in the chemical equation shows how students were not aware that the order of reaction is determined experimentally (Cakmakci & Aydogdu, 2011). In certain concepts, undergraduate students have similar misconceptions to secondary school students. This phenomenon was uncovered by Cakmakci et al. (2006) in which both secondary school students and some undergraduate students were unable to draw the graphical relationship between concentration of a reactant and time or to understand how the rate of reaction changes from the initial to the end of reaction and they confused the terms *initial rate*, *instantaneous rate* and *average rate*. In other research, students were aware of the role of an appropriate catalyst in increasing the rate of reaction, but not how the catalyst influences the reaction mechanism and how it works (Cakmakci & Aydogdu, 2011). Moreover, undergraduate students failed to recognize the slow step as the rate determining step; to differentiate the activated complex from the reactants and products; to differentiate between intermediate reaction and complex activation (Tastan et al., 2010). Gegios et al. (2017) uncovered that many students got into difficulty in understanding zero-order reactions, catalysis and reaction mechanisms. What is more, Kolomuç and Tekin (2011) found that some chemistry teachers also have similar misconceptions to grade 11 school students in terms of the effect of a catalyst on the reaction rate. Both of these groups got into difficulty in distinguishing between the plots representing catalysed reactions and uncatalysed reactions.

1.1.2.2 Mixing chemical kinetics concepts with other concepts

Students often use a chemical kinetics concept in explaining another concept inappropriately and vice versa. Students' understandings identified by Voska and Heikkinen (2000) noted the inappropriate mixing of chemical kinetics and chemical equilibrium. Similar confusion was reported by Tastan et al. (2010), in which students interpreted reaction rate changes using Le Chatelier's principle. Furthermore, Kousathana and Tsaparlis (2002) noted that many students equated yield of reaction and reaction rate. In relation to the former studies, Cakmakci and Aydogdu (2011) concluded that students linked chemical kinetics concepts with the spontaneous occurrence of reaction in inappropriate ways. The following conclusion was obtained from one student's assumption: exothermic reactions are faster because they occur spontaneously, while endothermic reactions cannot be spontaneous because endothermic reactions require energy to proceed (Cakmakci & Aydogdu, 2011). In the same article, students argued that an increase in temperature of the reaction (system) will only increase the rate of the reverse reaction because, in an exothermic reaction, the increase in temperature affects the other side of equilibrium. In this case, students seemed to link reaction rate with Le Chatelier's Principle (Cakmakci & Aydogdu, 2011). Correspondingly, students argued that when the initial temperature of a system increases, the rate of the exothermic reaction will decrease. To maintain this assumption, students explained that based on Le Chatelier's Principle, the increase in temperature in an exothermic reaction favours the reactant (Turányi & Tóth, 2013). Students' explanations of the effect of temperature on the direction of equilibrium shift are scientific, but their reasoning is flawed *to support their assumption of the rate of an exothermic reaction*. This confirms the confusion between chemical equilibrium and chemical kinetics concepts.

Similar confusion is noted by Sozbilir, Pinarbasi, and Canpolat (2010) in which students used thermodynamics principles to explain some kinetics phenomena such as using the concept of solubility to explain dissolution rate; the equilibrium concept to explain reaction rate; Gibbs free energy concept to explain the reaction rate, and enthalpy change to explain reaction rate. These inappropriate explanations led them to some misconceptions in chemical kinetics (Sozbilir et al., 2010). In addition, they suggested that some university students cannot differentiate between thermodynamics and kinetics entities. Similarly, Gegios et al. (2017) stated that many students got into difficulty when differentiating between kinetics and thermodynamic parameters. Cakmakci and Aydogdu (2011) argued that one of the roots of students' limited understanding of chemical kinetics is an inadequate knowledge of thermodynamics and chemical equilibrium.

1.1.3. Why are chemical kinetics concepts difficult?

Students' difficulties in learning chemistry, including chemical kinetics, can be ascribed to several factors. Justi (2002) summarized the difficulties as follows: dealing with mathematical operations in the rate equation, the use of chemical language, inability in interpreting diagrams, the interrelation of kinetics with thermodynamics, and the relationship between empirical data and mathematical models of chemical kinetics.

Haim (1989) highlighted incomplete explanations in chemistry textbooks as an additional factor leading to misunderstandings. For example, chemistry textbooks generally explain the role of a catalyst in lowering activation energy. This explanation is commonly followed by the catalysed and uncatalysed diagrams of reaction pathways. The absence of an explanation for the pathway of the catalysed and uncatalysed reactions makes students assume that both reactions proceed by the same mechanism (Haim, 1989). Similarly, Cunningham (2007) stated that many textbooks provide the explanation to assist students in understanding reaction rate concepts, but how students understand the concepts constructively is rarely discussed.

What is more, the understanding of chemical kinetics requires an integrated conceptual understanding of some fundamental ideas: the particulate nature of matter, the kinetic molecular theory and dynamic aspects of chemical reactions including the speed and energy distribution (Cakmakci, 2010; Gegios et al., 2017; Justi, 2002). Many students get into difficulty as mastering chemical kinetics demands high cognitive ability in processing the abstract and complicated concepts and also the application of some mathematical operations (Gegios et al., 2017; Yan & Subramaniam, 2016). Gabel (1999) summarized five barriers to learning chemistry including the complex nature of chemistry, laboratory activities, unfamiliar materials, use of language, and the structure of the discipline. These barriers can explain some of the students' difficulties in chemical kinetics. Along with the nature of the chemical kinetic concepts, students' difficulty is also affected by how the concepts are introduced and presented in the chemistry teaching (Gegios et al., 2017).

1.1.4. Investigating undergraduate students' understanding of chemical kinetics; an essential issue

Regardless of the problems above, this topic is one of the most important in the chemistry curriculum, whether in secondary or at the university level (Chairam, Somsook, & Coll, 2009; Justi & Gilbert, 1999b). In many universities, chemical kinetics is taught in each year. It is commonly covered in general or fundamental chemistry in the first year, in physical chemistry in the second year and in chemical kinetics in the third year. However, the course arrangement is sometimes different from one university to another. Chemical kinetics concepts have a significant role to play in explaining the relationships between energy and chemical change, chemical reaction types, and the process of chemical changes (Kolomuç & Tekin, 2011). In addition, Tastan et al. (2010) highlighted the importance of this topic in terms of its application in industry such as in the manufacture of medicines and organic and inorganic synthesis. "Chemical kinetics is a unifying topic covering the whole of chemistry and many aspects of biochemistry and biology. It is also of supreme importance in both the chemical and pharmaceutical industries. Since the mechanism of a reaction is intimately bound up with kinetics, and since the mechanism is a major topic of inorganic, organic and biological chemistry, the subject of kinetics provides a unifying framework for these conventional branches of chemistry. Surface chemistry, catalysis and solid-state chemistry all rest heavily on a knowledge of kinetic techniques, analysis and interpretation" (Wright, 2004).

In considering the high importance of students' understanding of chemical kinetics, a study to identify students' understandings of this topic, particularly at the tertiary level is timely (Bain & Towns, 2016). However, research regarding understanding in chemical kinetics particularly among students at the university level is still limited (Justi & Gilbert, 1999a). In addition, a report regarding chemical kinetics teaching which is analysed from the perspective of either teachers' or students' understanding is very rare (Justi & Gilbert, 1999a).

1.1.5. Four-Tier Diagnostic Instrument in Chemical Kinetics (FTDICK)

Students' deep understanding in chemistry, particularly students' misconceptions cannot be identified by a common test such as a multiple-choice test. Deep understanding can only be investigated by a diagnostic instrument. At the initial time of research into students' understanding of chemistry, concept mapping (Novak, 1990), interviews (Osborne & Gilbert, 1980) and the multiple choice test (Peterson, Treagust, & Garnett, 1989; Taber, 1999) have been generally used as instruments. Yet, Kinchin (2000) emphasized students' ability to master vocabulary as a vulnerable point of concept mapping application, while the interview is time-consuming (Chandrasegaran, Treagust, & Mocerino, 2007). In addition, the validity of the items and test reliability values in the multiple choice test could be affected by students' test-wiseness skills (Towns & Robinson, 1993) and cannot uncover the full reason for students' answers (Pesman & Eryilmaz, 2010). In addition, guessing is a major factor which can impact on the results in this kind of test (Dindar & Geban, 2011).

1.1.5.1 Two-tier and three-tier instruments: a milestone of FTDICK

In considering the disadvantages of some previous methods in identifying students' understandings, diagnostic tests have become the most accepted instruments used in science education research recently. Treagust (1988) initiated the use of two-tier diagnostic instruments that investigate students' misconceptions in particular. The first tier consists of multiple choice questions with some options with one correct answer and several distractors. The second tier consists of asking for the reason for the chosen answer given some reasons with one logical scientific reason and several unscientific or illogical reasons (Chandrasegaran et al, 2007; Tan et al, 2002). All options in the reason tier are composed based on students' actual misconceptions and lack of understanding determined by preliminary tests, interviews and the literature. As proposed by Treagust (1988), the reason tier should be constructed from the students' misconceptions.

In science education, two-tier diagnostic tests have been used in several studies in different content areas (Gurcaya & Gulbasa, 2015) in physics; (Chu, Treagust, & Chandrasegaran, 2009) in physics; (Griffard & Wandersee, 2010) in biology; (Odom & Barrow, 1995) in biology; (Chandrasegaran et al., 2007) in chemistry; (Tuysuz, 2009) in chemistry; (Tan, Goh, Chia, & Treagust, 2002) in chemistry; (Loh, Subramaniam, & Tan, 2014) in chemistry and others. In the area of chemistry in particular, this kind of instrument has been used to identify students' understandings in several topics, for example, in covalent bonding (Peterson et al., 1989), chemical bonding (Treagust & Tan, 1999), chemical equilibrium (Tyson, Treagust, & Bucat, 1999), and qualitative analysis (Tan et al., 2002) but not in chemical kinetics.

However, in the last decade, many chemistry education researchers realized the deficiencies of the two-tier instrument. In certain circumstances, students chose an answer without scientific reason and selected it randomly. Unfortunately, this type of instrument cannot distinguish between a guess and a real misconception (Caleon & Subramaniam, 2010b; Hasan, Bagayoko, & Kelley, 1999). In addition, Voska and Heikkinen (2000) confirmed that two-tier instruments could only detect a small proportion of students' understandings. Recently, a three-tier instrument has been used in science education research to overcome the deficiencies of the two-tier instrument. The first two tiers are exactly the same as the first two tiers in the two-tier instrument while the third tier consists of asking students for their confidence level for the answer in the second tier (Caleon & Subramaniam, 2010a).

To date, the application of three-tier instruments in science education research is still limited. Several studies using this type of instrument have been conducted in physics such as Caleon and Subramaniam (2010a), Caleon and Subramaniam (2010b) and Pesman and Eryilmaz (2010). Meanwhile, in chemistry, this instrument has been applied by Dindar and Geban (2011) in acid-base chemistry; Arslan, Cigdemoglu, and Moseley (2012) in environmental chemistry and Kirbulut (2014) in states of matter. All of them proved that the three-tier instrument is more reliable and valid in uncovering chemistry undergraduates' understandings and misconceptions. In addition, Caleon and

Subramaniam (2010a) confirmed the advantage of this instrument in depicting students' conceptual changes and how deep their understandings are.

1.1.5.2 FTDICK, an instrument to investigate students' understandings in chemical kinetics

As stated above, the confidence level is only attached to the second tier (reason tier) of the three-tier instrument. Therefore, this instrument cannot identify whether students have different or similar levels of confidence between their answer in the first tier and the second tier (Arslan et al., 2012). Another drawback of this instrument is how to grade students' answers as this is more difficult than grading other diagnostic tests (Arslan et al., 2012). In addition, research that investigates students' misconceptions and distinguishes these misconceptions from poor understanding and guessing is still limited (Sreenivasulu & Subramaniam, 2013). To overcome the drawback of the three-tier instrument, the four-tier instrument has recently been developed. The confidence level of students' answers in the multiple-choice question (the first tier) is considered as an additional tier or the fourth tier. As proposed by Loh et al. (2014) and Arslan et al. (2012), levels of confidence can also be attached to both tiers to ensure that the misconception identified is genuine and is not due to guesswork.

So far, results using a four-tier instrument have only been published by Caleon and Subramaniam (2010b), Gurel, Eryilmaz, and McDermott (2017) both in physics education and Sreenivasulu and Subramaniam (2013) in chemical thermodynamics and none of these studies have focused on chemical kinetics. In agreement with Kirbulut (2014) who recommended this particular diagnostic instrument in the broader area, the development of a four-tier instrument in chemical kinetics is important. Therefore, in this study, a four-tier diagnostic instrument is developed to overcome the limitations of previous diagnostic instruments.

So far, there has not been a multiple tier instrument developed by previous researchers focused on the triplet representation of chemistry particularly at the microscopic level. The crucial role of the triplet representation in chemistry has been discussed widely in the previous paragraphs. Therefore, several questions in this instrument were presented pictorially in order to accommodate the triplet representations of chemical concepts. To differentiate between *genuine* misconceptions and *spurious* misconceptions such as guessing, ratings of confidence are attached to the second tier and the fourth tier. In addition, to resolve scoring difficulties as experienced by Sreenivasulu and Subramaniam (2013), the scoring flexibility is improved by providing a broader level of confidence ratings. Also, students gave a level of certainty in each rating of confidence chosen.

1.2. AIMS OF THE RESEARCH

The main purposes of this research are: (1) to develop and validate a reliable four-tier diagnostic instrument for assessing students' understanding of chemical kinetics, (2) to identify students' understanding including *genuine* and *spurious* misconceptions relating to chemical kinetics, (3) to determine whether students are algorithmic or conceptual problem solvers, (4) to contribute to the chemical education literature by distinguishing *genuine* and *spurious* misconceptions.

Specifically, the research questions which will be addressed in this study are:

1. Is the FTDICK instrument a valid and reliable instrument to investigate students' understanding of chemical kinetics?
2. To what extent does the FTDICK instrument identify first-year chemistry undergraduate students' understanding of chemical kinetics?
3. How do 1st-year chemistry undergraduate students understand the topic of chemical kinetics? What are their *genuine* misconceptions and *spurious* misconceptions?
4. To what extent does the FTDICK instrument differentiate between students' *genuine* misconceptions and *spurious* misconceptions?
5. Is there a positive correlation between students' general confidence and students' confidence in answering chemical kinetics questions in the FTDICK instrument?
6. Are the general misunderstandings of first-year Indonesian and UK chemistry students different? And if so, to what extent?
7. Are the confidence ratings of first-year Indonesian and UK chemistry students different? And if so, to what extent?

CHAPTER 2

METHODOLOGY

2.1. SAMPLES

The samples involved in this study were first-year students at the University of Reading, UK and first-year students in the Indonesian Universities as described in the table below. However, for the preliminary study conducted in the first year, second-year students were also allowed to participate because the main purpose of this stage is to collect students' unscientific ideas regarding chemical kinetics. As the research involves human participants, this study was approved by the ethics committee of the School of Chemistry, Food and Pharmacy, University of Reading, as in Appendix H.

Table 2.1 Sample group and the instrument used

No.	Year	Sample Group	Instrument	Size		Total
1.	1 (preliminary study)	Food Science students, University of Reading, UK	Multiple-choice with free response, short answer tests & interviews: Appendixes A	80	38%	212
		First-year Chemistry students, University of Reading, UK	Short answer tests: Appendixes B	57	27%	
		Second-year Chemistry students, University of Reading, UK	Multiple-choice with free response and confidence rating (a preliminary development of FTDICK): Appendix E	75	35%	
		First-year Chemistry students, State University of Malang, Indonesia	Multiple-choice with free response and confidence rating (a preliminary development of FTDICK): Appendix C	197	52%	379
		Second-year Chemistry students, State University of Malang, Indonesia		63	17%	
		Third-year Chemistry students, State University of Malang, Indonesia		56	15%	
		First-year Chemistry students, Haluoleo University, Indonesia		63	17%	
			Total			**591**
2.	2 (pilot study)	First-year Chemistry students, State University of Malang, Indonesia	Prototype of FTDICK: Appendix F	220	81%	271
		First-year Chemistry students, Haluoleo University, Indonesia		51	19%	
			Total			**271**
3.	3 (main study)	First-year Chemistry students, University of Reading, UK	FTDICK Instrument: Appendix G	83	25%	335
		First-year Chemistry students, State University of Malang & Haluoleo University, Indonesia		252	75%	
			Total			**335**

2.1.1. Brief description of students' background in the secondary school

Students participating in this study were mainly first year undergraduates, therefore their academic background in secondary school is relevant and is presented here. Around 60% Food Science students have an A level in chemistry. The remainder attended a fundamental chemistry module in semester 1, but did not study any chemical kinetics in this module. All Food Science students cover 2 hours of lectures in chemical kinetics in semester 2. The testing with the initial instrument was carried out after studying these lectures. All Food Science students have, as a minimum, GCSE or equivalent in science. Most Food Science students do not have an A level in mathematics but do have GCSE mathematics or equivalent.

All chemistry students have a grade C or higher in A level chemistry or the equivalent. Around 50% chemistry students have studied A level mathematics and all have GCSE in mathematics at grade C or higher. All chemistry students study a first-year module in 'Maths for Chemists' and were part way through the module at the time of testing with the FTDICK.

Indonesian chemistry students have a senior high school certificate with natural science major in which they have to complete mathematics, chemistry, physics and biology subjects along with other general subjects including religion, citizenship education, English, Indonesian language and others. Students have passed the national examination with a minimum pass grade of 60 out of 100 in each subject. Senior high school in Indonesia is equivalent to secondary school in the UK. In the first year of university, chemistry students in Indonesia generally study two basic chemistry modules including Basic Chemistry 1 and Basic Chemistry 2.

2.2. PROCEDURE FOR THE FTDICK INSTRUMENT DEVELOPMENT

The FTDICK was developed in three stages adopting a procedure defined by Treagust (1995). These stages involve (i) testing and interviewing, (ii) paper-and-pencil tests and (iii) four-tier tests. These stages were conducted within three years. Testing and interview was conducted in the first year and named as the preliminary study. Paper-&-pencil tests were conducted in the second year and named as the pilot study. Finally, the four-tier test was conducted in the third year and named as the main study. The detailed procedure for the development of the FTDICK in this study is described below.

2.2.1. Stage 1, testing and interviewing (preliminary study - first year)

The first stage which was conducted in the first year (2014-2015) was a preliminary study. The primary focus of this step was the development the prototype Four-Tier Diagnostic Instrument in Chemical Kinetics (FTDICK). The development of the prototype FTDICK was initiated by collecting students' unscientific ideas/misunderstandings. These misunderstandings include *genuine* and *spurious* misconceptions. The sample involved in this step was 212 first-year chemistry students at the University of Reading, UK and 379 first-year students in two Indonesian Universities. These students were tested using a multiple-choice test and short answer test and some of them were interviewed individually using semi-structured interviews (Table 2.1). The time allocated for answering the questions was flexible in this initial questionnaire. This flexibility was applied because the main purpose of this stage is to collect as many as possible students' unscientific ideas. Before doing the questionnaire, students filled out a consent form in which they are free to withdraw from the study at anytime without giving a reason. Students were also informed that the scores from the instruments would not affect their grades. For Indonesian students, the questionnaire was translated into the Indonesian language.

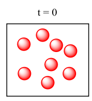
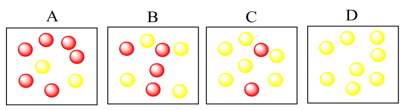
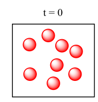
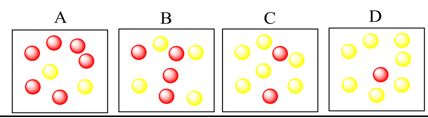
2.2.1.1. Testing and interviewing 1

This phase which was conducted from January to March 2015 involved 57 first-year students studying chemistry at degree level and 80 first year food science students taking a fundamental chemistry course. The instruments used in this phase were multiple choice and short answer tests (Appendix A & B). In answering multiple choice questions, along with choosing A, B, C or D, students were asked to explain how they arrived at their answers. The purpose of using both types of test was to gain a broader knowledge about students' understanding of chemical kinetics. Several students were chosen for follow-up interview sessions in order to confirm some unexpected findings in their responses to the test.

2.2.1.2. Testing 2

Preliminary data 2 is another set of data collected with different sample groups (two Indonesian universities). This phase was conducted from July to August 2015 and involved first-year chemistry students at the State University of Malang (UM) and Haluoleo University (UHO). The instruments used in this phase (Appendix C) were the upgrades of the instruments used for the Preliminary data 1. A translation to the Indonesian language (Appendix D) was provided in order to avoid a language bias. An example of the revision of a question in preliminary data 2 based on the results analysis of preliminary data 1 is given in Table 2.2. Option D in question Number 1 was not chosen by any students in testing 1. Therefore, option D was revised when it was used in the following test (testing 2).

Table 2.2. An example of a question in test 1 revised to be used in test 2

Question of Test 1	Item analysis	Question of test 2; an upgrade
The diagram shows the concentration of reactant S in the first order reaction S $\rightarrow$ T at time $t = 0$ minutes.  Red spheres represent S molecules are converted to yellow spheres that represent T molecules. Which is the appropriate figure (from A, B, C and D) that represents reaction at the half-life of reaction ($t\frac{1}{2}$)? 	- Option D was not considered as the correct answer for all students	The diagram shows the concentration of reactant S in the first order reaction S $\rightarrow$ T at time $t = 0$ minutes.  Red spheres represent S molecules are converted to yellow spheres that represent T molecules. Which is the appropriate figure (from A, B, C and D) that represents reaction at the half-life of reaction ($t\frac{1}{2}$)? 

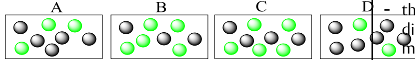
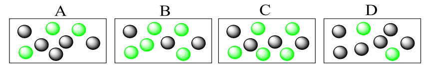
2.2.1.3. *Testing 3*

This phase which was conducted in October 2015 involved 75 first-year chemistry students at the University of Reading. The instruments used in this phase were upgrades of the instruments used for Preliminary data 2. The instrument was in two-tier form (Appendix E) as developed by Treagust (1988), but in answering the questions students were asked not only to choose the correct answer and correct reason but also to show how they arrived at their responses.

2.2.1.4. *Constructing the prototype of the FTDICK instrument*

The data obtained in all 3 times of testing were used as answer options (the first tier) and reason options (the third tier) for the prototype of the FTDICK instrument. The result from this preliminary study is **"a prototype FTDICK instrument".** This prototype was used in the second stage within the second year (pilot study). This example will explain how some preliminary study results were used in the pilot study.

Table 2.3. Example of preliminary study result to be used in the piloting study

Question in preliminary study	Students' reasons (preliminary study result)	Question in pilot study
1	**2**	**3**
For the hypothetical reaction X + Y → Products, the black spheres represent molecules of X and the green spheres represent molecules of Y. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?  	- the similar amount of both reactants - almost equal amount each so most collision between X and Y - The double the concentration, the double the rate. So if both X and Y are equal maximum product will be formed - there is an equal distribution of molecules X and Y, therefore there is more chance of collision, therefore more reactants will be produced	First tier: For the hypothetical reaction X + Y → Products, the black spheres represent molecules of X and the green spheres represent molecules of Y. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?  Second tier: State the confidence rating of your answer 1. very unconfident 4. quite confident 2. not very confident 5. very confident 3. average Third tier: what is the scientific reason for your answer to the previous question? A. The concentrations of both reactants are almost same, therefore the ratio of collision is more favourable B. The concentration of Y is much higher than the concentration of X and this leads to the reaction being completed faster C. It has the highest concentration of the reactant which is 2nd order Fourth tier: State the confidence rating of your answer 1. very unconfident 4. quite confident 2. not very confident 5. very confident 3. average

The question posted in column 1 was a question given in the preliminary study 1 that involved Food Science students at the University of Reading. Column 2 provides some students' reasons for their answers to the question in column 1. Some students as shown in column 2 assumed that the similar relative concentrations of both reactants led to the increase in reaction rate. Furthermore, option A included as the third tier in column 3 (*the concentration of both reactants is almost same*) accommodates these students' understanding.

2.2.2. Stage 2, paper-and-pencil test (pilot study - second year)

The second stage which was conducted in the second year (2016) was a pilot study. The primary focus of this stage was to validate the prototype FTDICK instrument which was developed in the preliminary study. This stage was conducted from May to June 2016 and involved 271 chemistry students at two Indonesian Universities, including 220 students at the State University of Malang and 51students at the University of Haluoleo. The instrument used in this phase is the prototype FTDICK (Appendix F). The time allocated for answering the questions was 1.5 hours. Before doing the questionnaire, students filled out a consent form which states they are free to withdraw from the study at anytime without giving a reason. Students were also informed that the scores from the instrument would not affect their grades. At this stage, the questionnaire was in English. The pilot study showed that the allocated time was sufficient for students and the language was not a barrier for students in understanding the questions. Therefore, the same time allocation was applied in the main study which is the next stage. The questionnaire was also given in English for Indonesian students.

2.2.2.1 Item analysis of the instrument

Item analysis is the procedure of assessing the quality of test items by collecting, summarising and interpreting information gained from students' responses (Anderman & Anderman, 2009; Karelia, Pillai, & Vegada, 2013; Mitra, Haleagrahara, Ponnudurai, & Judson, 2009; "Understanding Item Analyses," 2017). Item test analysis is a procedure introduced to identify items that should be removed from or revised in an assessment. The elimination procedure based on item statistics, therefore, should help to improve the quality of the test in an objective manner (Muntinga & Schuil, 2007).

The specific procedures involved in item analysis are divided into two broad categories including qualitative analysis and quantitative analysis. Both procedures were adopted in this study.

2.2.2.1.1 Qualitative analysis

In some literature such as Bloom, Madaus, and Hastings (1981) and Allen and Yen (2002), the term 'content validity' is preferred rather than qualitative analysis. The procedures in this analysis included careful proofreading of the instrument prior to its administration for typographical errors, for grammatical cues that might inadvertently tip-off examinees as to the correct answer, and for the appropriateness of the reading level of the material (Zurawski). This procedure involved discussions with examinees who have already taken the test, or experts competent in the field (Bloom et al., 1981; Zurawski). This procedure can assist the instructor in determining whether certain students (such as those who performed well or those who performed poorly on a previous exam) misinterpreted particular items, and it can help in determining why students may have misinterpreted a particular item (Zurawski). The instrument used in this study was examined qualitatively by Professor Elizabeth Page and physical chemistry staff at the University of Reading.

2.2.2.1.2 Quantitative analysis

In some literature such as Airasian (1994), the term 'post-test item analysis' is preferred rather than quantitative analysis. A review of students' performances after testing in order to identify faulty items is a valuable step to ensure the quality of an instrument (Airasian, 1994). This analysis includes analysis of the difficulty level, discriminatory index, validity, reliability and distractor effectiveness (Airasian, 1994; Bloom et al., 1981;

Muntinga & Schuil, 2007; Zurawski). Distractor effectiveness is only appropriate for multiple-choice questions.

2.2.2.1.2.1 Difficulty level (DL)

The difficulty level (DL) refers to the proportion of students who answer the question correctly (Allen & Yen, 2002). The DL indices provide a guide to whether concepts being investigated have been taught to students ("Understanding Item Analyses," 2017).

The formula for this parameter is:

$$\text{Difficulty level} = \frac{N_c}{N}$$

where, N_c = the number of students who answer correctly; N = the total number of students who participated in this study

Equation 2.1 Equation for difficulty level

This equation is derived from the explanation provided by Bloom et al. (1981); Airasian (1994); and Muntinga and Schuil (2007). The expected DL indices range between 0.50 and 1.0 because this range will have a better discriminatory index (Nunnally, 1952). However, the authors strongly believe that a DL index of 1.0 is not effective in differentiating between upper and lower achievement students. An item with a DL index close to 1.0 means that the question is too *easy* and can be correctly answered by high and low achieving students. Similarly, an item with a DL index close to 0.0 means that the question is too *difficult* and cannot be correctly answered by high and low achieving students. In these situations, the discriminatory index for the items will be low and ineffective. This is supported by Allen and Yen (2002), that an item with DL indices close to 1.00 and 0.00 should be removed because they do not provide sufficient information regarding the different levels of understanding between students. To sum up, the ideal DL index for a four-option multiple-choice question is 0.74 (Feldt, 1993; Nunnally, 1952). The instrument in this study has four options in the answer tier and mostly 4 options in the reason tier. Some questions have more or less than 4 options in the reason tier.

Actually, there is no general agreement on interpreting the difficulty criterion of an item based on its DL indices. However, Allen and Yen (2002) stated that the ideal range of DL indices that can provide sufficient information to differentiate between the levels of understanding of students is between 0.30 and 0.70. Therefore, by considering reports in the literature including Nunnally (1952), Feldt (1993) and Allen and Yen (2002), the criteria as proposed by Arikunto (1993) below were used in this study.

Table 2.4 The criteria used to interpret difficulty level

Difficulty level	Criteria
0.00 – 0.30	Difficult
0.31 – 0.70	Moderate
0.71 – 1.00	Easy

(Arikunto, 1993)

2.2.2.1.2.2 Discriminatory index (DI)

The discriminatory index (DI) represents an item's ability to differentiate among students on the basis of how well they understand the concept being tested. The formula for this parameter is

$$\text{Discriminatory index} = \frac{N_u - N_l}{\frac{1}{2}N}$$

Where, N_u = the number of upper group who answer correctly
N_l = the number of lower group who answer correctly
N = the total number of students who participated

Equation 2.2 Equation for discriminatory index (Allen & Yen, 2002).

This equation is also derived from the explanation provided by Bloom et al. (1981); Airasian (1994); and Muntinga and Schuil (2007). Students in the upper and lower groups are determined based on their total score obtained. Students are arranged from the highest score to the lowest one. Students in the top half form the upper group and those in the bottom half form the lower group. If the size of a sample is too large, upper and lower groups can be ranged from 10% to 33% of the sample. If the total scores are normally distributed, 27% of students from the upper group and 27% of students from the lower group is allowed (Allen & Yen, 2002). The criteria used to interpret the discriminatory index are given in Table 2.5 below.

Table 2.5 The criteria used to interpret discriminatory index

DI index	Category
0.00 - < 0.10	poor
0.10 - <0.30	fair
0.30 - < 0.75	good
0.75 - 1.00	excellent
Discrimination index negative	unsuitable item

(http://www.udel.edu/educ/gottfredson/451/unit9-guidance.htm).

2.2.2.1.2.3 Distractor effectiveness

Another useful parameter in reviewing the effectiveness of a test item is the distractor effectiveness. To be considered effective, a distractor should be chosen by at least one examinee (DiBattista & Kurzawa, 2011). If no one chooses a distractor it is important to revise the option and attempt to make the distractor a more plausible choice.

2.2.2.1.2.4 Validity

Validity refers to whether the information obtained from a test represents the actual understanding of examinees (Airasian, 1994; Allen & Yen, 2002). Validity refers to the legitimacy of interpretation that is obtained on the basis of examinees' responses (McMillan, 2001). There are many formulae that can be used to calculate the validity of items in an instrument. The correlation coefficient, product moment correlation, is preferred in this study and was calculated using SPSS statistic 21. To determine whether an item or question is categorized as valid or not valid, the value of $r_{xy\text{-}calculation}$ of each item is compared with the critical value of the r_{xy} coefficient. The higher the $r_{xy\text{-}calculation}$ value, the greater the validity.

2.2.2.1.2.5 Reliability

Reliability is the degree to which a test consistently measures whatever it is designed to measure. There are many algorithms that can be used to calculate the reliability of a test/ instrument. The internal-consistency reliability using coefficient α formula is preferred in this study and was calculated using SPSS statistic 21. For one test administration, an internal-consistency reliability is applied (Allen & Yen, 2002).

Table 2.6. The criteria used to interpret reliability

Reliability	Interpretation
0.90 and above	Excellent reliability
0.80 - 0.90	Very good
0.70 - 0.80	Good
0.50 - 0.60	Fair, revision is needed
$<$0.5	Poor

("Understanding Item Analyses," 2017)

The outcome of this pilot study was "the Final FTDICK instrument" to be used for the main study in the third year. This instrument is simply named the FTDICK Instrument.

2.2.3. Stage 3, four-tier test (main study - third year)

The last stage which was conducted in the third year (2017) constituted the main study. The primary focus of this stage was to identify students' misunderstandings regarding chemical kinetics using the FTDICK instrument produced in the pilot study. The instrument used in this stage was the FTDICK instrument (Appendix G). This stage involved 83 first year chemistry students at the University of Reading and 252 students at both the Indonesian universities in the first year. The time allocated for answering the questions was 1.5 hours. Before completing the questionnaire, students filled out a consent form which stated they are free to withdraw from the study at anytime without giving a reason. Students were also informed that the scores when answering the questionnaire would not affect their grades.

2.3. DATA ANALYSIS

2.3.1. Analysis of preliminary data (first year)

Preliminary data were collected using multiple-choice with a free response, short answer tests and multiple-choice with free response and confidence rating. Descriptive analysis was used in this step. Students' responses were analysed qualitatively and categorized as good understanding, partial understanding, misconceptions and other students' weaknesses. The good understanding category involved a correct answer with a scientific reason, whereas partial understanding included a correct response with no scientific explanation. The misconceptions were designated based on students' unscientific reasons.

2.3.2. Analysis of pilot data (second year)

Pilot data are obtained using the prototype FTDICK instrument that was produced from the preliminary study. Before being used for data collection, the instrument was reviewed for clarity of language and scientific accuracy by staff in the Department of Chemistry, University of Reading and student feedback was secured to ensure the instrument was understandable. The data collected from this pilot study are designed to answer the research question (1).

Research question (1) is expressed based on the results of item analysis using the parameters: difficulty level (DL), discriminatory index (DI), the effectiveness of distractor, validity and reliability. The way to determine and interpret these parameters has been described in the previous section.

2.3.3. Analysis of the main data (third year)

The main data were obtained using the FTDICK instrument that was produced from the pilot study. Before being used for data collection, the instrument was reviewed for clarity of language and scientific accuracy by staff in the Department of Chemistry, University of Reading. The data collected from this main study are designed to answer the research questions (3) - (7). The section below explains the detailed procedure to analyse the main data.

2.3.4. Grading scheme

Data analysis was initiated by grading students' responses to the FTDICK instrument. Those students' responses were graded according to the following parameters.

2.3.4.1 Answer tier grade

This grade is only considered from students' answers in the answer tier (A tier). A correct answer in the A tier was scored '1' and an incorrect answer was scored '0'.

2.3.4.2 Confidence rating of answer tier (CR(TA))

This grade is only attributed to students' confidence rating in the A tier. The value of students' CR(TA) is calculated for each answer option (A, B, C and D) in every question. Therefore, each question includes CR(TA) of answer A; CR(TA) of answer B; CR(TA) of answer C; and CR(TA) of answer D. These CR(TA) are determined from the average value of all confidence ratings of students selecting the answer option. For example, for question 1, the CR(TA) of answer B is 2.5. This means that the average of all students' confidence ratings who selected option B as their answer in the A tier is 2.5.

2.3.4.3 Reason tier grade

This grade is only considered from students' answers in the reason tier (R tier). A correct reason in the R tier was scored '1' and an incorrect reason was scored '0'.

2.3.4.4 Confidence rating of reason tier (CR(TR))

This grade is only attributed to students' confidence rating of the R tier. The value of students' CR(TR) is calculated for each reason option (A, B, C, D, E and so on) in every question. Therefore, each question includes CR(TR) of reason A; CR(TR) of reason B; CR(TR) of reason C; CR(TR) of reason D; CR(TR) of reason E and so on. These CR(TR) are determined from the average value of confidence ratings of students selecting the appropriate reason option. For example, at question 1, the CR(TR) of reason F is 2.5. This means that the average of all students' confidence ratings who selected option F as their reason in the R tier is 2.5.

2.3.4.5 Answer-reason/both tiers grade

This grade is considered from students' answers in the A tier and students' reasons in the R tier simultaneously. If both A tier and R tier were correct, a score of "1" was allocated for the B tier. If either or both A tier and R tier were incorrect, a score of "0" was allocated to the B tier.

2.3.4.6 Confidence rating of answer-reason tiers (CR(TB))

This grade is attributed to students' confidence rating of the answer and reason tiers simultaneously. The average value of the students' average confidence rating in both their CR(TA) and their CR(TR) is calculated and defined as CR(TB), i.e. the average confidence rating for both tiers. For example, the value of CR(TB) of Q2-DF is 3.5. This means that for question 2, the confidence rating of students selecting Answer D & Reason F simultaneously is 3.5.

2.3.5. Grade interpretation

Several terms and parameters used to determine the level of students' understanding/ misunderstanding based on the students' confidence ratings are adopted from Caleon and Subramaniam (2010) and Milenkovic, Dusica, Tamara, Mirjana, and Sasa (2016). These terms are scientific understanding, *genuine* misconception, and *spurious* misconception

2.3.5.1 Scientific understanding

This parameter is attributed to the correct Answer and Reason simultaneously. The level of scientific understanding is categorized based on the criteria in table 2.7.

Table 2.7. Criteria used to categorise students' scientific understanding

No.	CR(TB) value of correct A-R tiers	Category
1.	>4.00 - 5.00	Strong
2.	>3.00 – 4.00	Moderate
3.	>2.00 - 3.00	Weak
4.	0.00 - 2.00	Guessing

2.3.5.2 Genuine misconception

This parameter is attributed to either or both incorrect A tier and R tier with confidence ratings higher than 2.75. The level of genuine misconception is categorized based on the criteria in Table 2.8 below.

Table 2.8. Criteria used to categorise students' *genuine* misconceptions

No.	Students' response		CR(TB)	Category
	A tier	R tier		
1.	incorrect	incorrect	>4.00 - 5.00	Strong
2.	incorrect	incorrect	>2.75 - 4.00	Moderate
3.	correct	incorrect	>4.00 - 5.00	Strong_false positive
4.	correct	incorrect	>2.75 - 4.00	Moderate_false positive
5.	incorrect	correct	>4.00 - 5.00	Strong_false negative
6.	incorrect	correct	>2.75 - 4.00	Moderate_false negative

2.3.5.3 *Spurious misconception*

This parameter is attributed to either or both incorrect A tier and R tier with confidence ratings from >2 to 2.75. The level of spurious misconception is categorized based on the following criteria:

Table 2.9. Criteria used to categorise students' *spurious* misconceptions

No.	Students' response		CR(TB)	Category
	A tier	R tier		
1.	incorrect	incorrect	>2.00 - 2.75	weak
2.	correct	incorrect	>2.00 - 2.75	weak_false positive
3.	incorrect	correct	>2.00 - 2.75	weak_false negative
4.	incorrect	incorrect	>1.00 - 2.00	Lack of knowledge
5.	correct	incorrect	>1.00 - 2.00	Lack of knowledge _false positive
6.	incorrect	correct	>1.00 - 2.00	Lack of knowledge _false negative
7.	incorrect	incorrect	>0.00 - 1.00	Guesswork
8.	correct	incorrect	>0.00 - 1.00	Guesswork _false positive
9.	incorrect	correct	>0.00 - 1.00	Guesswork _false negative

In addition, guesswork can also be defined by considering the logical connection between the selected A tier and the selected R tier. This means that in some circumstances although *a combination of wrong answer-wrong reason* shows a confidence rating which is higher than 1.00 but it still can be categorized as guesswork if selected A tier and R tier is difficult to be interpreted.

2.3.6. Additional parameters

Other variables/parameters were also calculated in order to give supportive information in determining the level of students' understanding. These parameters are given in every tier in every question. This calculation is in line with the previous research carried out in psychology (Lundeberg, Lundeberg, Fox, Brown, & Elbedour, 2000; Stankov & Crawford, 1997) and work using a similar four-tier instrument (Caleon & Subramaniam, 2010; Sreenivasulu & Subramaniam, 2013, 2014). The variables are:

2.3.6.1 *Mean confidence (CF)*

This parameter is calculated based on the total of students' confidence ratings divided by the total number of students;

2.3.6.2 *Confidence of students when they gave correct answers (CFC)*

This parameter is calculated based on the average of students' confidence ratings who gave the correct answer.

2.3.6.3 Confidence of students when they gave wrong answers (CFW)

This parameter is calculated based on the average of students' confidence ratings who gave the wrong answer.

2.3.6.4 The confidence discrimination quotient (CDQ = CFC-CFW/ standard deviation of confidence)

CDQ indicates whether the participants can discriminate between what they know and what they do not know.

Some statistical tests were used in this study such as paired sample t-test, Wilcoxon Signed-Rank test, Spearman Rho (ρ) test and Pearson correlation.

CHAPTER 3

COLLECTING STUDENTS' UNSCIENTIFIC IDEAS IN CHEMICAL KINETICS: BASIC DATA FOR DEVELOPMENT OF THE FTDICK INSTRUMENT

3.1 INTRODUCTION

3.1.1 The brief steps in the development of the FTDICK instrument

As discussed in Chapter 2, in general, the FTDICK instrument in this study was developed according to the following procedure: (i) mapping chemical kinetics topics, (ii) constructing the test, (iii) testing and interview, (iv) collecting students' unscientific ideas, (v) developing the prototype FTDICK instrument, (vi) validating the prototype FTDICK instrument, (vii) constructing and administering the final FTDICK instrument. The steps are described below.

i. Mapping chemical kinetics topics

In this step, chemical kinetics topics are identified in order to develop several questions to investigate students' unscientific ideas in chemical kinetics. This instrument is designed to be used to investigate 1st-year university students', including Indonesian and UK students, understanding of chemical kinetics topics. These students had not experienced a chemical kinetics module at the university level. Therefore, the chemistry syllabuses for senior high schools in Indonesia and for secondary education in the UK were taken into account. The level and scope of questions designed were relevant to the syllabuses. The chemical kinetics concepts identified include: expression of the rate law, dependence of rate on concentration, reaction order, half-life, successive half-lives, determining the rate law by the initial rates method, the rate constant, the dependence of rate on temperature, activation energy, collision theory, Boltzmann distribution, and reaction mechanisms. From these topics, several questions to be used in the instrument were constructed.

ii. Constructing the test, testing and interview

This step was carried out three times with the following participants: food science students at the University of Reading, chemistry students at the University of Reading and chemistry students from two Indonesian universities. Data collection in each group above was conducted at three sequential times with three different sets of tests. The detailed description of this step, including how the three tests are related to each other, the time of data collection for each group, how tests were administered (language, timing, format of question and number of questions on each test) have been presented in Chapter 2.

iii. Collecting students' unscientific ideas

From the three sequential tests which were administered to the three groups above, several students' unscientific ideas were found. These unscientific ideas along with literature results and the authors' experiences were used to develop the prototype FTDICK instrument. These students' unscientific ideas are discussed in the next section (section 3.2) in this chapter.

iv. Developing and validating the prototype FTDICK instrument

This step aims to measure the quality of the prototype FTDICK instrument both qualitatively and quantitatively. In this step, the prototype FTDICK instrument was revised. This step is described in detail in the next chapter (Chapter 4).

v. Constructing and administering the final FTDICK instrument

Based on the results of validation in the previous step, the final FTDICK instrument was constructed and administered to Indonesian and UK students. The results of this step are described in detail in the following chapter (Chapter 5).

3.1.2 The rationale for collecting students' unscientific ideas

This FTDICK instrument consists of answer and reason tiers with an associated confidence rating for each tier. The answer tier consists of a multiple-choice question. The reason tier consists of a set of one correct scientific reason and several unscientific or incorrect reasons. Unscientific reasons represent ideas held by students that do not conform to the correct scientific concept. These unscientific ideas are obtained from students' actual misunderstandings, interview and the literature (Treagust, 1988). The authors' experiences were also included when constructing these unscientific reasons.

Students' actual misunderstandings in chemical kinetics were obtained from UK and Indonesian students' answers to questions collected in 2015. UK students were represented by chemistry and food science students at the University of Reading, while Indonesian students were represented by chemistry students at the State University of Malang and Haluoleo University. This step was conducted in the first year of this study and is called the preliminary study. The primary focus in this step was to investigate some students' unscientific understanding of chemical kinetics concepts among undergraduate students. These unscientific understandings were used as the distractor options for the prototype of the four-tier diagnostic instrument in chemical kinetics (FTDICK) that was developed and used for the next step in the second year of the project (pilot study).

The literature includes several published studies regarding students' misconceptions around chemical kinetics. Interview results were not taken into account in this study for several reasons. Firstly, interview sessions in this procedure were intended to clarify students' unclear explanations when responding to questions in the paper test. To avoid the requirement for interviews, the format of the questions was designed so as to provide sufficient space for students to explain how they arrived at their answers. In the multiple-choice questions given to food science students, the respondents were also asked to explain their answers to each question. In addition, students' answers on paper were generally clear enough to be interpreted by the authors. Secondly, some students who were chosen to be invited for further interview were not available and so interviews were not generally conducted.

3.2 STUDENTS' UNSCIENTIFIC IDEAS

3.2.1 Food Science Students Year 1, University of Reading

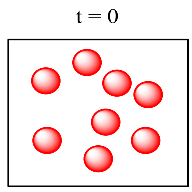
The set of questions (instrument/test) used with this group of students is attached in Appendix A. The test consists of 10 multiple-choice questions and 6 short-answer questions. For the multiple-choice questions, besides selecting the correct answer students were required to explain how they arrived at their answers. Students' misunderstandings found in this test are presented under each theme below.

3.2.1.1 *The concentration of a reactant at its half-life*

In this task, students were asked to determine the half-life concentration after 1, 2 and 3 half-lives of a reactant in a particular order of reaction. This task is represented by Q1[*], Q4, Q9 and Q15.b (Appendix A).

[*] Q1 = question number 1
([*]*...text*): *author's interpretation*

The diagram shows the concentration of reactant S in the first order reaction S → T at time $t = 0$ minutes.



Red spheres represent S molecules are converted to yellow spheres that represent T molecules. Which is the appropriate figure (from A, B, C and D) that represents reaction at the half-life of reaction(t½)?

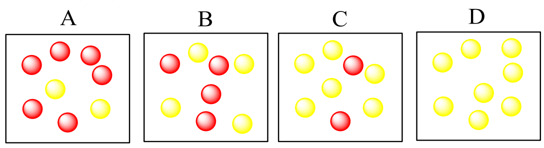


Figure 3.1. Q1 for food science students, UoR

Q1 asked students to determine the half-life concentration of a first-order reactant. Figure 3.2 shows that 96.25% of students responded correctly, 2.50% showed an incorrect answer and only a small number did not answer the question. 1.25% of students considered option A as the correct answer with his/her reason that "*in (*a) first-order reaction, if the concentration of reactant is doubled, so is the rate. Thus, the time taken for the reaction (*reactant) to half (*to be half of its initial concentration) would be constant and the reactant would equal product t½*". The explanation provided by these students is acceptable except the last phrase "*the reactant would equal product t½*" sounds confusing. Although the student explanation of the first phrase sounds unclear, it still indicates that he/she understands that the concentration of a reactant at its half-life is a half of its initial concentration. However, his/her choice of answer is surprising. The possible explanation in this context is that students are only memorizing a scientific definition without adequate understanding of its conceptual meaning. Option D was not chosen by any students. This indicates that this distractor does not work and should be revised.

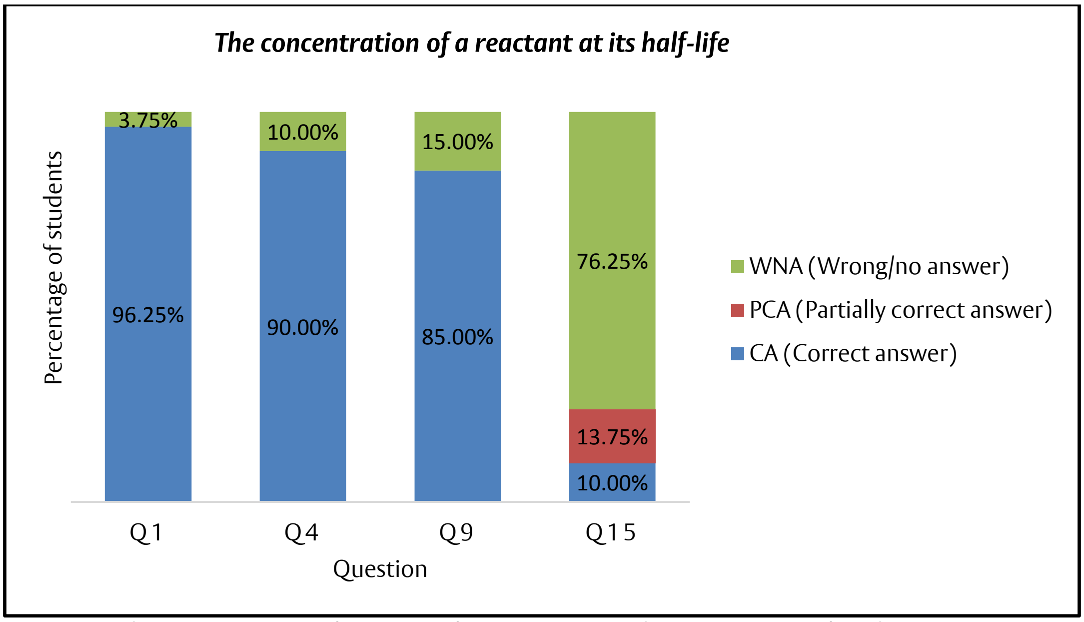


Figure 3.2. The percentage of food science students in answering the questions regarding the concentration of a reactant at its half-life

By consideration of the large numbers of students who answered the question correctly, it can be concluded that they fully understand that the concentration of a reactant at the half-life, $[A]_{t½}$, is a half of the concentration at its initial value, $[A]_{t=0}$. This argument is supported by several students' reasons which were given as the following.

- *Half of the molecule(*s) has(*have) been used in the reaction*
- *in (*a) first-order reaction, half the (*~~molecule of~~) reactant (*molecules) will have reacted at t½; 8/2 = 4*
- *half the reactant is left*
- *(*the) half-life represents the time a reaction takes for the original concentration of reactant to drop by half.*

However, many students who chose the correct answer failed to provide the scientific reason behind their answer. Also, the student's reason (who chose A as the correct answer) as discussed previously confirms that limited understanding prevails in this concept.

A 12.0 mg radioactive sample decays by first order reaction. How many grams of this sample remain after two half-lives?
A. 10 mg B. 6 mg C. 3 mg D. 0 mg

Figure 3.3. Q4 for food science students, UoR

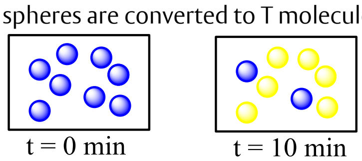
Q4 explores the same basic concepts as Q1, but this question investigates what students understand about successive half-lives of a first-order reaction. In addition, this

(*...text): *author's interpretation*

question is portrayed in a conceptual verbal format while the former question is in a microscopic format. The vast majority of students (90%) as shown in Figure 3.2 answered Q4 correctly. Only a small proportion of students got into difficulty in differentiating between the first half-life (t½) and the second half-life (t¼). They understood these half-lives to be the same concept. A typically poor understanding uncovered in this question is "*after the first minute (*the concentration of reactant) will be half*". This student seems to consider the first minute as the half-life of a reaction. Several articles reviewed such as (Cakmakci, 2010; Cakmakci & Aydogdu, 2011; Cakmakci, Leach, & Donnelly, 2006; Kolomuç & Tekin, 2011; Kousathana & Tsaparlis, 2002; Sözbilir, Pınarbaşı, & Canpolat, 2010; Taştan-Kırık, Yalçınkaya, & Boz, 2010; Turányi & Tóth, 2013; Voska & Heikkinen, 2010) did not discuss such a misconception.

Meanwhile, options A and D in this question need to be revised because they were not chosen by any of the students. The fact that no students chose option D in Q1 and Q4 confirms that all students participating in this study realize that the reactant has not completely disappeared at the half-life. Q9 was answered correctly by 85% students, incorrectly by 5% students and 10% students did not answer the question. Option D "16 minutes" should be changed as no students chose this option.

The first order reaction S → T is shown pictorially below, where S molecules represented as blue spheres are converted to T molecules represented as yellow spheres.



Based on the figure above,

a. What is the rate constant of the reaction?
b. How many S (blue) molecule and T (yellow) molecule present at t = 15 minutes?

Figure 3.4. Q15 for food science students, UoR

The final question on the topic of half-life is Q15. This question was displayed as a short answer question. Figure 3.2 shows that 18% of students gave a correct answer (CA), 10% gave a partially correct answer (PCA) and 76.25% gave the wrong answer (WA). PCA students generally answered Q15 part (a) correctly but failed to answer Q15 part (b). While, there was only a small number of students who answered part (b) correctly, but failed to answer part (a) correctly.

Although all four questions examine the same concept, Q15.b is considered to be the most difficult one. The difficulty level of this question is 0.18 which is categorized as a *difficult* question. Q9 and Q15 explore the same concept but were given in multiple choice format for the former question and short answer format for the latter one.

However, the number of students who solved each question correctly is significantly different. The high percentage of students who gave a correct answer to the multiple-choice question may result from guessing. This is supported by the high percentage of students who answered the question correctly without providing the scientific reason.

3.2.1.2 *The dependence of reaction rate on concentration*

In this topic, students were asked to determine the relationship between concentration and rate of reaction for a particular order of reaction. This topic was represented by Q2, Q3, Q5, Q6, Q12 and Q13.

For the hypothetical reaction X + Y → Products, the black spheres represent molecules of X and the green spheres represent molecules of Y. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?

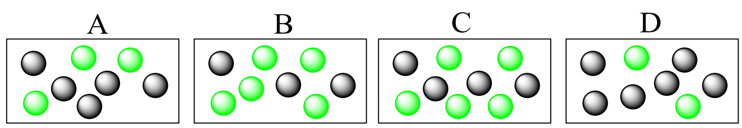


Figure 3.5. Q2 for food science students, UoR

Figure 3.6 shows that Q2 was answered correctly by 75% of students, answered incorrectly by 15% and was not answered by 10%. Although the number of students who answered correctly is high, some unusual explanations were found in this group of students. Some students argued that C is the correct answer because the numbers of both reactant molecules are almost equal. They argued that equal numbers of reactant molecules lead to a higher reaction rate. Therefore, they argued that if both X and Y are equal the maximum amount of product will be formed. This typical misconception is a new finding in chemical kinetics area so far.

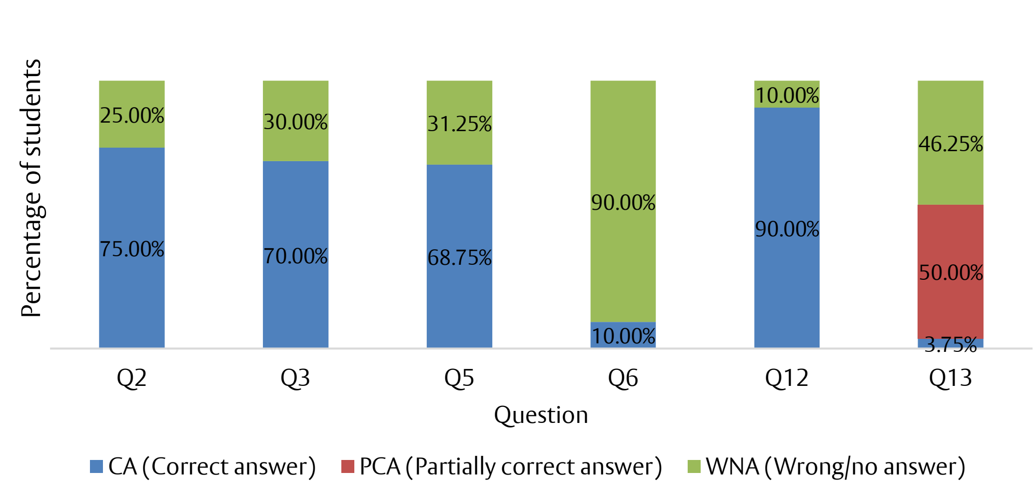


Figure 3.6. The percentage of food science students in answering the questions regarding the dependence of reaction rate on concentration

In addition, 2.50% students from the 15% of students who answered the question incorrectly assumed option B as the correct answer and 12.50% chose option D. Both groups of students considered that the reaction that has a higher percentage of one reactant to another is the correct answer. Therefore, students who chose B considered Y as the dominant factor in determining the reaction rate, while students choosing option D considered that molecules X determine the reaction rate. Even though it was stated clearly in the question that the reaction is first-order in both reactants, some students considered molecule Y as being zero-order. This could be due to carelessness in reading the question or because they made a general link between the effect of concentration on reaction rate without considering the order of reaction. This conclusion is supported by students' answers to Q3 which will be described below. Meanwhile, option A in this question (Q2) needs to be revised because it was not chosen by any students.

The reaction of $HCO_2H(aq)$ and $Br_2(aq)$ is a first order with respect to Br_2 and a zero order with respect to HCO_2H. If the concentration of both reactants increases by a factor of 3, the reaction rate will….

A. Increase by a factor of 3	C. Decrease by a factor of 9
B. Increase by a factor of 6	D. Remain constant

Figure 3.7. Q3 for food science students, UoR

Q3 was displayed in conceptual verbal format and was answered correctly by 70% of students, incorrectly by 25% of students and not answered by 5% of students (Figure 3.6). 14% of students chose option B "*increase by a factor of* 6" as the correct answer. This group of students is not aware that the increase or decrease in concentration of a zero-order reactant does not affect the reaction rate. They considered that the effect of concentration for both orders (first and zero orders) on a reaction rate is the same. This finding supports a result revealed previously by Cakmacki that an increase in concentration of a reactant will increase/decrease the reaction rate of a zero-order reaction (Cakmakci & Aydogdu, 2011). Besides, the students' misconception is similar to the research result uncovered by Cakmacki in Kirik and Boz (2012) that some students generalize that the reaction rate decreases as reaction progresses. This generalization is unacceptable because a zero-order reaction has a constant rate which is independent of the reactant's concentration. Q5 was displayed in microscopic representation and was answered correctly by 68.75% of students, answered incorrectly by 25% and not answered by 6.25% of students. These percentages are in keeping with the number of students giving the correct answer for Q2.

For a hypothetical reaction: X + Y → Products, the blue spheres represent molecules of X and red spheres represent molecules of Y. The rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?

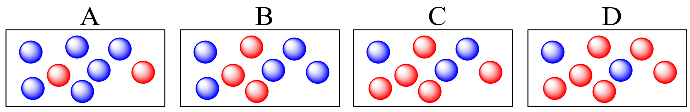


Figure 3.8. Q6 for food science students, UoR

Q6 examined the same concepts as Q2, Q3 and Q5, but showed different results. Only 10% of students answered correctly, 76.25% answered incorrectly and 13.75% of students did not answer the question. Q2, Q3, and Q5 were generally answered correctly by almost all students, while Q6 shows an anomalous result. In this question, 68.75% of students chose A as the correct answer with similar reasons to each other. For example: (1) *highest concentration of blue spheres (molecule of X), and X is second order so it will create the higher rate of reaction; (b) A contains the most amount of X, while X is 2nd order, therefore doubling the concentration quadruples the rate; (c) increasing second order reactants results in a greater increase in rate; (d) X is second order therefore an increase in X concentration increases the rate more significantly than an increase in Y".* These students' reasons confirmed that they have failed to consider the concentration ratio between the second-order and first-order reactants. Many students only focused on the number of molecules of second-order reactant without doing a mathematical calculation based on the rate equation.

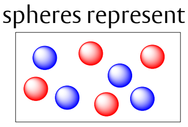
Students' misconceptions of this concept were uncovered from some students' reasons for their answers to Q6 below. "(a) The best answer is C because *every 1 of X want (*wants) 2 of Y, as X is first order and Y is second order"*. Although this student seems to understand the relationship between X and Y, he/she chose the wrong answer. Another poor understanding is "*(b)* the best answer is D because *of the greatest concentration of 1st order* ($\uparrow[A]_0 = \uparrow k$) *with the lowest concentration of 2nd order* ($\uparrow\frac{1}{[A]_0} = \downarrow k$) *reactants"*. In the first phrase, this student believes that the higher the initial concentration of first-order reactant, the higher the rate. Indeed, this is scientifically correct because the rate law for a first-order reaction, R = k[A] confirms it. However, in their second phrase, this student seems confused between the rate equation for a second-order reaction and the expression for the half-life of a second-order reaction, that is $t_{1/2} = \frac{1}{k[A]_0}$. Therefore, he/she (by considering $[A]_0$ as the denominator) argued that the increase in

(...text): author's interpretation*

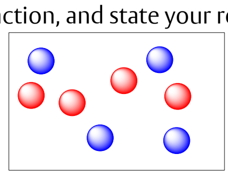
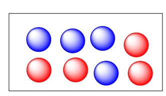
concentration of a second-order reactant will lead to a decrease in its reaction rate. "(c) *second-order reactant is a fast step, while first order is the slow step*." This student seems to believe that the order of a reactant is directly related to whether the reactant is in a fast or a slow step in the reaction mechanism.

In addition, some students' difficulties in converting a verbal statement to a mathematical or algorithmic operation are uncovered in this topic. For example, in answering Q3, some students argued that the reaction rate will increase by a factor of 6 because "*both reactants are increased by a factor of 3, 2 x 3 = 6*". Another explanation is shown by this opinion "*for (*a) first-order reaction, double (*doubling the) concentration of reactant results in double (*the) rate, thus if (*concentration) increase by factor of 3, double (*~~of~~) 3 would by (*be)* 6". In addition, a student with the same choice of answer argued that "*by increasing [reactant] by a factor of 3 the first order nature of* Br_2 *will cause a doubling in rate, hence rate will increase by a factor of 6*". There are at least two misunderstandings identified based on this answer: (a) poor understanding of the effect of different reaction orders on the reaction rate and (b) poor understanding in converting a verbal statement to a mathematical/algorithmic operation. The research result published by Cakmacki in Kirik and Boz (2012) as stated above strengthens these findings.

The hypothetical reaction of A + B → Products is the first order for both reactants. In the picture below blue spheres represent A molecules and red spheres represent B molecules.



The size of the box is proportional to the volume of the reaction container. State whether the three changes below represented by the pictures A, B and C will ......(*increase or decrease*).....the rate of reaction, and state your reason.

A.  .... because .... B.  .... because ....

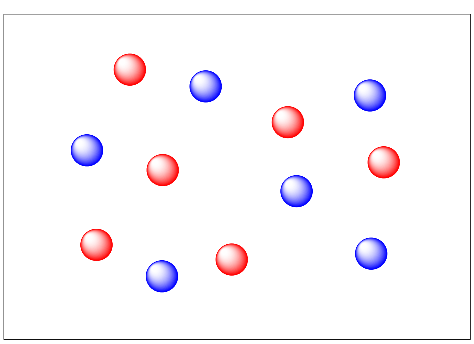
C.  .... because ....

Figure 3.9. Q13 for food science students, UoR

Meanwhile, in considering the reaction of $HCO_2H(aq)$ and $Br_2(aq)$ to be first order with respect to Br_2 and zero order with respect to HCO_2H, this student's assumption: "*both reactants increase by 3 meaning there is an overall increase in the reaction of* 6" confirms a poor understanding of how different orders of reactions affect the reaction rate. In a more detailed explanation, a student argued that "*since B and D both have more molecules, increasing the collisions the rate of reaction will be higher*". The same poor understanding is revealed by students' answers to Q5. Several students chose B or D as the correct answer giving the same reason: "*the higher (*the) overall (*concentration of) [reactant], the higher reaction rate*". This phenomenon appears in line with the findings uncovered by Cakmakci et al. (2006).

Q13 was provided in microscopic format and given in 3 parts (a, b, and c). Each part showed representations of concentration/volume change from the initial concentration/ volume. The question was answered correctly by 3.75% of students, 50% showed PCA and 46.25% showed WNA. Students with CA and PCA generally answered question part (a) and part (b) correctly. They provided the correct scientific explanation about the relationship between volume and concentration and how both variables affect the reaction rate. In addition, other students only wrote the final answer without proving how they arrived at it. Meanwhile, almost all students with PCA failed to answer question part (c). Part C was answered correctly by only a small number of students.

Meanwhile, 46.25% students could not answer the question. This phenomenon suggests that a significant percentage of students' correct answers to Q2, Q3 and Q5 are probably caused by guessing. If their answers to questions were based on a conceptual understanding, they would provide a scientific explanation to Q13. This fact suggests that guesswork plays a role in multiple choice questions.

3.2.1.3 *Rate expression*

In this topic, represented by Q7 and Q8, students were expected to interpret the rate in terms of how sensitive the rate is to changes in the concentration of each reactant, rate constant, and other information that can be interpreted from the rate expression.

Q7 required students to identify the reaction order with respect to both $NO_2(g)$ and $CO(g)$ in the reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ from its rate law, *Rate* = $k[NO_2]^2$. Furthermore, they had to interpret the dependence of the reaction rate on the increase in the concentration of each reactant by a factor of 3. In Figure 3.11, it was found that 71. 25% of students solved this task correctly, and 23.75% solved it incorrectly and the remainder did not answer the question.

The rate law of the reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is $Rate = k[NO_2]^2$, where Rate is the rate of reaction at any time and k is the rate constant. If the concentration of CO increases by a factor of 3, the reaction rate will....

A. Increase by a factor of 3
B. Increase by a factor of 9
C. Decrease by a factor of 3
D. Remain constant

Figure 3.10. Q7 for food science students, UoR

One of the issues uncovered in this question is students' carelessness as shown by the following reason for their answer. "*$[NO_2]^2 = [CO]^0$. (*The) second order (*reactant) follows the idea that if [2A] = 4x faster; [3A] = 9x faster*". The phrase *$[NO_2]^2 = [CO]^0$* is clearly meaningless. However, it seems that students who gave this reason would like to explain that the reaction is second-order with respect to NO_2 and zero order with respect to CO. Furthermore, another student chose B as the best answer, that is the reaction rate will increase by a factor of 9. Based on his/her reason, this student clearly understands that if the concentration of a second-order reactant increases by a factor of 3, the reaction rate will increase by 9 times. Unfortunately, he/she probably did not read the question carefully to realize that it was only concerned with the increase in CO concentration, not the NO_2.

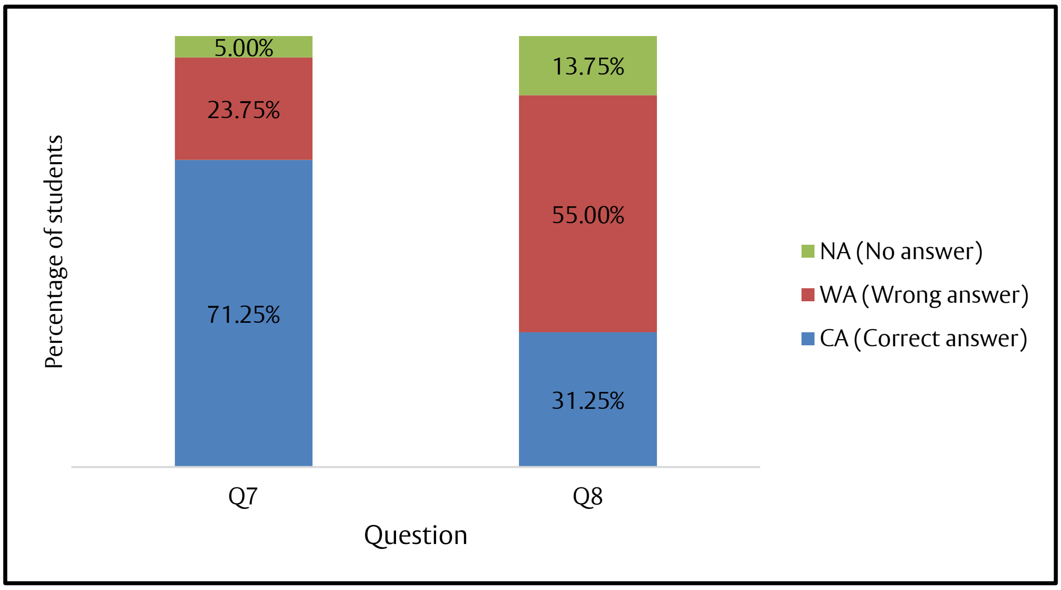


Figure 3.11. The percentage of food science students in answering the questions regarding the rate expression

The decomposition of N_2O_5 in a solvent occurs according to the following equation
$N_2O_5 \rightarrow 2NO_2 + ½ O_2$
In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M.
Which of the following options is not a correct expression of the reaction rate?

A. Rate = 0.001 M.minute^{-1} N_2O_5 consumed
B. Rate = 0.002 M.minute^{-1} NO_2 formed
C. Rate = 0.002 M.minute^{-1} O_2 formed
D. Rate = 0.001 M.minute^{-1}

Figure 3.12. Q8 for food science students, UoR

(*..text): author's interpretation

Q8 was concerned with students' understanding of what rate of a reaction means. Although this was a simple question, surprisingly only 31.25% of students gave the correct answer, 55% gave an incorrect answer, and 13.75% did not answer the question (Figure 3.11). For the students who answered incorrectly, many reasons were given as shown below:

1. "*Since there is a decrease in reactant, it is wrong to answer that the reactant remains constant as it is not zero order*". This explanation is confusing because "the reactant remains constant" was not stated in the question.
2. *"In 20 minutes decreases by 0.02. It doesn't tell you if that's the rate of NO_2 or O_2 formed or N_2O_5 consumed"*. This student did not understand that when the rate of reaction with respect to one substance is known, the stoichiometric coefficients in the balanced equation can be used to find the rates of production or disappearance other substances.
3. "*N_2O_5 cannot be formed."* This is similar to the confusion as discussed in point (a). Indeed, because this is an irreversible reaction, the reaction can only proceed in the forward reaction to consume N_2O_5.
4. *"the rate is too fast for the time and $[N_2O_5]$ consumed".*
5. *"it doesn't state what rate is of."*
6. "*unit is $mol.dm^{-3}.s^{-1}$ and not related to reactant or product consumed*".

These reasons indicate that students are very unclear about the meaning of reaction rate. Similar to this result, Kolomuc and Calik (2012) found that some chemistry teachers and students cannot explain the meaning of reaction rate correctly. They assume that this is probably as a result of their difficulties in differentiating between the concept of reaction rate and time of reaction.

3.2.1.4 *Using mathematical equations for reaction rate in a particular order of reaction*

This topic was represented by Q10. In this question, students were asked to calculate the concentration of a second order reactant at a certain time of reaction. Students were given an equation sheet in order to solve the question. Students were only required to select the appropriate equation and insert the numbers from the question. 63.75% of students chose the correct answer, but some of them did not show how they worked it out; 8.75% of students answered incorrectly and 27.50% did not answer the question.

The decomposition of nitrogen dioxide to nitric oxide and oxygen at 300^0C is a second order reaction. $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$ What is the concentration of NO_2 at t = 10 minutes, if its initial concentration is 8.00 x 10^{-3} M and the rate constant is 0.54 $M^{-1}.s^{-1}$? A. 0.54 M B. 7.94 x 10^{-3} M C. 2.23 x 10^{-3} M D. 3.61 x 10^{-5} M

Figure 3.13. Q10 for food science students, UoR

Meanwhile, some of the students' difficulties in solving this problem were shown by 8.75% of students who answered incorrectly. These difficulties are: (1) choosing the appropriate equation. Some students used the rate law for the first-order reaction instead of the rate law for second-order reaction. (2) Mathematical operation weaknesses. Some students chose the appropriate equation but failed in doing the mathematical operation. This finding confirms the students' weaknesses in dealing with mathematical operations in chemical kinetics as summarized by Justi (2002).

3.2.1.5 *Determining rate law using the initial rate method*

In this topic that was represented by Q11 and Q14, students were expected to determine the rate law of a reaction and the rate constant. Q11 was provided in microscopic representation while Q14 was given in numerical type. This type of question (Q14) is common in several textbooks. 5% of students showed a correct answer to both questions (Q11 and Q14). Figure 3.14 shows that the number of students with partially correct answers (PCA) to Q11 is higher (36.25%) than the number of PCA to Q14 (20.00%).

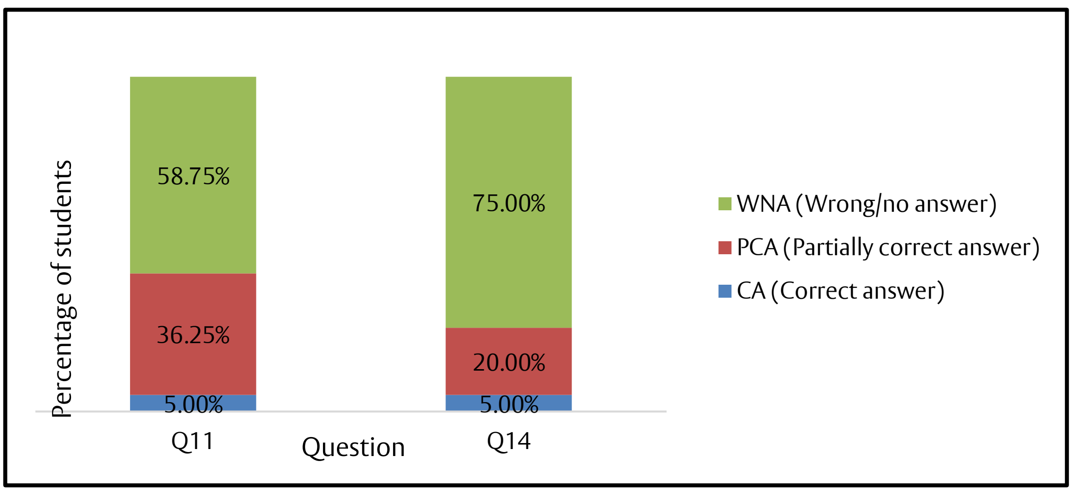
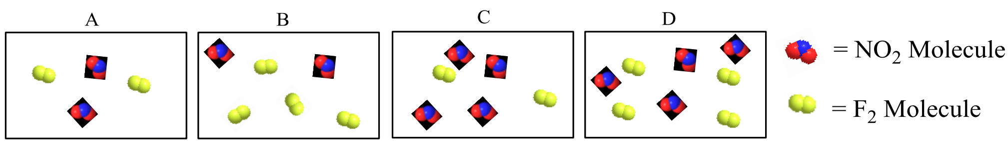


Figure 3.14. The percentage of food science students in answering the questions regarding determining rate law using the initial rate method

The gas-phase reaction of nitrogen dioxide and fluorine is written as
$2NO_2(g) + F_2(g) \rightarrow 2NO_2F\ (g)$
The relative rates of reaction for reaction mixtures depicted in the containers (A,B,C,D) are 1:2:2:4. The concentration of each reactant is represented by the spheres according to the key below.



Determine,

a. The order of reaction with respect to NO_2 and F_2
b. The overall order of the reaction

Figure 3.15. Q11 for food science students, UoR

Meanwhile, more than 50% of students gave a wrong answer to both questions. Some students provided a better explanation to Q14, but only a small percentage of students showed a good explanation to Q11. Because students are familiar with questions such as Q14, they gave a completely correct explanation. However, it was more difficult for students to give a good explanation to Q11 because it was presented in an unfamiliar format.

The reaction of nitric oxide with hydrogen is represented by the equation: $2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$. The following data were collected at a certain temperature,

Experiment	$[NO]_0$ (M)	$[H_2]_0$ (M)	r_0 (M/s)
1	0.015	0.015	0.048
2	0.030	0.015	0.192
3	0.015	0.030	0.096
4	0.030	0.030	0.384

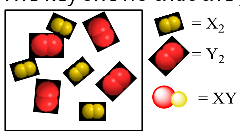
Determine: (a) the rate law, (b) the rate constant

Figure 3.16. Q14 for food science students, UoR

3.2.1.6 *The dependence of reaction rate on temperature*

In Q16, students were asked to decide which microscopic figure represents the reaction mixture at the higher temperature. 12.50% of students gave a correct answer with a correct scientific reason; 15.00% of students gave a correct answer without a scientific reason; and more than half did not answer the question. Students who answered the question correctly showed that they fully understood the relationship between temperature and reaction rate.

The figure below describes the initial mixture in a reaction represented by $X_2 + Y_2 \rightarrow 2XY$
The key shows that the yellow molecules are X_2 and the red molecules are Y_2.



If the reaction is carried out at two different temperatures over the same time period, which figure (A or B) represents the reaction at the higher temperature? State your reason

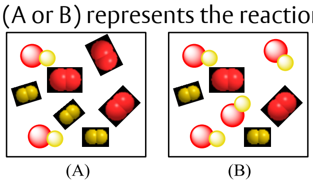


Figure 3.17. Q16 for food science students, UoR

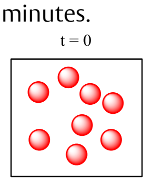
3.2.2 Chemistry Students Year 1, University of Reading

The set of questions (instrument/test) used to investigate this group of students is attached in Appendix B. The test consists of 13 short answer questions. Students' misunderstandings are presented in each theme/topic below

3.2.2.1 *The concentration of a reactant at its half-life*

In this topic, students were asked to determine the half-life concentration (1st, 2nd and 3rd half-lives) of a reactant in a particular order of reaction. This topic was represented by Q1, Q2, and Q7. Q1 and Q7 were given in microscopic representation, while Q2 was presented in conceptual verbal question format.

The diagram shows the concentration of reactant S in the **second order** reaction S → T at time $t = 0$ minutes.



Red spheres represent S molecules are converted to yellow spheres that represent T molecules.

a. Draw the appropriate diagram that represents this reaction at the half-life of reaction ($t_{\frac{1}{2}}$).
b. **If the reaction is first order**, draw the appropriate diagram after the first half-life and the second half-life of reaction.

Figure 3.18. Q1 for chemistry students, UoR

Q1 was presented as a two-part question with sub-questions (a) and (b). Q1(a) focuses on the half-life of second-order reaction, while Q1(b) focuses on the half-life of a first-order reaction. This question is intended to investigate whether students are sure that "the concentration of a reactant at its half-life is equal to half its initial concentration" occurs for any order of reaction. Figure 3.19 shows that 38.60% of students showed a correct answer (CA), 50.90% showed a partially correct answer (PCA) and 10.50% of students did not answer the question or answered it incorrectly (WNA).

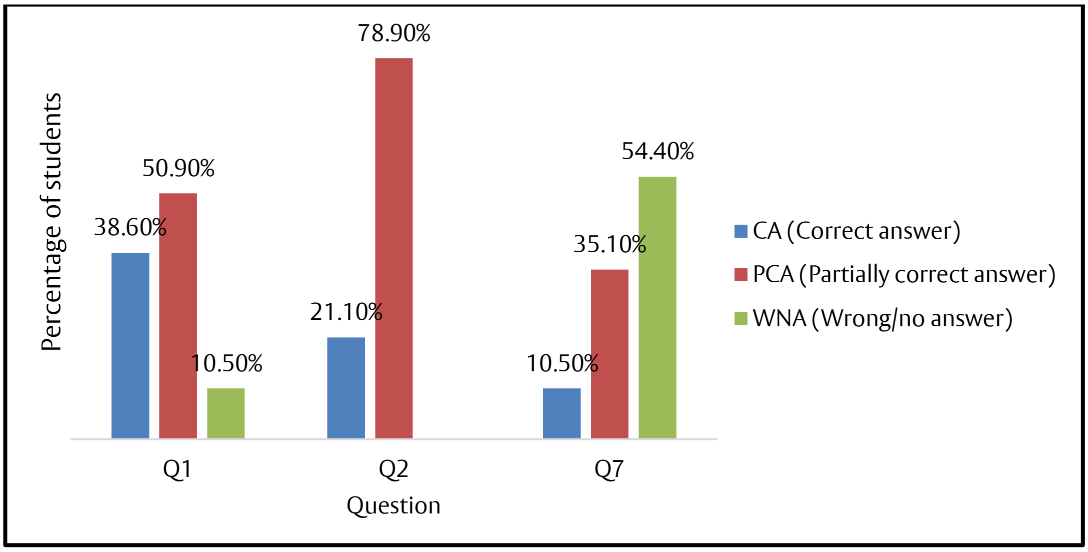


Figure 3.19. The percentage of chemistry students in answering the questions regarding the concentration of a reactant at its half-life

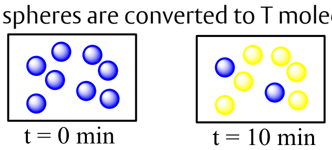
We can assume that students with the correct answer (CA) understand deeply that regardless the order of reaction, the concentration of a reactant at its half-life is equal to half its initial concentration. This is shown by their efforts in answering Q1 points (a) and (b) along with their correct scientific reason. Meanwhile, about a half the students who showed a partially correct answer (PCA) to Q1 had the following responses. Some students with PCA answered the questions without providing a scientific explanation. The second set of students with PCA answered Q1.b correctly but did not answer Q1.a. This shows their doubts about the concept of $[A]_{t½}, = ½\ [A]_{t=0}$. Whether the relationship that the concentration of $[A]_{t½}, = ½\ [A]_{t=0}$ prevails for any reaction order is unclear for many students. This demonstrates students' limited understanding that the $[A]_{t½}, = ½\ [A]_{t=0}$ is only applicable to a first-order reaction. A third set of students answered Q1(b) correctly and Q1(a) incorrectly without providing a scientific reason for both answers.

A 12.0 mg radioactive sample decays by the first order reaction.
a. How many milligrams of this sample remain after two half-lives?
b. Assume that two half-lives is reached in 126 days, what is the rate constant of this reaction?

Figure 3.20. Q2 for chemistry students, UoR

Q2 was also a two-part question and was displayed in straightforward textual format. It relates to the same concept as in Q1. Figure 3.19 shows that Q2 part (a) is followed by part (b) and requires the determination of the rate constant when t¼ is known. The results show that 21.10% of students gave CA and 78.90% gave PCA. As the majority of students gave the correct or partially correct answer we can assume that the microscopic representation of this concept is a more challenging way of presenting the question than the straightforward textual style. In addition, generally students with PCA determined the mass of radioactive sample after two half-lives correctly, but they failed in using the t¼ data to determine the rate constant. A typical misconception uncovered in this task is that many students think that the concept of t¼ is same as the concept of t½. This misconception was also uncovered with non-chemistry students as previously discussed. In addition, many students did not include a unit.

The first order reaction S → T is shown pictorially below, where S molecules represented as blue spheres are converted to T molecules represented as yellow spheres.



Based on the figure above,

a. What is the rate constant of the reaction?
b. How many S (blue) molecule and T (yellow) molecule present at t = 15 minutes?

Figure 3.21. Q7 for chemistry students, UoR

Q7 was also given to non-chemistry students as discussed in the previous session. This question is the final question that addresses half-life and rate constants and again was a two-part question. Q7 Part (a) requires students to determine the rate constant of a first-order reaction from a microscopic representation of the reaction and to determine t½ from this. If students understand how to determine t½, they should be successful in solving this question. Meanwhile, Q7 part (b) investigates students' ability to visualize the microscopic representation of this reaction at t = 15 minutes. Basically, this question involves the same concepts as Q1 and Q2 as attached in Appendix B, however, students are required to use more thought in solving this question. The question is slightly more difficult than the former two questions. This increased difficulty is shown by the low percentage of students showing CA (10.50%) and the high percentage of students showing PCA and WNA (35.10% and 54.40% respectively). This question can be solved directly by using the equation $\ln[A]_t = \ln[A]_0 - kt$ or the equation $k = \frac{\ln 2}{t^{1}/_{2}}$. In order to apply the last equation, students should understand how to get t½ from the microscopic representation.

Generally, students with PCA tried to use the first equation in solving this question, but they got into difficulty processing it correctly. A lack of conceptual understanding coupled with inadequate mathematical skills is suggested as the biggest obstacle for students. Justi (2002) & Cakmakci (2010) emphasized that the understanding of chemical kinetics requires an integrated conceptual understanding of some fundamental ideas: the particulate nature of matter, the kinetic molecular theory and dynamic aspects of chemical reactions. In addition, mastering chemical kinetics demands high cognitive ability in processing the abstract concepts and the application of some mathematical operations. A lack of conceptual understanding is shown by the fact that students cannot determine the concentration of a reactant correctly at t=0 and t= 10 minutes. Meanwhile, inadequate mathematical ability is demonstrated in several instances as shown in a student answer to Q6. One of the students failed in solving the following calculation: $\frac{6\ x\ 10^{-3}\ \mathrm{M/minute}}{(1\ x\ 10^{-3}\mathrm{M})(1\ x\ 10^{-3}\mathrm{M})}$. This calculation is intended to calculate the rate constant of a second-order reaction: $k = \frac{Rate}{[\mathrm{A}]^2}$. This student could substitute the value of rate and concentration of reactant correctly, but he/she failed to obtain the correct calculation result. This confirms that it is often weak mathematical ability that causes students to make errors, but it could also be explained by carelessness. In addition, most students with PCA could correctly determine the number of molecules of both reactants at t=15 minutes. However, they struggled to provide the correct scientific reason for their answer.

3.2.2.2 *Relative rates and reaction stoichiometry*

When the value of a reaction rate with respect to one substance is known, the coefficients of the reaction's balanced chemical equation can be used to find the relative rates with respect to the other substances. In this task, students were asked to express the relative rates of substances involved in a reaction based on its stoichiometric chemical equation. Students were required to express the rate of the chemical reaction in terms of the rate of formation (or disappearance) of another product or reactant. Their awareness of the sign of the change in concentration was also explored to ascertain their understanding of the difference between the rate of consumption of reactant or the rate of formation of product.

The combustion of ammonia is represented by the following equation: $4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O$ In the interval between 20 minutes and 40 minutes, the $[NH_3]$ decreases from 0.1 M to 0.080 M. Write 4 different expressions for the rate of this reaction!

Figure 3.22. Q3 for chemistry students, UoR

This topic is represented by Q3. Even though this task looks straightforward, only 21.40% students showed CA and 39.30% students showed PCA and WNA for each. Some students' answers revealed that they know that for a generalized reaction $a\mathrm{A} + b\mathrm{B} \rightarrow c\mathrm{C} + d\mathrm{D}$, the relative rates are given as:

$$-\frac{1}{a}\frac{\Delta[A]}{\Delta t} = -\frac{1}{b}\frac{\Delta[B]}{\Delta t} = +\frac{1}{c}\frac{\Delta[C]}{\Delta t} = +\frac{1}{d}\frac{\Delta[D]}{\Delta t}\ .$$

However, a knowledge of this relative rate equation was not sufficient to help them answer the question. Some students only focused on the mathematical operation without a sufficient conceptual understanding. This indication is shown by students' ability in providing the mathematical expression of the rate with respect to NH_3, ($\frac{1}{4}$ $[NH_3]$). However, by missing the negative sign, indicating that NH_3 is consumed, they show their inadequate conceptual understanding of this concept. An example of students' difficulty with this question is given in Figure 3.23 below.

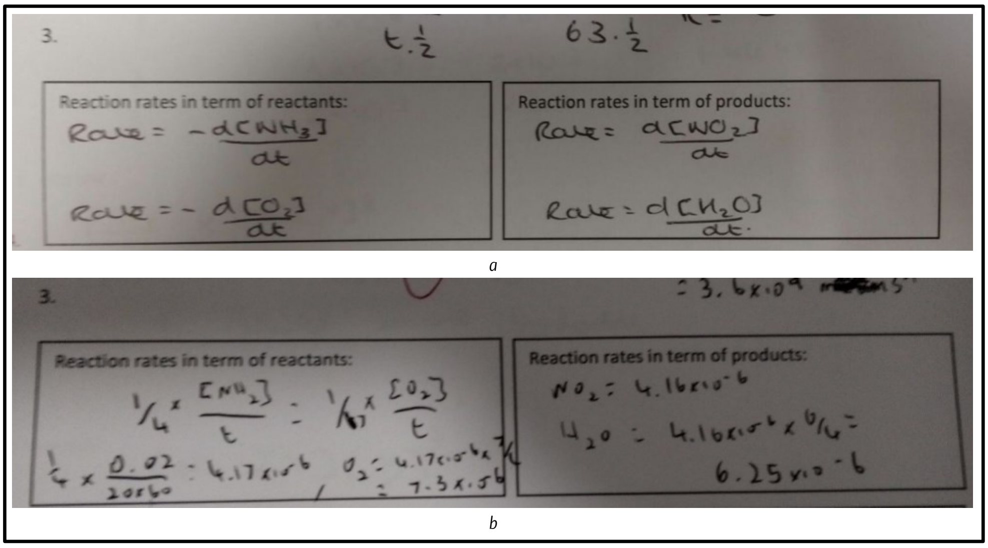


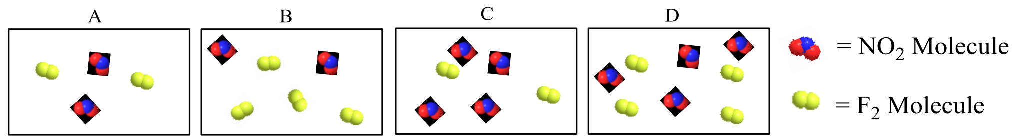
Figure 3.23. An example of students' difficulty in solving relative rates and reaction stoichiometry task

In Figure 3.23.a, the student provided the rate law expression (for example $\frac{-\mathrm{d[NH_3]}}{\mathrm{dt}}$) and included the negative and positive signs, but he/she missed the stoichiometric coefficient of the reactant. Meanwhile, in Figure 3.23.b, the student missed both signs and the unit. However, the result from the calculation is correct, $\frac{1}{4}\frac{\mathrm{[NH_3]}}{dt} = \frac{1}{7}\frac{\mathrm{[O_2]}}{dt}$. This example shows that it is sometimes difficult to understand students' explanations and working. The fact that many students generally ignored the sign suggests that they might appreciate that by convention the rate is always expressed as a positive quantity.

3.2.2.3 *Determining rate law using the initial rates method*

Rate laws are always determined experimentally. In this task students were asked to determine the reaction order and the rate constant from the initial concentration of reactants and initial reaction rates. This is generally known as the 'initial rates method'. In order to write the rate law correctly, students must find the order of reaction with respect to each reactant. This task is represented by Q4 and Q6. Q4 is given in microscopic representation, while Q6 is represented in numerical/ algorithmic format where a series of experimental data is presented.

The gas-phase reaction of nitrogen dioxide and fluorine is written as
$2NO_2(g) + F_2(g) \rightarrow 2NO_2F\ (g)$
The relative rates of reaction for reaction mixtures depicted in the containers (A,B,C,D) are <u>1:2:2:4</u>.
The concentration of each reactant is represented by the spheres according to the key below.



Determine,

a. The order of reaction with respect to NO_2 and F_2

b. The overall order of the reaction

Figure 3.24. Q4 for chemistry students, UoR

Q4 was also given to non-chemistry students as discussed in the previous section. Figure 3.25 shows that this question was only answered correctly by 1.79% of students, while 78.6% students showed PCA and the remaining 19.60% showed WNA. Almost all the students with PCA could only state the order of reaction with respect to NO_2 and F_2 without providing a scientific explanation. This phenomenon suggests that students' understanding in microscopic representation is fairly low. This conclusion is supported by the results for Q6 that focussed on the same concept but was provided in numerical format.

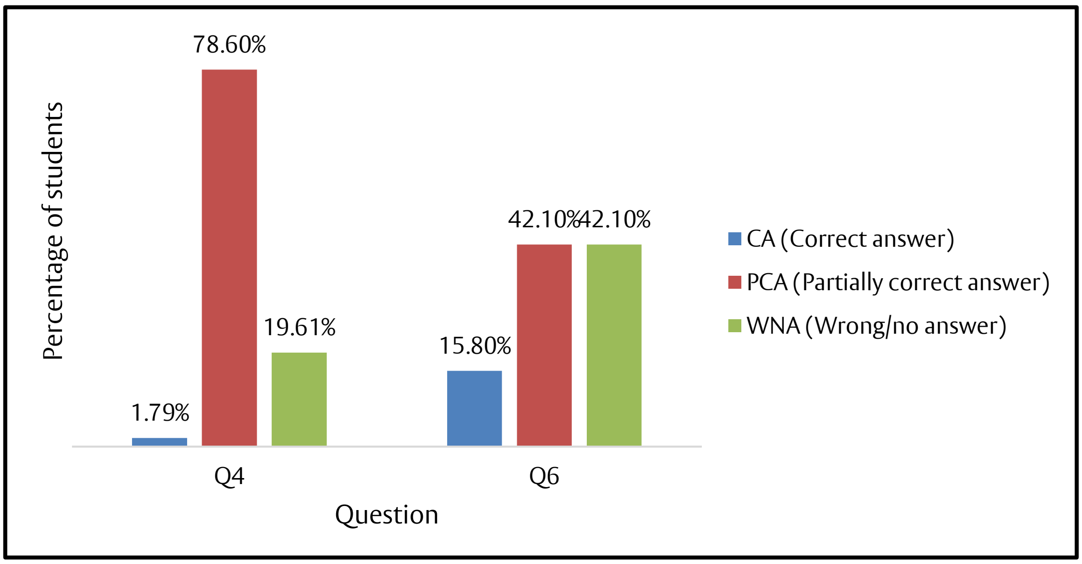


Figure 3.25. The percentage of chemistry students in answering the questions regarding determining rate law using the initial rate method

The initial rate data below are obtained from the reaction: $2X + 3Y \rightarrow 2S + Z$

Experiment	$[X]_0$	$[Y]_0$	Initial rate of formation of Z
1	1.00×10^{-3} M	1.00×10^{-3} M	6.00×10^{-3} M/minute
2	3.00×10^{-3} M	2.00×10^{-3} M	1.44×10^{-1} M/minute
3	2.00×10^{-3} M	1.00×10^{-3} M	1.20×10^{-2} M/minute

Determine: (a) the rate law, (b) the rate constant of this reaction

Figure 3.26. Q6 for chemistry students, UoR

Q6 provides a series of experimental results. Although Q6 explores the same concept as Q4, Q6 actually demands a higher mathematical ability than Q4. However, as shown by Figure 3.25, the result for students with CA (16.10%) is significantly higher than that for Q4. These results suggest that students have more difficulty interpreting the microscopic representation rather than textual data. It could be that students are more accustomed to interpreting textual data and this finding has been reported previously in, for example, Kozma (2003), Kozma and Russell (1997), Tan, Goh, Chia, and Treagust (2009), Cakmakci et al. (2006) and others. This could be explained by stating that although students are able, in some cases, to solve algorithmic problems they do not always have a full understanding of the concepts and use recall and simple parameter substitution to solve problems. A similar result was revealed by Nyachwaya, Warfa, Roehrig, and Schneider (2014), i.e. that some students can balance chemical equations algorithmically without sufficient conceptual understanding of the meaning.

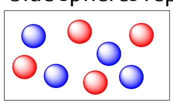
3.2.2.4 *The dependence of reaction rate on concentration*

In this topic, students were asked to determine whether changes in volume of the container as represented at the microscopic level will increase or decrease the rate of reaction. This task is represented by Q5 with a three-part question (a, b, and c).

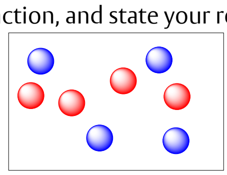
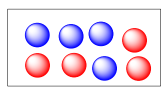
Q5 was given to non-chemistry students and the result has been discussed in the previous section. Each part represents the final condition in the reaction microscopically in terms of volume and number of molecules and hence concentration. Q5 part (a) explores whether students understand that an increase in volume leads to a decrease in concentration and hence decrease in reaction rate. Q5 part (b) explores whether students understand that a decrease in volume leads to an increase in concentration and hence an increase in reaction rate. However, Q5 part (c) demands critical thinking skills of students as both the volume and the number of reactant molecules increases and so there are opposing effects on the rate.

Overall, this question was answered correctly by 10.70% students while 82.10% of students show PCA and 7.14% show WNA. Most students understood the implications of parts (a) and (b), but they had difficulty in answering part (c). Almost all students with PCA failed in solving part (c). It is expected that students can argue that the rate can be either increased or decreased because both the number of molecules and the volume are increased. Because there are no figures given, the effect on the reaction rate cannot be determined exactly. However, only a small number of students gave such an analytical answer.

The hypothetical reaction of A + B → Products is the first order for both reactants. In the picture below blue spheres represent A molecules and red spheres represent B molecules.



The size of the box is proportional to the volume of the reaction container. State whether the three changes below represented by the pictures A, B and C will ......(*increase or decrease*).....the rate of reaction, and state your reason.

A.  .... because .... B.  .... because ....

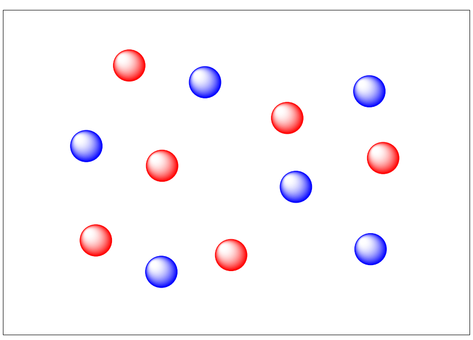
C.  .... because ....

Figure 3.27. Q5 for chemistry students, UoR

The number of chemistry students with CA is significantly higher than the number of non-chemistry students. However, the quality of explanations provided by both groups is similar. Some students argued that the reaction rate will be relatively unchanged because of both volume and concentration increase. Other students argued that the reaction rate will decrease because the increase in volume is considered to have more effect than the increase in concentration. Therefore, the effect of the massive increase of volume will be more dominant. All these reasons are acceptable because values for the volume and concentration were not given. The salient point is that students demonstrate their analytical thinking in answering this question.

3.2.2.5 *Activation energy*

Activation energy, E_a, is the energy difference between the energy of the reactants and the activated complex in the highest energy transition state in the reaction pathway. The molecular arrangement shown at the top of the potential energy "hill," or barrier, is either the activated complex or the transition state. The activation energy (E_a) and the energy difference (ΔH) are generally depicted in an activation energy diagram.

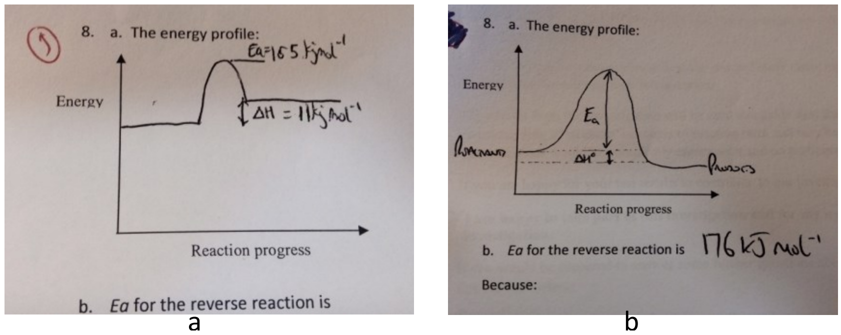
> The activation energy for the reaction $NO_2(g) + NO_3(g) \rightarrow N_2O_5(g) \quad \Delta H^0 = 11\ kJ/mol$ is 165 kJ/mol.
> a. Sketch the energy profile for this reaction, and label Ea and ΔH
> b. What is Ea for the reverse reaction?

Figure 3.28. Q8 for chemistry students, UoR

Q8 is intended to investigate students' understanding of the energy profile for an endothermic reaction $NO_2(g) + NO_3(g) \rightarrow N_2O_5(g)$. Q8 part (a) requests students to draw the energy profile of the reaction in term of E_a and ΔH and the next part asks students to determine E_a for the reverse reaction. Analysis of the results confirms that 25% students show CA, 35.70% show PCA and 39.30% show WNA.

Some examples of students' responses are shown in Figure 3.29. The answer in Figure 3.29. (a) is typical of a PCA. These students generally could only draw the energy profile of the reaction but failed in determining the E_a for the reverse reaction. This indicates a lack of conceptual understanding of this concept. They memorize the energy profile diagram of activation energy, but they do not understand the meaning of the diagram. Therefore, they were not able to interpret some information in the diagram. Furthermore, Figure 3.29.(b) which is WNA is typical of two or three students' answers. They drew the profile for this reaction as an exothermic reaction. As displayed in Figure 3.29.b below, if the reaction is exothermic with values of Ea and ΔH of 165 kJ/mol and -11 kJ/mol respectively, Ea for the reverse reaction should be 176 kJ/mol. Unfortunately, the reaction in the question is endothermic. Therefore, this student's answer is still wrong. There are two possible causes for this student's difficulty. Firstly, they could not differentiate between endothermic and exothermic reactions. The second reason may be due to carelessness.

Meanwhile, the vast majority of students with WNA answered the question incorrectly or left their answer sheets blank. One example of their incorrect answers is that they considered the value of activation energy to be 176 kJ/mol as shown in Figure 3.29.(b) (while the correct value is 154 kJ/mol). Students getting this answer must have assumed that E_a for the reverse reaction is the sum of the activation energy and ΔH. In addition, they could not draw the energy profile correctly. Their inability to draw the correct plot coupled with an incorrect value for E_a demonstrates a typically poor understanding of the concept.



a b

Figure 3.29. An example of PCA (left) and WNA (right) for the activation energy diagram

However, students with CA could not provide a satisfactory scientific explanation for their answer as displayed in Figure 3.30 below. They showed the correct answer, but limited understanding is represented by their explanation in Figure 3.30 part (b). Their explanations generally only focused on the mathematical relationship between E_a and ΔH.

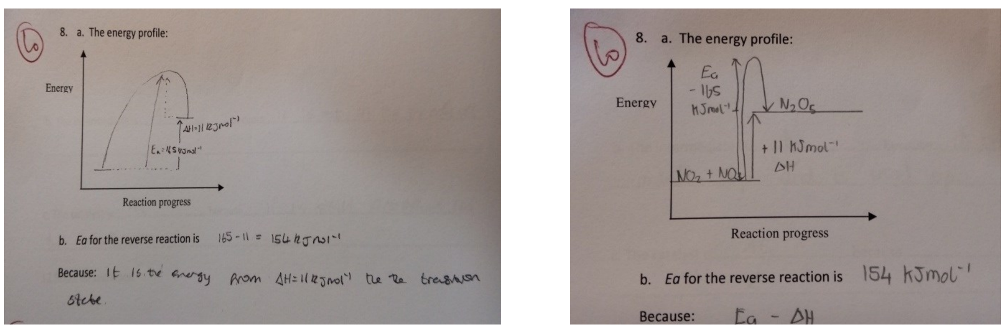


Figure 3.30. An example of CA for the activation energy diagram

This phenomenon indicates that students' understanding of activation energy diagrams is inadequate. Research results in activation energy understanding so far have generally been concerned with students' understanding of the definition of activation energy. Cakmacki in Cakmakci and Aydogdu (2011) revealed that some high school and undergraduate students in Turkey assumed that activation energy is the kinetic energy of reactant molecules or activation energy is the (total) amount of energy released in a reaction. Meanwhile, Kıngır and Geban in Kirik and Boz (2012) reported that some students believed that temperature affects activation energy.

3.2.2.6 *Predicting the rate law based on the reaction mechanism*

The rate of a reaction usually depends on both the reactant concentrations and the value of the rate constant. In addition, another significant issue in chemical kinetics is the reaction mechanism, the sequence of molecular events, or reaction steps, that describe the pathway from reactants to products. The rate law for the overall reaction can be predicted based on the elementary steps in the reaction mechanism. In order to predict the rate law, acknowledging the rate determining step is important.

The reaction formation of HI(g) may occur with the following mechanism:

$$I_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2I \qquad \text{fast}$$

$$I + I + H_2 \xrightarrow{k_2} 2HI \qquad \text{slow}$$

Predict the rate law based on this mechanism!

Figure 3.31. Q12 for chemistry students, UoR

Q12 explores students' understanding in predicting the rate law of reaction based on its reaction mechanism. Analysis of the results shows that only 3.57% students show CA while 21.40% students show PCA and 75.00% show WNA. The low number of students with CA confirms that this task is considered a difficult question for students. This is supported by the difficulty index of this question (0.013). Most students left their answer sheet empty for this question. In considering pre-service (trainee) chemistry teachers' understanding as uncovered by Tastan, Yalçinkaya, and Boz (2010), it is not surprising that first-year students have difficulty with this type of question. Even trainee chemistry teachers tend to be confused as to whether the slow step is the rate-determining step or not (Tastan et al., 2010).

Apparently, some students were aware that the slow step is the rate-determining step but failed to use this information to solve the question correctly. For example, in Figure 3.32, some students indicate their awareness of the rate-determining step. However, students have no idea that "I" is an intermediate generated in the forward reaction of step 1. Intermediates are usually unstable and have a low and unknown concentration. Thus, the rate law for the slow step depends on the indefinite concentration of an intermediate, which is not helpful in predicting the rate law of reaction (Brown et al., 2017). Because of this, the fast step in this reaction must also be included when predicting the overall rate law.

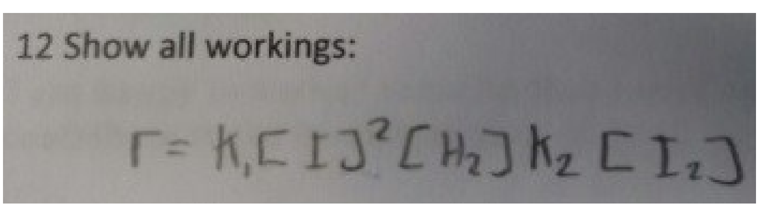


Figure 3.32. An example of a student's answer who was aware that the slow step is the rate-determining step.

Another student shows better understanding even if the answer is not correct as presented in Figure 3.33 below. This student seems aware of the rate determining step and the equation for the fast step as well. Unfortunately, he/she failed to obtain the correct rate law due to errors in substituting the two equations.

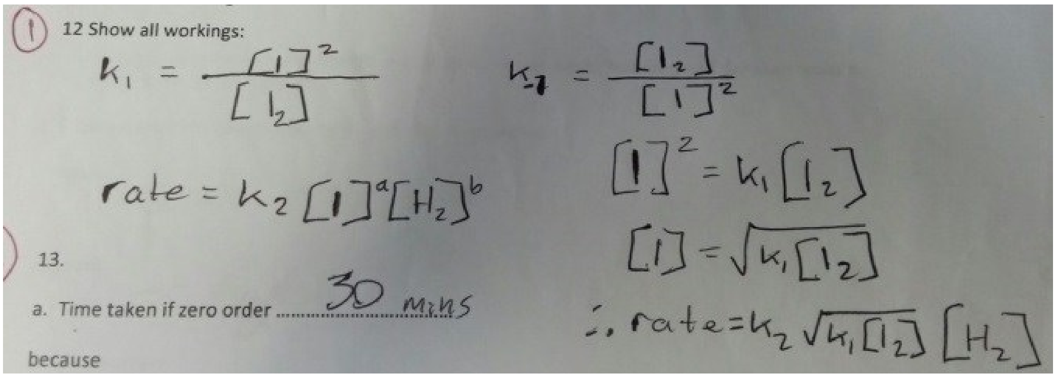


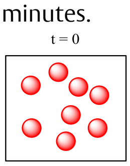
Figure 3.33. An example of a student's answer who was aware that the slow step is the rate-determining step.

3.2.3 Indonesian Students: Chemistry Students of the State University of Malang & Haluoleo University

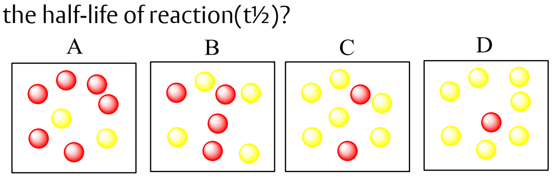
The instrument used in this step is multiple choice with confidence rating (Appendix C). This was intended as a preliminary development of the FTDICK instrument, in which students were also asked to show how they arrived at their answers.

3.2.3.1 The concentration of a reactant at its half-life

The diagram shows the concentration of reactant S in the first order reaction S → T at time $t = 0$ minutes.



Red spheres representing S molecules are converted to yellow spheres that represent T molecules. Which is the appropriate figure (from A, B, C and D) that represents reaction progress at the half-life of reaction(t½)?



Show working:

State the confidence rating of your answer

1. no idea, just guessing	2. very unconfident	3. unconfident
4. confident	5. very confident	6. absolutely confident

If the reaction is Second order, draw the appropriate diagram after the first half-life and the second half-life

Show working:

State the confidence rating of your answer

1. no idea, just guessing	2. very unconfident	3. unconfident
4. confident	5. very confident	6. absolutely confident

Figure 3.34. Q1 for Indonesian students

The analysis results show that the definition of half-life is a familiar term for Indonesian students. This phenomenon is confirmed by the high number of students (76%) who selected the correct answer to Q1.a. In this question, which was presented pictorially, students were asked to determine the concentration of a first-order reactant at its half-life. By comparing the number of students who gave the correct answer with the number of students who gave the wrong answer, it seems that this concept was generally well understood by students. However, when stating the reason for their chosen answer, many students gave unscientific explanations. In addition, the low confidence rating of students who gave the correct answer (2.36) confirms students' lack of knowledge of this concept. This phenomenon was strengthened by students' answers to Q1.b. The latter question was asking for the concentration of the second-order reactant at its half-life. Only 17% of students provided a correct answer with a higher confidence rating (2.99). This small proportion of students demonstrated a good understanding of the concept of half-life.

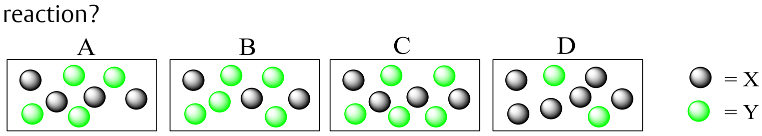
The large difference in percentages of students correctly answering Q1.a and Q1.b confirms that some students could define the half-life literally without a full understanding of the meaning of the definition. In addition, students seemed unsure whether the concept of $[\mathrm{A}]_{t½}, = ½\ [\mathrm{A}]_{t=0}$ is applicable only for a first-order reaction or for any order of reaction. Some students believed that the consumption of a second-order reactant will be faster than that of a first-order reactant. Therefore, students rose to the conclusion that the concentration of a first-order reactant at its half-life is higher than half of its initial concentration. On the other hand, they argued that the concentration of a second-order reactant at its half-life is lower than half of its initial concentration, $[\mathrm{A}]_{t½} < ½[\mathrm{A}]_0$.

In addition, students generally always tried to answer the question by using mathematical equations. This question did not actually require the use of a mathematical operation to solve it. For example, students tend to find out the concentration of a reactant at its half-life by using this equation, $[\mathrm{A}]_{t\frac{1}{2}} = (\frac{1}{2}[\mathrm{A}]_0)^n$ (when *n* is the order of reaction). This equation will only work for first-order reactions. The tendency to use this equation could be one of the reasons why students cannot differentiate successive half-lives. They probably assume the $[\mathrm{A}]_0$ value is always the starting concentration. This confirms that students' ability to do mathematical calculations was not supported by their conceptual understanding. In addition, the concept of successive half-lives is a challenge for many students. They generally assumed the first half-life and the next half-lives to be the same concept.

3.2.3.2 The dependence of reaction rate on concentration

The concept that as the concentration of a reactant changes at constant temperature, the rate of reaction changes, is fully understood by many students. However, there are two prominent challenges related to this concept. Firstly, some students stated that if the concentrations of two reactants are the same or almost the same, the reaction rate will be higher. They argued that each one molecule from one reactant will collide with one molecule from another reactant in a proportional manner. This finding can be categorized as a misconception. This misconception is uncovered from students' answers to Q2. This reason was revealed by some students who chose A and C as the correct answer with confidence ratings of 2.62 and 3.52 respectively. Even though options A and C were selected by 28.16% and 43.04% students respectively, only 16.46% of the total number of students gave this unscientific reason with a confidence rating of 2.73. Actually, C is the correct answer which was chosen by the highest number of students, however, some of these students provided unscientific reasons behind their answer. It indicates that these students can only calculate the result using the rate equation without a deep understanding of the concept.

For the hypothetical reaction X + Y → Products. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



Show working:

State the confidence rating of your answer

1. no idea, just guessing	2. very unconfident	3. unconfident
4. confident	5. very confident	6. absolutely confident

Figure 3.35. Q2 for Indonesian students

Secondly, some students expressed the opposite view to the previous one. 8.54% students with a confidence rating of 2.33 believed that the reaction rate will be higher when two reactants have a large difference in concentration. This unscientific explanation was revealed by some students when answering Q2 and Q13. For Q2, the explanation was provided by 6.96% and 18.04% students who selected B and D respectively as the correct answer. Meanwhile, for Q13 this explanation was provided by some students who selected A, B, C and D as the correct answer. Those students supported their explanations with the reason that the reactant with a very low concentration will disappear quickly. These students considered the time needed to complete the reaction to be the reaction rate. They seem to have confused their understanding of this concept with their understanding of the limiting reagent in an inappropriate manner. Difficulty with chemical terminologies can be the reason for this apparent lack of knowledge. Both these misconceptions that were uncovered have not been published by other researchers so far.

In addition, some non-scientific understandings were found in a small fraction of students. About 2 or 3 students argued that the higher the concentration, the slower the rate because the increase in concentration decreases the space for movement of molecules. These students seemed not to be aware of collision theory that explains how reactions occur. Another non-scientific understanding uncovered is that an increase in volume increases the rate of reaction.

3.2.3.3 How the order of reactant affects the reaction rate

The order with respect to a reactant determines how sensitive the rate is to changes in concentration of that reactant. The effect of an increase in concentration of a first-order reactant is usually explained correctly by many students. However, mistakes are often made when converting the verbal explanation to a mathematical expression. For example, these students realise that doubling the concentration of a first-order reactant doubles the reaction rate but they have difficulty solving mathematical problems that require this relationship.

> The rate law of the reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is $Rate = k[NO_2]^2$, where Rate is the rate of reaction at any time and k is the rate constant. If the concentration of CO increases by a factor of 3, the reaction rate will….
>
> A. Increase by a factor of 3 B. Increase by a factor of 6
> C. Increase by a factor of 9 D. Remain constant
>
> Show working:
>
> State the confidence rating of your answer
> 1. no idea, just guessing 2. very unconfident 3. unconfident
> 4. confident 5. very confident 6. absolutely confident

Figure 3.36. Q9 for Indonesian students

The common misconception found in this topic is that the increase in concentration of a zero-order reactant will increase the reaction rate. This unscientific reason is uncovered from students answering Q9. Those students included 14.56% students who selected option A, 6.33% who selected option B and 17.41% who selected option C. The number of students who gave this unscientific explanation (21.51%) had a confidence rating of 3.19 warrants this explanation to be categorized as a misconception. This finding is similar to the one which was uncovered by Cakmakci (2010).

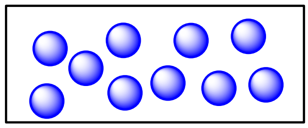
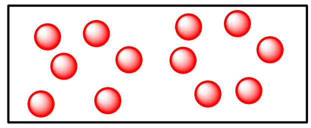
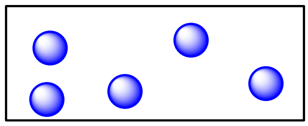
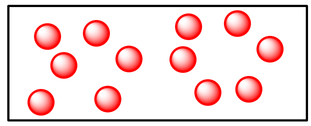
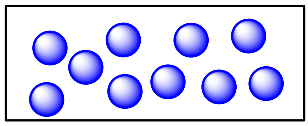
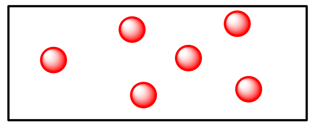
However, an opposing view was identified in this concept. A small fraction of students argued that the increase in concentration of a zero-order reactant will decrease the reaction rate. Besides, another student claimed that the increase in concentration of a zero-order reactant does not affect the rate because it obeys the law of conservation of mass. Another non-scientific understanding uncovered is that the increase in volume increases the rate. These findings confirmed similar findings as published by Hackling & Garnet (1985) and Bilgin & Geban (2006). They found that several students believed that when the volume of the reaction vessel is decreased, the rate of the reverse reaction is decreased. In addition, a small number of students explained that the increase in concentration of a first-order reactant will increase the rate more than the increase in concentration of a second-order reactant.

3.2.3.4 Rate law

The dependence of the reaction rate on the concentration of each reactant is given by an equation called the rate law. A common misconception found in this topic is that some students assumed that the values of the exponents in a rate law are directly deduced from the stoichiometry of the reaction. This misconception was uncovered for 39.56% students who selected option D for Q3. Even though only 3.16% harboured this misconception, the high confidence rating (4.1) which was demonstrated by those students confirms the previous results published by Cakmakci et al. (2006), Cakmakci and Aydogdu (2011), Kingir & Geban (2012), and Turányi and Tóth (2013).

Meanwhile, a small number of students assumed that all reactants in the chemical equation should be written in the rate law including a reactant which is zero-order. This sometimes leads students to believe a zero-order reactant is actually first-order because it appears in the rate law. In addition, some students got into difficulty in identifying the order of a reactant from the rate law provided.

Consider the reaction between t-butylbromide and a base at 55°C:
$(CH_3)_3CBr(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq) + Br_2(aq)$, the blue spheres represent molecules of $(CH_3)_3CBr$ and red spheres represent ion of OH^-
A series of experiments is carried out with the following results:

Experiment	$[(CH_3)_3CBr]$ (mol/L) x 10^{-1}	$[OH^-]$ (mol/L) x 10^{-1}	Rate (mol/L.s)
1.			0.01
2.			0.005
3.			0.01

Based on this information, which of the following options is *not* a correct statement?

A. The reaction is first order with respect to $(CH_3)_3CBr$
B. $k = 0.010\ s^{-1}$
C. at the higher temperature, the rate of 2nd experiment will be > 0.005 mol/L.s
D. Rate = $k\,[(CH_3)_3CBr]\,[OH^-]$

Show working:

State the confidence rating of your answer

1. no idea, just guessing	2. very unconfident	3. unconfident
4. confident	5. very confident	6. absolutely confident

Figure 3.37. Q3 for Indonesian students

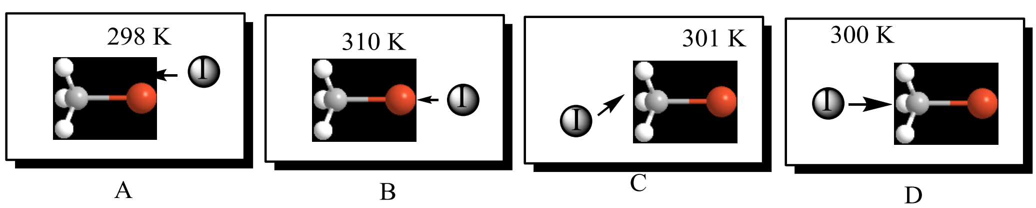
3.2.3.5 *Temperature and Rate of Reaction*

The dependence of rate of reaction on temperature is generally explained correctly by most students. However, a small fraction of students revealed some misconceptions in this topic. Some students claimed that temperature does not affect the reaction rate. This misconception is in line with the findings of Cakmakci (2010) and Yalçınkaya, Taştan-Kırık, Boz, and Yıldıran (2012). Meanwhile, several students explained that the lower the temperature, the higher the reaction rate. Another misconception found is that an increase in temperature increases activation energy and that leads to an increase in reaction rate. Such a misconception is in keeping with the findings of Kaya & Geban (2012) and Yalçınkaya et al. (2012). However, a novel idea which was uncovered in this study is that the higher the temperature, the stronger the attractive forces between different molecules. Although the limited evidence for this idea warrants further exploration.

3.2.3.6 *Collision and reaction rate*

Collision theory plays an important role in explaining the reaction rate concept. Students generally hold a limited understanding of this concept. This limitation is shown by the vast majority of students who left their answer sheet blank for Q4 and Q11. However, several non-scientific understandings were uncovered. Many students are generally not aware that the orientation of the molecules on collision is important but are only concerned with the effect of temperature. These students simply assumed that all collisions result in a reaction. Another unscientific understanding which was revealed in this topic is that the collision will be more effective when two particles colliding have a bigger charge difference because the collision will be "stronger" and lead to reaction which increases the rate. Those misunderstandings have not been published in the literature.

The reaction of $I^- + CH_3Br \rightarrow CH_3I + Br^-$ is represented pictorially below. Which figure (A, B, C or D) that represents the highest rate of reaction? The arrows represent the direction of the collision.



Show working:

State the confidence rating of your answer

1. no idea, just guessing
2. very unconfident
3. unconfident
4. confident
5. very confident
6. absolutely confident

Figure 3.38. Q11 for Indonesian students

In addition, the most prominent misconception in this topic is that the lower the temperature, the more effective and faster the collisions. This effect leads to a higher rate of reaction. Although the number of students who harboured this misconception is small, it is important that such a misconception is resolved. This finding strengthened the misconception which was revealed by Van Driel (2002). He found that some high school students believed that an increase in initial temperature of the system decreases the reaction rate: collisions of fast-moving particles would be less effective because the particles would bounce back.

3.2.4 Inappropriate mixing of chemical kinetics with other topics

Generally, chemistry concepts have a hierarchical relationship with other concepts and are rarely isolated within chemistry courses. However, some students often make an inappropriate connection when relating one concept to another. Some findings around this aspect were revealed.

Firstly, some students stated that an increase in reactant concentration leads to longer reaction time. These students seem to confuse the rate of reaction and time of reaction. They defined reaction rate as reaction time. This finding is similar to the result released by Cakmakci et al. (2006) and Cakmakci and Aydogdu (2011). Another misunderstanding around this aspect is that the longer the reaction takes, the faster the rate.

Secondly, increasing the temperature favours the exothermic reaction, so that the amount of product increases while the amount of reactant decreases. Some misunderstandings can be identified from this explanation. Firstly, these students confuse reaction rate and Le Châtelier's Principle as revealed by Yalçınkaya et al. (2012). Secondly, these students showed their inadequate understanding of Le Châtelier's Principle because actually, a temperature increase favours an endothermic reaction, and a temperature decrease favours an exothermic reaction. Similar unscientific conflations between both concepts were reported by Yalçınkaya et al. (2012) and Kolomuç and Tekin (2011).

Thirdly, the higher the concentration of reactant and the lower the concentration of product, the higher the rate. These students made an inappropriate mixing of chemical kinetics with Le Châtelier's Principle. Lastly, a small proportion of students considered the reactant with the lower number of molecules to be the solute, while that with the higher number is the solvent. This may be because students are misinterpreting the pictorial representation in the question. They confuse the two different reactants depicted in the question as representing a solution when one reactant is the solute and the other is the solvent. This point was considered in the next instrument. However, students' explanation in support of their answer that "If the concentration of solvent is much higher than the concentration of solute, the reaction rate increases" confirmed students' misconceptions as discussed in the previous topic (concentration and rate).

3.2.5 Mathematical error

Mathematical error was also one of the main reasons that caused students' difficulty when answering questions. Often students selected an appropriate mathematical equation but made a mistake when doing the calculation. In addition, they often used a mathematical equation to solve the problem when this was not necessary. As a result, students often correctly carry out mathematical calculations without an adequate conceptual understanding. Therefore, students' mathematical ability was investigated in the next instrument (the prototype FTDICK).

3.3 INCORPORATING MISUNDERSTANDINGS IN THE DEVELOPMENT OF THE NEXT INSTRUMENT

Many of these students' unscientific ideas were used as incorrect answers and reasons in the prototype FTDICK. Meanwhile, some questions, such as the dependence of reaction rate on temperature, were understood correctly by the majority of students. Therefore, questions on these topics were not included in the prototype FTDICK instrument. In addition, some unscientific ideas listed in Table 3.1 were not included in the prototype FTDICK instrument as the number of students showing these ideas was not significant. Table 3.1 below presents the question numbers in the prototype FTDICK instrument where these misunderstandings were found.

These unscientific ideas which are presented in Table 3.1 below were not the only source when developing the prototype FTDICK instrument. The literature and authors' experiences when teaching were also considered. The literature contains many students' unscientific ideas from previously published studies.

Table 3.1. Students' misunderstandings and the relevant question numbers used in the prototype FTDICK

No.	Misunderstanding	Students	Q in prot FTDICK
1	Memorizing a scientific definition of half-life without adequate understanding of its conceptual meaning	▪ FS, UoR ▪ Indonesian	Q1, Q2, Q3, Q7, Q11,
2	That the $[A]_{t½}$, = ½ $[A]_{t=0}$ is only applicable for a first-order reaction	▪ FS, UoR ▪ Chem, Uor ▪ Indonesian	Q2, Q3, Q7
3	Lack of knowledge regarding the concept of successive half-lives	▪ FS, UoR ▪ Chem, Uor ▪ Indonesian	Q1, Q3, Q11, Q18
4	Equal numbers of reactant molecules lead to a higher reaction rate	▪ FS, UoR ▪ Indonesian	Q6,
5	The increase in concentration of a zero-order reactant increases the rate	▪ FS, UoR ▪ Indonesian	Q19
6	Lack of knowledge regarding rate-determining step	▪ FS, UoR	Q12, Q17
7	The increase in concentration decreases the rate of second-order reaction	▪ FS, UoR ▪ Indonesian	Q3
8	Lack of knowledge regarding the rate law expression	▪ FS, UoR ▪ Indonesian	Q4,
9	Lack of knowledge regarding the relative rates law	▪ FS, UoR ▪ Chem, Uor ▪ Indonesian	Q20
10	Using the integrated rate law of first-order reaction to calculate a question regarding second-order reaction	▪ FS, UoR	Q3
11	Lack of knowledge of energy profiles for endothermic and exothermic reactions	▪ Chem, Uor	Q10,
12	Lack of ability to extract Ea from an energy profile of a reaction	▪ Chem, Uor	Q10, Q13, Q14,
13	Lack of knowledge regarding activation energy	▪ Chem, Uor ▪ Indonesian	Q10, Q14, Q15
14	Lack of knowledge in predicting the rate law of a reaction based on the elementary steps in the reaction mechanism	▪ Chem, Uor	Q12
15	The reaction of second-order reactant will proceed faster than that of first-order reactant	▪ Indonesian	Not included
16	The reaction rate will be higher when two reactants have a large difference of concentrations	▪ Indonesian	Q6
17	An increase in volume increases the rate of reaction	▪ Indonesian	Q11
18	The increase in concentration of zero-order reactant increases/decreases the reaction rate	▪ Indonesian	Q5, Q19
19	The values of the exponents in a rate law are directly deduced from the stoichiometry of the reaction	▪ Indonesian	Q4, Q12, Q17
20	All reactants in the chemical equation should be written in the rate law including a reactant with zero-order. This sometimes leads to the condition where these students recognized a zero-order reactant as first-order	▪ Indonesian	Not included
21	Difficulty with identifying the order of a reactant from the rate law provided	▪ Indonesian	Not included
22	An increase in temperature doesn't affect the rate	▪ Indonesian	Q16
23	The lower the temperature, the higher the reaction rate	▪ Indonesian	Q16
24	An increase in temperature increases activation energy that leads to an increase in reaction rate	▪ Indonesian	Q10
25	A collision will be more effective when two particles colliding have a big charge difference because the collision will be stronger and increase the rate	▪ Indonesian	Not included
26	The lower the temperature, the more effective and faster the collisions	▪ Indonesian	Not included
27	Simple mathematical error	▪ FS, UoR ▪ Chem, Uor ▪ Indonesian	Q2, Q7, Q8, Q11, Q12, Q17
28	Lack of ability in transferring a verbal statement to a mathematical or algorithmic operation and vice versa.	▪ FS, UoR ▪ Indonesian	All Q
29	Terminology	▪ FS, UoR ▪ Chem, Uor ▪ Indonesian	All Q
30	Lack of ability in interpreting a diagram, graph and table	▪ Chem, Uor ▪ Indonesia	Q3, Q6, Q9, Q10, Q13, Q14, Q15, Q16, Q18, Q19

3.4 CHAPTER SUMMARY

The results show that unscientific ideas about chemical kinetics exist in all groups of students studied. Several misunderstandings such as no.2, no.3, and no.9 in Table 3.1 were experienced by all groups of students, while others were only found among particular groups as shown by the table. Although some misunderstandings are classified as being experienced by a single group, it is possible that the same misunderstanding may be experienced by other groups as not all the same questions were given to every group. For example, misunderstanding "no. 11" was only found among chemistry students at the UoR because the relevant question on the topic was only given to those students.

The result of this preliminary study confirms that further investigations of Indonesian and UK students' understanding of chemical kinetics is important and should be further explored for several reasons. Firstly, these groups of students showed many similarities regarding their unscientific ideas of chemical kinetics. Secondly, these groups also show similar weaknesses regarding mathematical operations, chemical terminology, transferring a verbal statement to a mathematical or algorithmic operation and interpreting a diagram, graph and table. Thirdly, because the set of questions was different for each group it is not possible to draw conclusions about the different abilities of Indonesian and UK students in chemical kinetics. An identical set of questions needs to be given to both groups to enable a full comparison to be made. In addition, the particular strengths and weaknesses of both groups will be explored.

CHAPTER 4

ITEM ANALYSIS OF THE PROTOTYPE FTDICK INSTRUMENT (PILOT STUDY)

4.1. INTRODUCTION

4.1.1 Definition of the Four-Tier Diagnostic Instrument in Chemical Kinetics (FTDICK)

In educational terminology, an instrument is a set of procedures used to collect information regarding students' understanding and other aspects of learning. An instrument includes a test, questionnaires, interviews and other interventions. The FTDICK instrument in this study is a test to identify students' understanding of chemical kinetics. A test is a formal and systematic procedure for assessment and involves a set of questions to be answered by students (McMillan, 2001). Tests and other evaluation procedures can be classified as placement, formative, diagnostic and summative evaluations (Gronlund & Linn, 1990). A diagnostic evaluation aims to identify students' difficulties, misconceptions and other learning issues, and generates a strategy to deal with these issues (Gronlund & Linn, 1990).

The Four-Tier Diagnostic Instrument in Chemical Kinetics (FTDICK) in this study is a diagnostic instrument in the form of a four-tier test designed to identify 1st year students' misunderstandings in chemical kinetics before they embark on a more advanced physical chemistry module involving chemical kinetics topics. The results of this study are intended to inform chemistry educators and to be used when designing chemical kinetics courses and resources for teaching 1st year students at the university level.

4.1.2 Item Analysis of the FTDICK Instrument

This FTDICK instrument is constructed in the form of a multiple-choice questionnaire. An instrument to identify students' understanding/misunderstanding should be of high quality to ensure that the information obtained represents the students' actual understanding/misunderstanding. A rigorous instrument can provide information that can be used to improve students' understanding and also inform educators when designing teaching materials for his/her class (McMillan, 2001). An instrument for educational assessment is expected to provide a robust contribution to the enhancement of teaching and learning (Black & Wiliam, 1998).

According to Thorndike, as quoted by Haladyna (2004), several procedures should be carried out in order to produce a robust instrument. The procedure for measuring the quality of an instrument is called "item analysis". Item analysis is both a qualitative and quantitative procedure designed to evaluate the quality of the instrument (Gochyyev & Sabers, 2010). The main purpose of item analysis is to identify items that should be removed from or revised in an assessment. The elimination procedure is based on item statistics and therefore, should help to improve the quality of the test in an objective manner (Muntinga & Schuil, 2007). As stated by Räisänen, Tuononen, Postareff, Hailikari, and Virtanen (2016), an assessment for higher education should have sound validity and reliability indices as it is used to justify students' grades which is important for students' employability in the future. An invalid and unreliable instrument will lead to an unfair justification of students' performance (Räisänen et al., 2016).

The qualitative procedure involves discussions with examinees who have already taken the test, or experts competent in the field, in order to do careful proofreading of the instrument prior to its administration for typographical errors, for grammatical cues that might inadvertently tip-off examinees as to the correct answer and for the appropriateness of the reading level of the material (Bloom, Madaus, & Hastings, 1981; Zurawski). The FTDICK was examined qualitatively by Professor Elizabeth Page and physical chemistry staff at the University of Reading.

The quantitative procedure is a review of students' performances after testing in order to identify low value and faulty items (Airasian, 1994; Anderman & Anderman, 2009). The procedure is administered by collecting, summarizing and interpreting information gained from students' responses (Anderman & Anderman, 2009; Karelia, Pillai, & Vegada, 2013; Mitra, Haleagrahara, Ponnudurai, & Judson, 2009). The quantitative procedure includes determining the difficulty level, discriminatory index, distractor effectiveness, validity and reliability (Airasian, 1994; Bloom et al., 1981; Muntinga & Schuil, 2007; Zurawski). The difficulty level (DL) refers to the proportion of students who answer the question correctly. The discriminatory index (DI) represents the ability of an item to differentiate between students on the basis of how well they understand the concept being tested. Validity refers to whether the information obtained from a test represents the actual understanding of examinees (Airasian, 1994). Reliability is the degree to which a test consistently measures whatever it is designed to measure.

This chapter discusses the results of the quantitative analysis of the prototype FTDICK instrument. This prototype instrument was constructed based on the preliminary results. These preliminary results have been discussed in Chapter 3. The complete description of the development of this instrument was presented in Chapter 2. This prototype instrument was administered to 271 chemistry students from two Indonesian universities. The instrument used is attached in Appendix F. This procedure resulted in the final FTDICK instrument which was used for primary data collection in the main study.

4.2. ITEM ANALYSIS RESULTS FROM THE PROTOTYPE FTDICK INSTRUMENT

Several parameters were used to describe the quality of the prototype FTDICK instrument, including the difficulty level (DL), the discriminatory index (DI), the distractor effectiveness, validity and reliability. In order to be suitable for use the instrument must comply with all the parameters used to assess it. The results obtained for each parameter are given below to demonstrate the quality of this prototype instrument.

4.2.1. Difficulty level (DL)

The difficulty level (DL) refers to the proportion of students who answer the question correctly. The lower the DL value, the fewer the number of students answering the question correctly. The formula to calculate this parameter is presented in Chapter 2 and is given below (Equation 4.1).

The formula for this parameter (DL) is

$$\text{Difficulty level} = \frac{N_c}{N}$$

where, N_c = the number of students who answer correctly
N = the total number of students who participated in this study

Equation 4.1 Equation for difficulty level

Table 4.1 below describes the DL of the instrument. This table shows that the DL of the A tier, R tier and B tier ranged from *difficult* to *moderate*, none of the tiers was *easy*. In the A tier, the percentage of questions that falls into the *difficult* category is 40%, including Q1 (question 1), Q3, Q6, Q13, Q14, Q17, Q18, and Q20. Of these questions, Q6 has the lowest DL (0.16). The DL values of Q1 (0.18) and Q20 (0.17) are only slightly higher. The remainder of the questions (60%) in the A tier fall in the *moderate* category. Of these questions, Q5 has the highest DL value (0.56) while Q2 is only slightly lower (0.55).

Table 4.1. Difficulty level (DL) of the prototype FTDICK instrument

Question	Difficulty Level (DL)		
	A tier	R tier	B tier
1	0.18	0.11	0.01
2	0.55	0.61	0.46
3	0.26	0.07	0.04
4	0.51	0.44	0.32
5	0.56	0.46	0.35
6	0.16	0.20	0.06
7	0.48	0.51	0.26
8	0.32	0.36	0.20
9	0.51	0.19	0.07
10	0.42	0.39	0.17
11	0.39	0.07	0.03
12	0.44	0.30	0.17
13	0.08	0.16	0.01
14	0.25	0.30	0.06
15	0.32	0.37	0.14
16	0.37	0.28	0.13
17	0.28	0.27	0.16
18	0.28	0.27	0.12
19	0.32	0.19	0.08
20	0.17	0.06	0.03
Mean	**0.33**	**0.28**	**0.14**

Red = *difficult* category
Green = *moderate* category

In the R tier, the percentage of questions that falls into the *difficult* category is 55%, including Q1, Q3, Q6, Q9, Q11-Q14, Q16-Q20. Of these questions, Q20 has the lowest DL (0.06). Q3 and Q11 are only slightly higher (0.07 for both questions). Meanwhile, the rest of the questions (45%) in the R tier fall in the *moderate* category. Of these questions, Q2 has the highest value of DL (0.61).

For a combination of both tiers (B tier), the percentage of questions that falls into the *difficult* category is 85%, including Q1, Q3, and Q6-Q20. Of these questions, Q1 is the lowest with a DL of 0.01. Only 15% of questions in this tier fall in the *moderate* category, including Q2, Q4 and Q5. Of these questions, Q2 has the highest DL of 0.46.

The average DL of all questions is 0.33 for the A tier, 0.28 for the R tier and 0.14 for B tier. These values indicate that the test was reasonably difficult and only those students with a good understanding of the problem are able to answer the questions correctly. Generally, the DL value of the R tier is lower than that of the A tier. This supports the finding uncovered by Caleon and Subramaniam (2010) that many students answer the A tier better than the R tier because in answering the A tier, students simply apply their content knowledge, but a good conceptual reasoning is required to answer the R tier correctly. Furthermore, the DL of the B tier is always the lowest of all three tiers. This trend implies that only students with a *genuine* understanding can answer both the A and R tiers correctly and consequently it can be inferred that the concept tested is not problematic.

4.2.2. Discriminatory Index (DI)

The discriminatory index (DI) represents the ability of an item to differentiate students on the basis of how well they understand the concept being tested. The higher the DI value, the better the question is in discriminating between high and low achieving students. The formula to calculate this parameter is presented in Chapter 2 and given below (Equation 4.2). The DI values of questions are presented in Table 4.2 below. DI values of the A tier, R tier and B tier ranged from *poor* to *good*, none of them was *excellent*.

Table 4.2. Discriminatory index (DI) of the Prototype FTDICK instrument

Question	Discriminatory Index (DI)		
	A tier	R tier	B tier
1	0.33	0.04	0.04
2	0.38	0.36	0.59
3	0.04	0.16	0.08
4	0.58	0.45	0.66
5	0.53	0.44	0.74
6	0.22	0.04	0.15
7	0.47	0.34	0.47
8	0.40	0.48	0.38
9	0.19	0.07	0.14
10	0.18	0.26	0.05
11	0.45	0.08	0.11
12	0.41	0.30	0.30
13	0.03	0.12	0.03
14	0.16	0.40	0.12
15	0.27	0.41	0.23
16	0.40	0.33	0.26
17	0.47	0.52	0.38
18	0.40	0.42	0.30
19	0.25	0.08	0.08
20	-0.03	0.08	-0.01
Mean	0.30	0.27	0.25

yellow = *good*
teal = *fair*
pink = *poor*
dark yellow = *unsuitable*

The formula for this parameter is

$$\text{Discriminatory index} = \frac{N_u - N_l}{\frac{1}{2}N}$$

Where, N_u = the number of students in the upper group who answer correctly
N_l = the number of students in the lower group who answer correctly
N = the total number of students who participated in this study

Equation 4.2 Equation for discriminatory index

In the A Tier, the percentage of questions that falls into the *poor* category is 10%, including Q3 and Q13. The DI values of these questions are almost the same (0.04 and 0.03 respectively). 30% of the questions fall in the *fair* category, including Q6, Q9, Q10, Q14, Q15 and Q19. Of these questions, Q15 has the highest value (0.27). 55% of questions fall into the *good* category, including Q1, Q2, Q4, Q5, Q7, Q8, Q16, Q17 and Q18. Of these questions, Q4 has the highest DI index of 0.58.

In the R Tier, the percentage of questions that falls into the *poor* category is 30%, including Q1, Q6, Q9, Q11, Q19 and Q20. 15% of the questions fall in the *fair* category, including Q3, Q10 and Q13. Of these questions, Q10 has the highest value (0.26). 55% of questions fall into the *good* category, including Q2, Q4, Q5, Q7, Q8, Q12, and Q14-Q18. Of these questions, Q17 has the highest DI index of 0.52.

In the B tier, the percentage of questions that falls into the *poor* category is 25%, including Q1, Q3, Q10, Q13, and Q19. 30% of the questions fall in the *fair* category, including Q6, Q9, Q11, Q14, Q15 and Q16. Of these questions, Q16 has the highest value (0.26). 40% of questions fall into the *good* category, including Q2, Q4, Q5, Q7, Q8, Q12, Q17 and Q18. Of these questions, Q5 has the highest DI index of 0.74.

40% of the questions, including Q2, Q4, Q5, Q7, Q8, Q12, Q17 and Q18 are categorized as *good* in each of the A, R and B tiers. This phenomenon indicates that these questions are reasonably able to discriminate between upper and lower ability students. Meanwhile, the rest of the questions have a DI category which differs between tiers. For instance, Q11 is categorized as *good* and *fair* for the A and B tiers respectively, but *poor* for the R tier. This phenomenon suggests that the reason options for this question need to be either revised or replaced. Q20 has negative indices of DI of -0.03 and -0.01 for the A and B tiers respectively. These indices show that the question is unsuitable in discriminating between high and low achieving students. The indices strongly suggest that the question should be revised or substituted.

However, when deciding whether a question should be revised or replaced by changing the answer or reason options, all parameters should be considered. In some circumstances, even a question with a poor DI still can be retained because the primary purpose of this instrument is to identify students' understanding instead of differentiating between high and low achieving students (Suruchi & Rana, 2014). The two parameters (DL & DI) confirm that including both the A and R tiers in the instrument is beneficial in identifying students' understanding of chemical kinetics.

4.2.3. Distractor effectiveness

This parameter is intended to provide students with an alternative incorrect answer or reason and so highlight students with a poorer understanding of the concept. Careful design of distractors is important as they should integrate common misconceptions as identified in the initial study. The distractor effectiveness values for each answer and reason are presented in Table 4.3 below which shows the percentage of students choosing each answer and reason. For example, the distractor indices for Q1 option A are 26.94 and 25.09 for the A and R tiers respectively. This means that 26.94% of all students selected answer A and 25.09% selected reason A.

Table 4.3. Values of distractor effectiveness (%) for the prototype FTDICK instrument

Question	**1**		**2**		**3**		**4**		**5**	
Option	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**
A	26.94	25.09	4.80	16.24	34.69	11.44	9.23	19.93	4.80	46.13
B	10.33	22.88	18.08	61.25	33.95	35.06	50.55	21.03	18.82	9.23
C	39.85	10.70	54.61	7.01	25.83	20.66	24.35	44.28	55.72	23.25
D	18.08	18.08	5.17		2.95	13.65	11.81	7.01	15.13	11.44
E						7.38				
F						1.48				
Question	**6**		**7**		**8**		**9**		**10**	
Option	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**
A	28.04	34.69	47.97	22.51	10.70	6.64	26.20	12.18	18.45	11.07
B	15.87	17.71	8.49	50.55	19.56	24.72	50.55	8.12	13.28	39.11
C	16.24	19.93	11.81	10.70	25.46	35.79	6.27	18.82	41.70	9.23
D	25.09	14.76	23.25		32.10	14.39	10.33	14.02	19.19	12.18
E								25.83		7.38
F								4.80		2.21
G										5.17
H										0.74
Question	**11**		**12**		**13**		**14**		**15**	
Option	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**
A	19.93	12.18	19.19	21.77	52.03	43.54	14.39	12.18	10.33	36.53
B	13.28	15.13	19.56	19.93	9.96	15.87	29.52	19.56	31.37	22.14
C	18.82	29.15	43.91	11.07	21.40	13.65	20.30	29.89	31.73	15.50
D	39.48	15.13	5.90	29.89	8.12	10.33	25.09	9.59	18.45	13.65
E		6.64						7.38		
F		1.48						2.95		
G		4.43								
Question	**16**		**17**		**18**		**19**		**20**	
Option	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**	**A tier**	**R tier**
A	20.30	19.93	19.19	27.31	24.35	27.31	6.27	25.09	36.90	7.38
B	36.53	15.50	28.41	18.82	19.19	19.19	39.85	31.37	18.82	18.82
C	12.55	17.71	16.97	30.63	12.92	21.03	31.73	19.19	16.61	19.56
D	17.34	27.68	21.40	4.43	28.04	11.07	4.80		11.81	18.82
E										8.12
F										5.90

Yellow font = distractor in the A tier selected by less than 5% students
Pink font = distractor in the R tier selected by less than 5% students

All of the answers and reasons were selected by some students which implies that these were all functional as stated by DiBattista and Kurzawa (2011). In total, 91.95% of the answer and reason options were selected by more than 5% of students. Separately, 95% of the answers in the A Tier and 89.36% of the reasons in the R tier were selected by more than 5% of students.

8.05% of answers in the A Tier were chosen by less than 5% of students, including Q2-A (Question 2, answer A), Q3-D, Q5-A and Q19-D. Of these questions, Q3-D has the lowest distractor effectiveness of 2.95%. The low value indicates that this answer (option D) is not suitable. This could explain why Q3 is not effective in distinguishing between high and low achieving students as shown by the low value of the DI for the question in the A tier of 0.04 (see Table 4.2). As a result, it was concluded that Q3 option D (A tier) should be revised.

10.64% of the reason options in the R Tier were selected by less than 5% of students, including Q3-F (Question 3, reason F), Q9-F, Q10-F, Q10-H, Q11-F, Q11-G, Q14-F, and Q17-D. Of these questions, Q10-H has the lowest percentage of 0.74% and Q10-F also has a low percentage of 2.21%. These low distractor effectiveness indices could also be a reason for the poor ability of Q10 in discriminating between high and low achieving students (see the DI values in Table 4.2). Again, it was concluded that these reason options should be revised.

4.2.4. Validity

Validity refers to whether the information obtained from a test represents the actual understanding of the examinees (Airasian, 1994; Allen & Yen, 2002). The validity index is shown by the value of the Pearson correlation (r_{xy}) coefficient. To determine whether an item or question is categorized as valid or not valid, the value of $r_{xy\text{-}calculation}$ of each item is compared with the critical value of r_{xy} coefficient. The higher the $r_{xy\text{-}calculation}$ value, the greater the validity. A high r_{xy} value therefore confirms that students' answers reflect their actual understanding. Table 4.4 below shows the validity of each item/question of the prototype FTDICK instrument with a significance level of 0.05. The critical value of r_{xy} coefficient in this calculation is 0.117. If the validity index is higher than this coefficient (0.117), students' correct answers to the questions in the FTDICK instrument reflect their actual understanding. Similarly, students' wrong answers to the questions in the FTDICK instrument reflect their actual misunderstanding.

Table 4.4. Validity of items in the prototype FTDICK instrument with a significance level of 0.05 using Pearson correlation

Question		1	2	3	4	5	6	7	8	9	10
A tier	r_{xy}	0.34	0.47	0.13	0.53	0.55	0.28	0.39	0.38	0.33	0.23
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
R tier	r_{xy}	**0.07**	0.41	0.21	0.46	0.45	0.09	0.41	0.47	0.18	0.30
	category	**Invalid**	Valid	Valid	Valid	Valid	**Invalid**	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.24	0.48	0.21	0.60	0.58	0.31	0.42	0.46	0.27	0.26
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Question		11	12	13	14	15	16	17	18	19	20
A tier	r_{xy}	0.43	0.44	0.14	0.29	0.29	0.40	0.36	0.38	0.28	**0.06**
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	**Invalid**
R tier	r_{xy}	0.15	0.27	0.14	0.39	0.45	0.39	0.47	0.50	0.17	0.19
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.35	0.36	0.17	0.20	0.33	0.39	0.50	0.48	0.24	**0.01**
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	**Invalid**

As shown in Table 4.4, most of the questions are valid. For the A tier, the only invalid question is Q20. This question is considered to be a *difficult* question as shown by the low value of the DL of 0.17. This fact shows that even high achieving students got into difficulty answering the question correctly. The question cannot discriminate well between students with a good understanding and students with a poor understanding as confirmed by the value of the DI of -0.03. The DI value even shows that the number of students who answered the question correctly from the lower ability group is slightly higher than from the higher ability group. This anomaly could be due to guesswork.

Q20 is also the only invalid question in the B tier, while Q1 and Q6 are the two invalid questions in the R tier. The role of guesswork could also be the reason for these phenomena as confirmed by the low values of DL and DI. The validity of tier B Q20 is the lowest of all the validity indices at a value of 0.01. This low validity is also supported by the negative value of the DI that strengthens the suggestion that guesswork plays a role here as found by Sreenivasulu and Subramaniam (2013). In some circumstances, students can only provide the correct answer and reason (A and R tiers) by guessing. The existence of guesswork emphasizes the importance of the confidence rating tier which is attached to this instrument.

4.2.5. Reliability

Reliability is the degree to which a test consistently measures whatever it sets out to measure. The reliability of the instrument as calculated by SPSS is depicted in Table 4.5 below.

Table 4.5. Reliability of the prototype FTDICK instrument using Cronbach Alpha

Reliability Statistic	FTDICK	A Tier	R tier	B tier
Cronbach alpha	0.85	0.59	0.55	0.65

The reliability of the prototype FTDICK instrument was 0.85 and falls into the *very good* category. The reliability of both the A and R tiers are 0.59 and 0.55 respectively. When both tiers are considered, the reliability is relatively higher at 0.65. The reliability of A and R tiers range in the *fair* category. This implies that some revisions in the A and R tiers are needed. Therefore, by considering other parameters, some answer and reason options were revised and even eliminated.

The table also shows that the reliability of the students' confidence rating is higher in the B tier than in the A or R tiers. This phenomenon is in line with the finding published by Caleon and Subramaniam (2010). It can be argued that students giving correct answers to both the A and R tiers simultaneously implies a good understanding of the concept. This result again demonstrates the importance of using both A and R tiers in assessing students' understanding. Validity and reliability, in particular, are the most important parameters in determining the quality of an instrument (Kimberlin & Winterstein, 2008) and results given here have shown that this prototype FTDICK instrument is both valid and reliable and can be used in the main study. However, several questions were revised and even replaced after considering the results of the item analysis comprehensively. For example, Q3 of the A tier and Q11 of the R tier also show low validity with r_{xy} of 0.13 and 0.15 respectively. These low validities are in agreement with the low values of DI and distractor effectiveness (see Tables 4.2 and 4.3). These observations highlighted questions to be revised or substituted. The revised prototype FTDICK instrument called the final FTDICK instrument is given in **Appendix G**. This final instrument was used for data collection in the main study.

4.3. CHAPTER SUMMARY

Several parameters were used to describe the quality of the prototype FTDICK instrument, including the difficulty level (DL), the discriminatory index (DI), distractor effectiveness, validity and reliability. This study revealed that the prototype FTDICK instrument is valid and reliable and can be used in the main study. However, some revisions to some specific questions in the instrument are needed. The revisions required are presented in Table 4.6 below.

Table 4.6 Summary of revisions to the prototype FTDICK

No.	Question	Part to be revised	Rationale	Revision
1.	Q1	Reason C	Very low validity	The redaction was revised, but the meaning kept
2.	Q2	Whole question	Highest DI index	New question
3.	Q3	Answer D; Reason A, D and F	- Answer D: ineffective distractor - Reason A: language consideration - Reason D: the statement is not a correct reason for the question, but is a correct statement in itself - Reason F: ineffective distractor	- Answer D: replaced - Reason A: small revision of the redaction - Reason D: eliminated - Reason F: eliminated
4.	Q4	No revision		
5.	Q5	No revision		
6.	Q6	Reason C	Low validity; Language consideration	redaction was revised but the meaning kept
7.	Q7	Reason D	More reasonable distractor	Replaced
8.	Q8	Whole question	To be equivalent with a pictorial question	New question
9.	Q9	No revision		
10.	Q10	Reason E, F, G, H	Very low distractor indices	Condensed as E and F
11.	Q11	Whole question	The same concept was covered by many other questions	New question
12.	Q12	No revision		
13.	Q13	Reason A, B, C and D	Low validity	redactions were revised but the meanings are kept
14.	Q14	Reason F	Ineffective distractor	Revised in redaction and meaning
15.	Q15	No revision		
16.	Q16	No revision		
17.	Q17	No revision		
18.	Q18	No revision		
19.	Q19	No revision		
20.	Q20	Reason C and E	Low validity	Redaction

The way in which these revisions improved the quality of the FTDICK instrument is discussed in the next chapter (Chapter 5).

CHAPTER 5

INVESTIGATING STUDENTS' UNSCIENTIFIC UNDERSTANDING USING THE FTDICK INSTRUMENT

5.1. THE FINAL FTDICK INSTRUMENT: ITEM ANALYSIS RESULTS

The final FTDICK instrument is an upgrade of the prototype FTDICK instrument. The prototype FTDICK instrument was administered to 271 Indonesian students from two universities. The complete results of item analysis of the prototype FTDICK instrument regarding difficulty level, discriminatory index, distractor effectiveness, validity and reliability have been discussed in Chapter 4. Based on those results, the prototype FTDICK instrument was revised. The revised prototype FTDICK instrument is named the final FTDICK instrument. The final FTDICK instrument was used for the main data collection. For simplification, from this point and beyond, the final FTDICK instrument will be known as the FTDICK instrument.

The FTDICK instrument was administered to 83 first year chemistry students, University of Reading, UK and 252 first year chemistry students at two Indonesian universities (State University of Malang and Haluoleo University). This subchapter describes the item analysis results of the FTDICK instrument and compares this with the item analysis results from the prototype one. The comparison between the two instruments is focused on their validity and reliability. Kimberlin and Winterstein (2008) stated that validity and reliability are the most important parameters in determining the quality of an instrument. In addition, the difficulty level, discriminatory index and distractor effectiveness are all useful in assessing the quality of an instrument being used to investigate the effectiveness of teaching and learning within a topic. In some circumstances a question with a poor DI can still be retained because the primary purpose of this type of instrument is to identify students' understanding rather than differentiating between high and low achieving students (Suruchi & Rana, 2014).

5.1.1 Validity

The validity of the FTDICK instrument was calculated by Pearson correlation using SPSS with a significance level of 0.05. Table 5.1 below shows the validity of each item/question of the FTDICK instrument.

Table 5.1. Validity of items of the FTDICK instrument with a significance level of 0.05 using Pearson Correlation

Question		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
A tier	r_{xy}	0.49	0.30	0.22	0.64	0.63	0.24	0.17	0.50	0.38	0.41
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
R tier	r_{xy}	0.50	0.43	0.25	0.48	0.61	0.29	0.38	0.57	0.41	0.40
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.50	0.41	0.27	0.68	0.71	0.30	0.37	0.65	0.51	0.40
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Question		Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
A tier	r_{xy}	**-0.03**	0.06	0.44	0.46	0.55	0.46	0.54	0.55	0.32	**-0.04**
	category	**Invalid**	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	**Invalid**
R tier	r_{xy}	0.11	0.24	0.35	0.38	0.60	0.51	0.60	0.58	0.23	0.31
	category	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.04	0.26	0.43	0.45	0.68	0.54	0.67	0.67	0.26	0.22
	category	**Invalid**	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

As shown in Table 5.1, most of the questions are valid except 3 items out of 60. These questions are: A tier Q11, B tier Q11 and A tier Q20. The lowest validity index is shown by the A tier Q20 with -0.04. A and B tiers indices of Q11 are also low with values of -0.03 and 0.04 respectively. These low validity indices fall in the *invalid* category. The total number of *invalid* items (3) in the FTDICK instrument is almost the same as the number of *invalid* items (4) in the prototype instrument. However, the validity index of the FTDICK instrument in each question is generally higher than the validity index of the prototype instrument. Figure 5.1 below depicts the validity index of the A tier in each instrument in each question.

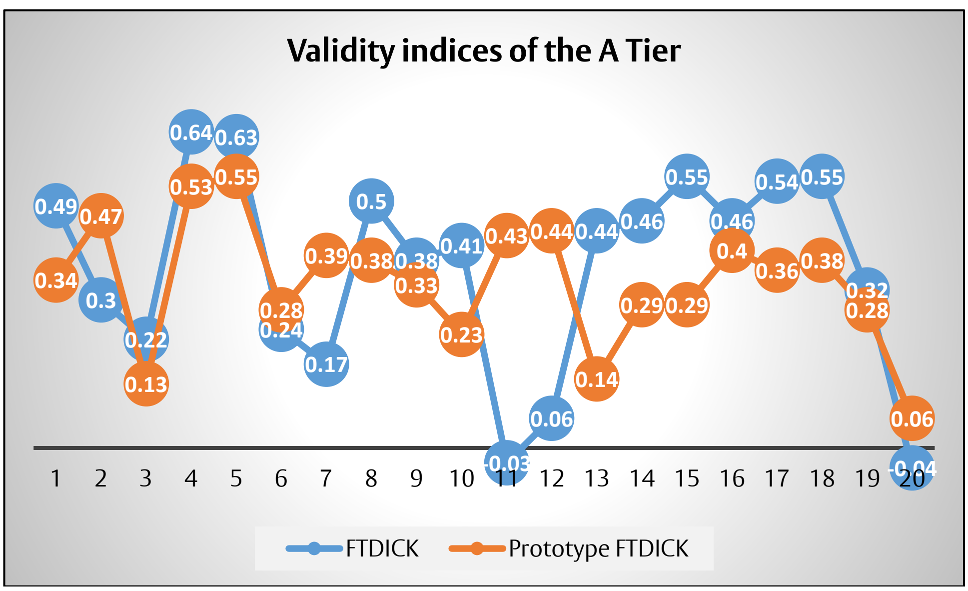


Figure 5.1. Validity indices of the FTDICK and the prototype FTDICK for the A tier

Figure 5.1 demonstrates that in the A tier, the validity indices of the FTDICK instrument (blue) are mostly higher than the validity indices of the prototype FTDICK (orange). 70% of the questions have higher validity indices in the final FTDICK rather than the prototype FTDICK. This is confirmed by the average validity index of the FTDICK (0.37) and the average of the prototype FTDICK (0.34). These averages are not significantly different, but still indicate that the quality of the FTDICK instrument is slightly higher than the prototype instrument.

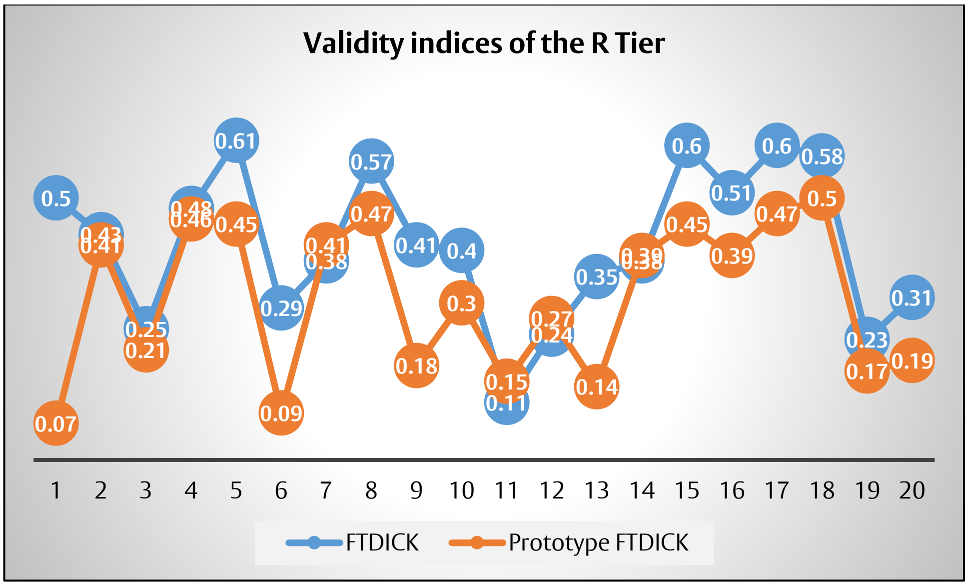


Figure 5.2. Validity indices of the final FTDICK and the prototype FTDICK for the R tier

Figure 5.2 demonstrates that in the R tier, the validity indices of the FTDICK instrument (blue) are mostly higher than the validity indices of the prototype FTDICK (orange). 75% of the questions have higher validity indices in the FTDICK compared to the prototype FTDICK. This is confirmed by the average validity index of the final FTDICK (0.41) and the average of the prototype FTDICK (0.31).

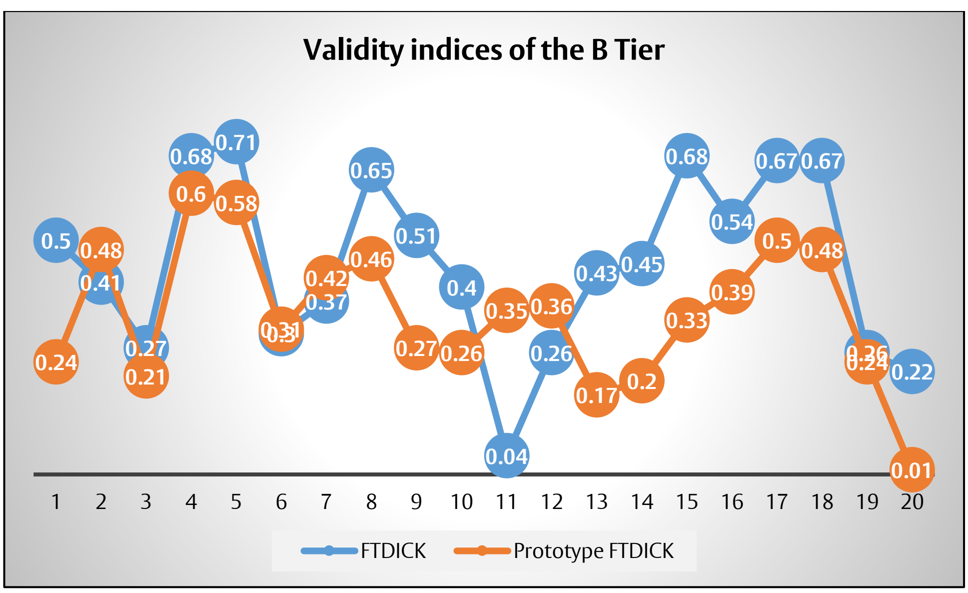


Figure 5.3. Validity indices of the final FTDICK and the prototype FTDICK for the B tier

Figure 5.3 demonstrates that in the B tier, the validity indices of the FTDICK instrument (blue) are mostly higher than the validity indices of the prototype FTDICK (orange). 75% of the questions have higher validity indices in the FTDICK compared to the prototype FTDICK. This is confirmed by the average validity index of the FTDICK (0.45) and the average of the prototype FTDICK (0.34). These results confirm that the validity index of the final FTDICK instrument is higher than the validity of the prototype one.

5.1.2 *Reliability*

Reliability is the degree to which a test consistently measures whatever it sets out to measure. The reliability of the instrument as calculated by SPSS using Cronbach Alpha is depicted in Table 5.2 below.

Table 5.2. Reliability of the final FTDICK instrument

Reliability Statistic	FTDICK	A Tier	R tier	B tier
Cronbach alpha	0.91	0.69	0.75	0.82

The reliability index of the FTDICK instrument is 0.91. The reliability index of the B tier is higher than those of the A or R tiers. This phenomenon is in line with the reliability of the prototype FTDICK and also with the study published by Caleon and Subramaniam (2010). This again emphasizes the importance of using the A and R tiers in assessing students' understanding.

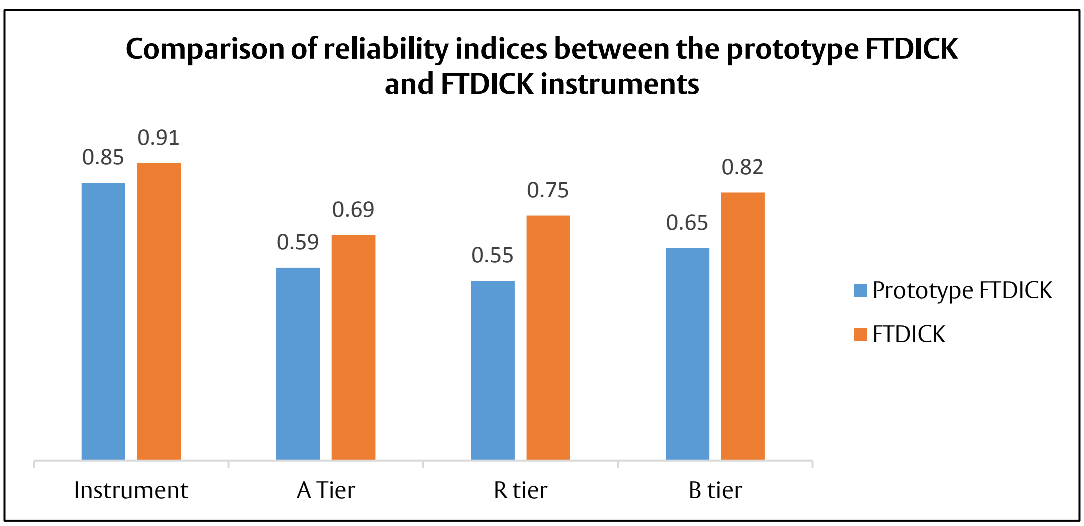


Figure 5.4. Reliability indices of the final FTDICK and prototype FTDICK instruments

The reliability indices of FTDICK instruments should always be higher than the reliabilities of the prototype ones in all tiers. The reliability of the FTDICK instrument (0.91) falls into the *excellent* category while the prototype FTDICK (0.85) in the *very good* category. The reliability indices of both the A and R tiers for the FTDICK instrument are 0.69 and 0.75 respectively and both fall into the *good* category. Meanwhile, the reliability indices of the prototype instrument both fall into the *fair* category. These results confirm that the reliability index of the FTDICK instrument is higher than the validity of the prototype one.

These results of validity and reliability imply that the FTDICK instrument is a valid and reliable instrument to investigate students' understanding of chemical kinetics. Therefore, the results uncovered using this instrument will be robust and represent the students' actual scientific understanding as well as their misconceptions, lack of knowledge and guesswork.

5.2. STUDENTS' CONFIDENCE RATINGS

The attachment of confidence ratings in this FTDICK instrument is intended to avoid misinterpreting students' misunderstandings or wrong answers. The values of confidence ratings (CR) determine how to categorise a student's incorrect answer and incorrect reason. By considering the CRs, students' incorrect answers and reasons can be categorized as *genuine* or *spurious* misconceptions. Further, *genuine* misconceptions are classified as *strong* and *moderate* misconceptions, while *spurious* misconceptions are classified as *weak* misconception, *lack of knowledge* and *guesswork*. In the same way, students' correct answers can also be categorized as actual scientific knowledge or *guesswork*. The detailed criteria of these categories have been presented in Chapter 2. Table 5.3 below gives a summary of students' CR when providing the wrong answer in the A, R and B tiers.

Table 5.3 below shows that many students hold unscientific ideas. From the "Popular wrong answer" column, *genuine* misconceptions can be seen to exist for most of the questions in the A tier except Q2, Q16 and Q19 which are classed as *spurious* misconceptions with the CR(TA) values of 2.67, 2.67 and 2.36 respectively. A similar trend is seen for the R and B tiers. In the R tier, *spurious* misconceptions are shown by Q7, Q8, Q10 and Q20 with CR(T_R) of 2.67, 2.57, 2.58 and 2.51 respectively. In the B tier, *spurious* misconceptions are only shown by Q2 and Q19 with CR(TB) of 2.28 and 2.56 respectively. Over half (55%) the questions show that students' confidence ratings when giving an incorrect answer in the A tier are higher than students' confidence ratings of the R and B tiers. Another 30% of questions show the highest confidence ratings on the B tier while the remaining 15% have the highest confidence rating in the R tier.

Most CR(TB) values are higher than 3.0, but in some cases, notably Q4, Q7 and Q16, the CR(TB) values are as high as 3.69, 3.64 and 3.64 respectively which implies a high degree of misunderstanding in the relevant concepts. The same trend is also exhibited in the A tier. The R tier shows a different trend. The number of CR(TR) values higher than 3.0 and the number lower than 3.0 are equal. Yet, those below 3.0 are generally still above 2.75 which implies a *genuine* misconception.

From the information in the column headed by 'wrong answer with the highest CR', the highest CR(TA) is shown by Q4 with a value of 3.97. The question with the highest confidence rating in the wrong reason is Q10 with CR(TR) of 3.34 and the question with the highest confidence rating in the B tier is also Q4 with CR(TB) of 3.79. These values show that some students harbour *strong* misconceptions around the concepts identified in the question. Most CR(TA) values are higher than 3.0 except those for Q2 and Q19, yet both still fall into the *genuine* misconception category. 70% questions also have CR(TR) values which are higher than 3.0. The same trend is shown by CR(TB). This implies a high degree of misunderstanding in the relevant concepts.

Table 5.3. Students' confidence ratings in the wrong answer

QUESTION	Popular wrong answer								
	A tier			R tier			B tier		
	Opt	%	CR(T_A)	Opt	%	CR(T_R)	Opt	%	CR(TB)
1	C	30.75	3.46	C	23.28	2.85	CE	8.96	3.38
2	D	13.43	2.67	C	17.31	2.81	DB	5.97	2.28
3	B	47.76	3.35	B	36.42	2.84	BB	22.09	3.13
4	C	32.54	3.84	B	26.57	3.15	CB	17.91	3.69
5	D	18.21	3.1	C	23.28	2.82	BC	35.22	2.75
6	A	40	3.43	A	41.19	3.3	AA	31.04	3.38
7	C	27.16	3.57	A	16.12	2.67	CB	17.01	3.64
8	A	27.16	3.05	B	25.07	2.57	AB	9.85	2.89
9	A	34.03	3.2	E	17.01	3.26	AA	7.76	3.02
10	A	17.91	3.3	A	11.94	2.58	AB	6.27	3.26
11	B	48.96	3.3	B	40	3.01	BB	25.07	3.11
12	B	45.97	3.3	A	33.43	3.02	BA	15.82	3.36
13	A	39.40	3.47	C	32.54	3.4	AC	19.10	3.7
14	C	22.39	3.29	B	25.67	3.2	CC	8.36	3.34
15	B	29.25	3.34	C	18.81	3.14	BC	8.96	3.35
16	C	14.33	2.67	B	20.30	3.12	DB	5.37	3.64
17	A	26.67	3.33	C	42.09	3.12	AC	17.91	3.63
18	A	31.64	3.35	B	22.99	2.88	AB	10.15	3.16
19	B	30.45	2.36	B	29.25	2.8	BC	9.55	2.56
20	A	45.67	3.15	C	28.96	2.51	AC	18.21	2.94

QUESTION	Wrong answer with highest CR								
	A tier			R tier			B tier		
	Opt	%	CR(T_A)	Opt	%	CR(T_R)	Opt	%	CR(TB)
1	C	30.75	3.46	B	16.12	2.96	CE	8.96	3.38
2	C	6.27	2.76	C	17.31	2.81	AB	5.07	2.29
3	D	1.19	3.5	C	20.30	3.15	AC	4.78	3.53
4	A	8.96	3.97	A	11.94	3.3	CA	5.67	3.79
5	D	18.21	3.1	D	10.75	3.25	BB	6.27	3.1
6	A	40	3.43	A	41.19	3.3	DA	2.09	3.71
7	C	27.16	3.57	C	15.52	2.9	CB	17.01	3.64
8	A	27.16	3.05	C	21.49	2.69	AB	9.85	2.89
9	A	34.03	3.2	D	14.03	3.28	AE	6.57	3.18
10	A	17.91	3.3	E	9.55	3.34	DE	4.78	3.44
11	A	24.48	3.51	B	40	3.01	AA	10.75	3.38
12	B	45.97	3.3	A	33.43	3.02	BA	15.82	3.36
13	A	39.40	3.47	C	32.54	3.4	AC	19.10	3.7
14	C	22.39	3.29	B	25.67	3.2	CD	6.27	3.36
15	B	29.25	3.34	C	18.81	3.14	BD	7.46	3.4
16	D	13.43	3.51	B	20.30	3.12	DB	5.37	3.64
17	D	25.67	3.36	C	42.09	3.12	AC	17.91	3.63
18	A	31.64	3.35	B	22.99	2.88	AD	7.76	3.17
19	D	9.25	2.97	B	29.25	2.8	DC	2.09	3.21
20	A	45.67	3.15	E	10.45	3.06	AD	7.16	2.96

% = the percentage of all students who participate in this study; CR = confidence rating

Other variables relating to students' confidence ratings that are used to explore students' levels of understanding are depicted in Table 5.4 below. The variables/parameters were also calculated in order to give supportive information in determining the level of students' understanding. CF (mean confidence) describes the average of students' confidence ratings in each question. This parameter is calculated based on the total of students' confidence ratings divided by the total number of students. CFC describes the confidence of students when they gave correct answers.

This parameter is calculated based on the average of students' confidence ratings who gave the correct answer. CFW describes the confidence of students when they gave wrong answers. This parameter is calculated based on the average of students' confidence ratings giving the wrong answer. CDQ (the confidence discrimination quotient) describes whether the participants can discriminate between what they know and what they do not know. The formula to calculate this variable is (CDQ = CFC-CFW/ standard deviation of confidence).

Table 5.4. The values of confidence variables per item of the FTDICK instrument

A Tier												
Que	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***		
CF	3.38	3.14	3.22	3.91	3.34	3.23	3.25	2.83	3.28	3.01		
CFC	3.81	3.54	3.18	4.09	3.73	3.71	3.41	3.16	3.54	3.18		
CFW	3.20	2.35	3.23	3.75	2.72	3.12	3.11	2.55	3.02	2.83		
CDQ	0.56	0.86	-0.04	0.32	0.86	0.50	0.22	0.50	0.49	0.32		
R Tier												
Que	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***		
CF	2.84	2.59	2.70	3.10	3.19	2.98	2.83	2.55	2.98	2.79		
CFC	3.21	3.11	2.91	3.45	3.78	3.33	3.21	2.93	3.21	3.20		
CFW	2.68	1.86	2.66	2.79	2.54	2.89	2.25	2.32	2.87	3.68		
CDQ	0.51	1.03	0.22	0.59	1.03	0.39	0.79	0.55	0.32	**-0.46**		
B Tier												
Que	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***		
CF	3.11	2.87	2.96	3.51	3.27	3.11	3.04	2.69	3.13	2.90		
CFC	3.66	3.61	3.08	3.88	3.92	3.57	3.46	3.20	3.51	3.31		
CFW	3.02	2.29	2.94	3.31	2.70	3.05	2.87	2.49	3.02	2.74		
CDQ	0.63	0.96	0.12	0.53	0.95	0.43	0.46	0.59	0.47	0.51		
A Tier												
Que	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***Mean***	***SD***
CF	3.18	3.10	3.32	3.45	3.20	3.07	3.18	3.11	2.52	2.75	**3.17**	0.28
CFC	3.14	3.18	3.45	3.93	3.64	3.42	3.20	3.32	2.85	3.12	**3.43**	0.32
CFW	4.17	4.04	4.41	4.66	4.26	4.54	4.49	4.29	3.39	3.44	**3.58**	0.73
CDQ	-0.87	-0.72	-0.81	-0.64	-0.54	-0.95	-1.06	-0.81	-0.42	-0.24	**-0.12**	0.65
R tier												
Que	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***Mean***	***SD***
CF	2.67	2.60	2.99	3.02	3.05	2.94	2.96	2.63	2.31	2.45	2.81	0.24
CFC	2.90	2.83	3.13	3.33	3.70	3.47	3.33	3.11	2.81	2.75	3.19	0.28
CFW	3.37	3.39	4.07	4.08	3.85	3.80	3.88	3.34	2.88	3.07	3.11	0.64
CDQ	**-0.43**	**-0.49**	**-0.84**	**-0.68**	**-0.14**	**-0.27**	**-0.48**	**-0.21**	**-0.06**	**-0.26**	0.06	0.57
B tier												
Que	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***Mean***	***SD***
CF	2.92	2.85	3.16	3.23	3.12	3.00	3.07	2.87	2.42	2.60	2.99	0.24
CFC	2.82	3.24	3.42	3.77	4.02	3.73	3.38	3.25	3.08	3.20	3.46	0.32
CFW	2.93	2.81	3.09	3.08	2.77	2.67	2.97	2.75	2.34	2.58	2.82	0.26
CDQ	**-0.09**	0.39	0.27	0.60	0.95	0.84	0.35	0.41	0.59	0.46	0.52	0.27

Several impressive trends in students' confidence ratings are reflected in Table 5.4. For the A tier, most CF values are higher than 3.0. In total, students demonstrate a *moderate* confidence rating as shown by the mean value of CF of 3.17. This *moderate* confidence is consistent with the *fair* category of the DL of the A tier (0.38) as presented in Appendix J. For the R tier, many CF values are lower than 3.0, but generally still in the *moderate* category (i.e. higher than 2.75). The mean value of CF (2.81) also confirms that students' confidence ratings when answering questions fall into the *moderate* category. This *moderate* confidence is consistent with the *fair* category of the DL of the R tier (0.34) as presented in Appendix J. A different trend is reflected in the mean CF of the B tier (2.99) which falls into the *moderate* category. However, the DL values of the B tier fall into the *difficult* category. This *moderate* confidence is not consistent with the *difficult* category of the DL of the B tier (0.22) as presented in Appendix J. These phenomena indicate that in general students' confidence ratings are consistent with the DL of the question.

This consistency is also revealed when individual questions are considered separately. For the A tier, the CF values of 60% of the questions demonstrate a *moderate* students' confidence rating. These are equivalent to DL values for these questions that fall into the *fair* category. Meanwhile, the remaining questions show no correlation between students' confidence ratings and the DL values. For instance, the DL of Q20 falls into the *difficult* category, but students' confidence rating for this question falls into the *moderate* category. In this A tier, the number of questions which are consistent with the DL level is higher than the number of the inconsistent questions. This phenomenon implies that students' confidence ratings in the A tier have a positive correlation with the DL of the question.

For the R tier, the CF values of 70% of the questions are equivalent to the DL values of the questions. Q2, Q19 and Q20 were considered *difficult*. These are equivalent to CF values that fall into the *weak* category. This also implies that students' confidence ratings in the R tier have a positive correlation with the DL of the question.

This correlation is only shown by 40% of the questions in the B tier. CF values of 60% of the questions in the B tier are inconsistent with the DL values of the questions. This implies that in some circumstances, students' confidence ratings are independent of the DL of questions which is a surprising finding. However, in consideration of the higher number of consistent questions in all tiers over inconsistent questions, the conclusion that students' confidence rating has a positive correlation with the DL level is still persistent.

Students' confidence ratings when giving the correct answer, as depicted by CFC values, also show some interesting trends. The mean values of CFC for each tier exhibit a *moderate* confidence of students when giving a correct answer. For the A tier, all CFC values fall into the *moderate* category except for Q4. In Q4, students exhibit a *strong* confidence with CFC of 4.09. The same trend is also shown by the CFC values of the R tier. Yet those values are generally slightly lower than the CFC values of the A tier. The

CFC values of the B tier are generally the highest among the tiers. Q15 in this tier has a high CFC value of 4.02 and falls into the *strong* category. This trend shows students' deep understanding in responding to the questions and also implies that the level of students' confidence rating doesn't depend on the difficulty of the questions, but on the understanding of the concepts.

Students' confidence ratings when providing an incorrect answer as depicted by the mean score of CFW for each tier also fall into the *genuine-moderate* category. However, when each question is considered separately, several trends are revealed. For the A tier, the CFW values of 40% of the questions including Q11, Q12, Q13, Q14, Q15, Q16, Q17 and Q18 fall into the *genuine-strong* category with CFW of 4.17; 4.04; 4.41; 4.66; 4.26; 4.54; 4.49 and 4.29 respectively. These *high/strong* confidence ratings when providing an incorrect answer imply a misconception (Sreenivasulu & Subramaniam, 2013, 2014). *Spurious-weak* categories are shown in Q2, Q5 and Q8 with CFW of 2.35, 2.72 and 2.55 respectively.

For the R tier, the CFW values of Q13 and Q14 fall into the *genuine-strong* category with CFW of 4.07 and 4.08 respectively. *Spurious-weak* categories are shown in Q1, Q2, Q3, Q5 and Q7 with CFW of 2.68, 1.86, 2.66, 2.54 and 2.25 respectively. For the B tier, the CFW values of Q2, Q5, Q8, Q10, Q16, Q19 and Q20 fall into the *spurious-weak* category. As with the former trend, students' CFW values don't have a positive correlation with the DL values. This fact indicates that students' misconceptions can exist even within easy questions. Students' misconceptions will be discussed in detail in the next section.

Another variable that describes students' confidence ratings is CDQ. This variable represents students' ability to distinguish between what they know and what they do not know (Caleon & Subramaniam, 2010). The mean value of CDQ for the A tier is -0.12. This implies that on average students are more confident when they give the wrong answer than the correct answer. This confirms some published findings by Caleon and Subramaniam (2010). When each individual question is considered separately, 55% of questions demonstrate negative CDQ values and support the previous finding. The most negative value is shown by Q17 with CDQ of -1.06. The remaining questions have positive CDQ values that range from 0.22 to 0.86.

In the R tier, 55% of the questions including Q10 – Q20 also have negative CDQ values which ranged from -0.84 to -0.06. The remaining questions have positive CDQ values that range from 0.22 to 1.03. Meanwhile, the mean CDQ value of the R tier is positive but small (0.06). This implies that, on average, students' confidence ratings when giving the correct reason are almost equal to their confidence when giving the wrong reason. In the B tier, only Q11 has a negative CDQ value of -0.09. Meanwhile, the remaining 19 questions have positive CDQ values ranging from 0.12 to 0.96. The mean CDQ value of this tier is positive and quite large with a value of 0.52. This implies that students are more confident when giving the correct answer and reason simultaneously rather than giving the wrong answer and reason simultaneously.

5.2.1 Students' confidence ratings in the A and R tiers

Students' confidence ratings in the A and R tiers as depicted in Table 5.5 confirm the difference between students' confidence levels in those tiers. Although the mean values of both CR(TA) and CR(TR) fall into the *moderate* category, the CR(TA) value is higher. In addition, the mean values of CF and CFC for the A tier are also higher than those for the R tier. This confirms that generally students found it more difficult to answer the R tier correctly than to answer the A tier as the A tier requires students to apply content knowledge while the R tier requires them to use scientific reasoning to answer correctly (Caleon & Subramaniam, 2010; Sreenivasulu & Subramaniam, 2013, 2014).

Table 5.5. The average confidence ratings of the A and R tiers of the FTDICK instrument

	Confidence Rating			**Confidence Rating**		**Average**	
Question	**A tier, CR(TA)**	**R tier, CR(TR)**	**Question**	**A tier, CR(TA)**	**R tier, CR(TR)**	**A tier, CR(TA)**	**R tier, CR(TR)**
1	3.4	2.9	**11**	3.3	2.9	**3.3**	**3.0**
2	3.3	3	**12**	3.2	2.8		
3	3.3	2.9	**13**	3.4	3.2		
4	4	3.3	**14**	3.6	3.2		
5	3.5	3.4	**15**	3.4	3.3		
6	3.4	3.1	**16**	3.2	3.1		
7	3.3	3.1	**17**	3.2	3.1		
8	3	2.8	**18**	3.2	2.9		
9	3.3	3.1	**19**	2.7	2.7		
10	3.1	3	**20**	2.9	2.7		

5.2.2 Students' general confidence

Along with the prototype FTDICK instrument, students' general confidence in chemistry, physical chemistry and in chemical kinetics, was also surveyed. This is intended to explore the correlation between students' general confidence in chemistry and students' confidence rating when answering the FTDICK instrument. Table 5.6 below shows the students' general confidence in chemistry, physical chemistry and chemical kinetics.

Table 5.6. General confidence in chemistry (N=335)

Area of Chemistry	Confidence mean	SD
Chemistry in general	3.70	0.9
Physical chemistry	3.12	0.83
Chemical kinetics as compared to other areas of chemistry	3.31	0.83
Chemical kinetics as compared to other areas of physical chemistry	3.39	0.81

The table shows that students have a *moderate* confidence in chemistry overall as shown by the mean score of 3.70. Students' confidence rating in physical chemistry modules is lower and the lowest among the four areas polled with a mean value of 3.12. Students also demonstrated a high confidence in chemical kinetics as reflected by the mean value of students' confidence in this topic (3.31) compared to other topics in physical chemistry (3.39).

The values between students' general confidence as presented in Table 5.6 and students' confidence ratings in the A and R tiers as presented in Table 5.5 are close and all fall into the *moderate* category. This implies that students' general confidence in chemistry, in physical chemistry and chemical kinetics has a positive correlation with students' confidence ratings when answering the questions of the FTDICK instrument. The statistics test using SPSS confirms the correlation between variables as presented in Table 5.7.

Table 5.7. The correlation between students' general confidence & confidence rating in the FTDICK instrument

Correlation				
		A_tier	R_tier	B_tier
GCh	Pearson Correlation	0.469**	0.363**	0.388**
	Sig. (2-tailed)	0.000	0.000	0.000
	N	306	306	305
PCh	Pearson Correlation	0.342**	0.319**	0.326**
	Sig. (2-tailed)	0.000	0.000	0.000
	N	304	304	303
CKo	Pearson Correlation	0.355**	0.304**	0.320**
	Sig. (2-tailed)	0.000	0.000	0.000
	N	303	303	302
CKp	Pearson Correlation	.343**	.309**	.349**
	Sig. (2-tailed)	.000	.000	.000
	N	303	303	302
	**. Correlation is significant at the 0.01 level (2-tailed).			

GCh: General Chemistry

PCh: Physical Chemistry

CKo: Chemical Kinetics and other topics

CKp: Chemical kinetics and other physical chemistry topics

Table 5.7 shows the correlation between students' confidence in chemistry, physical chemistry & chemical kinetics and students' confidence in answering the FTDICK instrument using Pearson correlation. The Pearson correlation indices show that students' general confidence has a positive correlation with the students' confidence rating in the A, R and B tiers. Among the tiers, the strongest correlation is shown between students' general confidence in chemistry (GCh) and students' confidence in the A tier with a Pearson correlation index of 0.47. These results confirm that students who are confident in chemistry tend to have confidence in answering the prototype FTDICK instrument. Furthermore, students' general confidence is significantly correlated with students' confidence in all tiers as reflected by the significant value of the Pearson correlation of all tiers that are less than 0.01. This finding is in keeping with the one published by Nicoll and Francisco (2001). They found that students holding a high confidence of their own ability in general also hold a positive belief in their success in chemistry. In the same way, students who do not have confidence in their own ability in general are also not confident of success in their chemistry course (Nicoll & Francisco, 2001). Nicoll and Francisco (2001) also revealed that students' confidence in their own ability does not have a positive correlation with their performance in physical chemistry.

5.3. STUDENTS' MISUNDERSTANDINGS IN CHEMICAL KINETICS

Students' misunderstandings in chemical kinetics were investigated using the FTDICK instrument (Appendix G). The study involved 335 students from the University of Reading, State University of Malang and Haluoleo University. Students' misunderstandings are revealed based on students' wrong answers in the A tier, students' wrong reasons in the R tier and importantly students' combined wrong answers and wrong reasons in the B tier. The misunderstandings revealed are classified as *genuine* and *spurious* misconceptions. These classifications refer to the value of students' confidence ratings in their answers in the A tier (CR(TA)), the R tier (CR(TR)), and the B tier (CR(TB)). *Genuine* misconception is attributed to an incorrect answer, an incorrect reason and an incorrect combination[1] with $CR \geq 2.75$. *Spurious* misconception is attributed to a student's incorrect answer and incorrect reason. *Spurious* misconception is attributed to an incorrect answer, an incorrect reason and an incorrect combination with $2<CR< 2.75$. In addition, *lack of knowledge* and *guesswork* are attributed to an incorrect answer, an incorrect reason and an incorrect combination with $CR <2$. The complete criteria for this categorization have been presented in Chapter 2. To provide a detailed and complete insight into students' misunderstanding of chemical kinetics, students' answers to each question were analysed and are presented below.

[1] Either or both answer and reason were incorrect

5.3.1. Question 1

The purpose of this question is to identify students' understanding of how the concentration of a first-order reactant changes for every successive half-life in a first-order reaction. This particular phenomenon is a fairly basic one within chemical kinetics.

A 64 mg sample of radioactive material decays by first-order reaction. After 10 minutes two half-lives have passed. What is the mass of sample that remains after 15 minutes?

A. 24 mg B. 23 mg C. 16 mg **D. 8 mg**

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. After 10 minutes, half of the initial sample remained
B. The rate of decay of this sample is a constant
C. For each successive half-life, the mass change of sample is a constant
D. The rate of decay of this sample increases as the mass of sample decreases
E. For each successive half-life, the mass of sample decreases by a factor of 2

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.5 Question 1

29.25% students answered this question correctly (A tier) with CR(TA) of 3.8. The same proportion of students (29.25%) gave the correct reason with CR(TR) of 3.2. For the B tier, 14.03% students gave the correct combination[2] with CR(TB) of 3.66. The difficulty level of the question was considered to be *difficult* with a DL of 0.29. Taking into account the confidence ratings in all the tiers, students' scientific understanding falls into the *moderate* category. Students' scientific understanding category describes how confident students are in their correct answer and correct reason. A correct answer and a correct reason which are associated with a high CR mean that students have a good understanding of the concept and have not used *guesswork*.

Most popular wrong answer and wrong reason

Option C (16 mg) is the most popular wrong answer. It was chosen by 30.74% students with a CR(TA) of 3.5. Reason C was also the most popular wrong reason and was selected by 23.28% students with CR(TR) of 2.89. The value of CR(TR) is sufficient to categorize the wrong reason as a *genuine* misconception and falls into the *moderate* category.

Wrong answer- correct reason (WACR) combination

Of students selecting the correct reason (E) but wrong answer, option C is the most preferred wrong answer and was selected by 8.96% of students with CR(TB) of 3.38. In order to obtain this answer students must have considered that in every 10 minutes the

[2] Correct combination; correct answer and correct reason

sample decreased by 32 mg. Another WACR combination is Q1-AE[3] and was selected by 4.48% students with CR(TB) of 3.23. Those students probably consider every 10 minutes the sample decreased by a half of the preceding mass. Both misunderstandings fall into the *moderate_false negative* category. This shows these students have a poor understanding of successive half- lives in a first-order reaction.

Correct answer- wrong reason (CAWR) combination

Of those students selecting the correct answer (D) but the wrong reason the most popular wrong reason was "B", (*the rate of decay of a first order reactant is constant)*. This CAWR combination was selected by 6.87% of all students and 46.94% of students having this combination. This could be caused by students thinking that because the time for successive half-lives of a first-order reactant is a constant, the rate of decay must also be constant. This could be because students often don't have a good understanding of chemical kinetics terminology. The word 'constant' may be the one they remember. The high CR(TB) of 3.22 associated with this reason is sufficient to categorize it as a *genuine* misconception which falls into the *moderate_false positive* category.

5.67% of all students and 38.78% of students having this CAWR combination selected reason C with CR(TB) of 3.26. This suggests these students have the same misconception as those who selected reason B. This is a *genuine* misconception that falls into the *moderate_false positive* category and strengthens the argument that a misunderstanding of chemical kinetics' terminology is often a source of misconception.

Wrong answer- wrong reason (WAWR) combination

The most popular WAWR combination is Q1-AA and was selected by 8.96% of students with CR(TB) of 2.78. To obtain this answer students probably considered that the sample decreased by a half of its preceding mass every 10 minutes. Rather than being a misconception, this wrong answer could be accounted for by a lack of knowledge of the concept of successive half-lives. This combination could be the result of an educated guess.

Another WAWR combination is Q1-CA which was selected by 5.97% of students with CR(TB) of 3.1. Those students believed that the first half-life and the second half-life are the same concept. The high value of their confidence rating strengthens this analysis. This is a typical misconception caused by a misunderstanding of chemical kinetics'

[3] Question 1-Anwer A; Reason E. The same interpretation as other similar combinations such as Q1-CA, Q4-CB

terminology as already discussed. The high confidence rating of this combination confirms it as a *genuine* misconception which falls in the *moderate* category.

Q1-BA[4] was selected by 3.88% students with CR(TB) of 3.0. This *genuine* misconception falls in the *moderate* category. This misunderstanding is in line with the misconception found by students who selected Q1-CA in which, by using simple logic, they assumed that every 10 minutes the sample decreases by 32 mg. However, students who gave this combination (Q1-BA) probably used the equation $ln\,[A] = ln[A]_0 - kt$ to answer the question. The preference for using an equation to solve numerical chemical problems is common for Indonesian students.

Q1-CD is another wrong combination and was selected by 2.99% of students with CR(TB) of 2.55. This *spurious* misconception falls into the *weak* category and is in opposition to the scientific principle that the rate of a first-order reaction decreases as the concentration decreases. This finding is consistent with other previous studies, such as those published by Cakmakci, Leach, and Donnelly (2006), Cakmakci (2010), Calik, Kolomuc, and Karagolge (2010), Tastan, Yalçinkaya, and Boz (2010), (Kolomuç & Tekin, 2011), and Yalçınkaya, Taştan-Kırık, Boz, and Yıldıran (2012).

5.3.2. Question 2

The purpose of this question is to investigate students' mathematical ability when calculating the time needed for a zero-order reactant to drop to a certain concentration using the integrated rate law equation.

In a reaction represented by K → L + M the integrated rate expression is given by: $[A]_t = [A]_0 - kt$. At the start of the reaction the concentration of K is 0.8 mol dm^{-3}. If the value of the rate constant is 2 mol dm^{-3} s^{-1} determine the time taken for the concentration of K to drop to 0.4 mol dm^{-3}.

A. 0.1 *s* **B. 0.2 *s*** C. 0.35 *s* D. 0.4 *s*

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The concentration of K at its half-life is twice its initial concentration
B. The concentration of K at its half-life is a half of its initial concentration
C. The concentration of K at its half-life is same as its initial concentration

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.2 Question 2

This question was answered correctly (A tier) by 66.57% students with CR(TA) of 3.5. 58.51% students gave the correct answer in the R tier with CR(TR) of 3.1. For the B tier, 43.88% students provided the correct combination[5] with CR(TB) of 3.61. The difficulty

[4] Question 1-Anwer B; Reason A. The same interpretation as other similar combinations such as Q1-CA, Q4-CB

[5] Correct combination: correct answer – correct reason (CACR)

level of the question was *fair* with a DL of 0.57. The confidence ratings in all tiers suggest that students' scientific understanding falls into the *moderate* category.

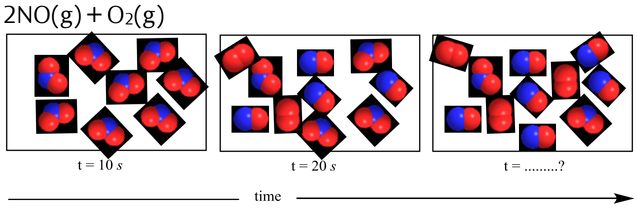
Most popular wrong answer and wrong reason

Option D (0.4 *s*) is the most popular wrong answer and was chosen by 13.43% students with a CR(TA) of 2.7. Reason C was the most popular wrong reason and was selected by 17.31% with CR(TR) of 2.8. The integrated rate law to solve this type of question was provided. By doing an appropriate selection and substitution, students could be expected to answer the question correctly. Students' errors in doing simple mathematical calculations could be the reason for their incorrect answers. This is in line with the work of Chairam, Somsook, and Coll (2009) who found that many 1st year students in Thailand showed inability in doing a calculation regarding reaction rate. In addition, misconceptions regarding the dependence of reaction rate on the concentration could also be the reason for students' incorrect reasons. However, as stated above, this question focused on students' ability to use mathematical operations in solving chemical problems. Students' understanding of the concept is explored further in Q3.

5.3.3. Question 3

The purpose of this question is to identify students' understanding of successive half-lives in a second-order reaction. This question is displayed pictorially here and Q11 is equivalent but presented in algorithmic format.

The decomposition of nitrogen dioxide to nitric oxide and oxygen at a certain temperature is shown pictorially below and is a second order reaction and the equation for the reaction is: $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$



The time at the final representation shown above is…

A. 25 *s* B. 30 *s* **C. 40 *s*** D. 50 *s*

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The value of each successive half-life is half the preceding one
B. The value of t½ is constant
C. The rate of disappearance of this sample increases with decrease in concentration
D. **The value of each successive half-life is twice the preceding one**

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.3 Question 3

For the A tier, this question was answered correctly by 25.97% students with CR(TA) of 3.2. For the R tier, 16.12% students gave the correct reason with CR(TR) of 2.9. For the B tier, 10.75% students provided the correct answer and reason with CR(TB) of 3.08. The difficulty level of the question was *difficult* with a DL of 0.18. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Option B (30 s) is the most popular wrong answer and was chosen by 47.76% students with a CR(TA) of 3.35. In order to obtain Answer B students have assumed that this is a first-order reaction and the half-life is constant. This popular wrong answer is consistent with the most popular wrong reason which is reason B "the value of the half-life is constant". This reason was selected by 36.42% students with CR(TR) of 2.84. The consistency between the selected wrong answer and selected wrong reason means that the conceptual relevance between the answer and reason is plausible. As shown above, students believed that the value of the half-life of a second-order reaction is constant. Due to this incorrect belief, those students assumed that the final half-life is also reached in 10 minutes using the same previous half-life. As a result, those students selected answer B (30 *s*).

Wrong answer- correct reason (WACR) combination

Q3-BD was selected by 2.99% students with CR(TB) of 3.35. In order to obtain Answer B students must assume that this is a first-order reaction and the half-life is constant. This suggests students are familiar with the concept of a constant half-life in a first-order reaction but are not familiar with half-lives in reactions with different orders. This misunderstanding falls into the *moderate_false negative* category.

Correct answer- wrong reason (CAWR) combination

Of those students selecting the correct answer (C) but wrong reason, Q3-CB was selected by 7.46% students with CR(TB) of 2.9. Q3-CC was also selected by 4.18% of all students and 46.94% of students having this combination with CR(TB) of 3.57. This CAWR combination implies that students assumed the rate of a 2^{nd} order reaction increases with decrease in concentration. This wrong assumption is at odds with the time needed to arrive at the final representation/half-life which is 20 second. This time is clearly longer than the time needed to arrive at the previous half-life which is 10 second. This *moderate_false positive* misconception could be caused by confusing terminology between reaction rate or reaction time.

Wrong answer- wrong reason (WAWR) combination

Students who selected Q3-AC (4.78%) and Q3-BC (10.75%) must have the misconception that the rate always increases with a decrease in concentration. The values of CR(TB) for the combinations are 3.53 and 3.01 respectively and confirm that this misconception is *genuine* and falls in the *moderate* category. This typical misconception could be explained by students' confusion between the concept of reaction rate and reaction time. Students' confusion between these concepts has been revealed by Cakmakci et al. (2006), Cakmakci (2010), Calik et al. (2010), Tastan et al. (2010), Kolomuç and Tekin (2011), and Yalçınkaya et al. (2012).

Q3-AB was also selected by a significant number of students (6.87%) with CR(TB) of 2.7. This combination demonstrates that the relationship between the answer and reason is unclear. If students firmly believed that the value of each successive half-life is constant, 30 seconds should be the correct answer. Q3-AA was selected by 8.36% with CR(TB) of 2.84. Answer A is obtained by assuming that each successive half-life is half the preceding one. This misunderstanding falls in the *moderate* category.

5.3.4. Question 4

The purpose of this question is to identify students' ability to express the rate law when given the stoichiometric equation for the reaction.

The second order reaction of $H_2O_2(aq) + 3I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_3^-(aq)$ is first order in H_2O_2, first order in I^- and zero order in H^+. The rate law expression for this reaction is....

A. $Rate = k\,[H_2O_2]\,[I^-]^3\,[H^+]^2$

B. $Rate = k\,[H_2O_2]\,[I^-]$

C. $Rate = k\,\frac{[H_2O]^2\,[I_3^-]}{[H_2O_2]\,[I^-]^3\,[H^+]^2}$

D. $Rate = k\,[H_2O_2]^x\,[I^-]^y\,[H^+]^z$ (x,y,z are $\neq 0$)

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The values of the exponents in the rate law are obtained from the coefficients in the balanced equation
B. The rate law is expressed based on the law of mass action that describes the relationship between the concentrations of the reactants and products.
C. The values of the exponents in the rate law are based on the order of the reactants which are determined experimentally
D. The information which is provided in the question is inadequate to determine the rate law.

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.4 Question 4

For the A tier, this question was answered correctly by 48.66% students with CR(TA) of 4.1. For the R tier, 47.76% students selected the correct reason with CR(TR) of 3.5. For the B tier, 35.22% students provided the correct answer and reason combination with CR(TB) of 3.88. The difficulty level of the question was considered *fair* with a DL of 0.44.

The CRs suggest that students' scientific understanding falls into the *moderate* category in general and the *strong* category for the A tier.

Most popular wrong answer and wrong reason

Option C is the most popular wrong answer and was selected by 32.54% students with CR(TA) of 3.84. Option B is the most popular wrong reason and was selected by 26.57% students with CR(TR) of 3.15. The most popular wrong answer is consistent with the most popular wrong reason. These show students' confusion between the law of mass action and the rate law.

Wrong answer- correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, Q4-CC was selected by the highest number of students (5.9%) with CR(TB) of 2.9. Q4-DC was also selected by 4.48% students with CR(TB) of 3.7. Both misconceptions are *genuine* and fall into the *moderate_false negative* category.

Correct answer- wrong reason (CAWR) combination

Among students providing this combination, Q4-BB is the most preferred and was selected by 6.27% of students with CR(TB) of 3.43. This CAWR combination is also a result of confusion about the law of mass action.

Wrong answer- wrong reason (WAWR) combination

Selection of Q4-AA by 2.99% students indicates a *genuine* misconception in that the power of the reactants in the rate law is equal to the stoichiometric coefficients in the balanced equation. With a high CR(TB) of 3.65, it is clear that those students are not aware that the relationship between rate, concentration and order of reactant must be determined experimentally. This misconception falls in the *moderate* category. A possible reason for this phenomenon is that examples of rate laws given in chemical kinetics' teaching often do align with the coefficients in the balanced equation. This could lead to the conclusion that the exponents in the rate law expression are directly obtained from the coefficients of the reactants in the chemical equation. This misconception is similar to that reported by Cakmakci et al. (2006), Cakmakci and Aydogdu (2011), Kıngır and Geban (2012), and Turányi and Tóth (2013). To avoid this misconception, teachers should provide varied examples of rate laws in which the stoichiometric coefficients are not the same as the exponents in the chemical equation. This can also be reinforced through practical work in which students determine the rate law from experimental data. The role of practical work in improving students' understanding has been published by Chairam et al. (2009) in chemical kinetics and Choi and Wong (2004) in acid/base chemistry.

A further misconception is revealed by 17.91% of students who selected Q4-CB. These students used the equilibrium-constant expression to derive the rate law. Students stated that the rate law is given by: $Rate = k\frac{[H_2O]^2\,[I_3^-]}{[H_2O_2]\,[I^-]^3\,[H^+]^2}$ because it is based on the law of mass action that describes the relationship between the concentrations of reactants and products. The high CR(TB) of 3.69 confirms this as a *genuine* misconception which falls in the *moderate* category. This phenomenon shows that students often confuse the law of mass action with the rate law. Voska and Heikkinen (2000) made the same observation regarding students confusing chemical kinetics and chemical equilibrium.

5.3.5. Question 5

The purpose of this question is to identify students' understanding as to how the change in concentration of a zero and second-order reactant affect the rate.

The reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is second order with respect to NO_2, but zero order with respect to CO. If the concentration of NO_2 increases by a factor of 2 and the concentration of CO increases by a factor of 3, the reaction rate will....

A. Increase by a factor of 36 B. Increase by a factor of 12
C. Increase by a factor of 4 D. Remain constant

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. Only an increase in concentration of NO_2 affects the rate
B. The higher the concentration of both reactants, the higher the rate
C. The overall order of reaction is 2, therefore an increase in the concentration of both reactants increases the rate by the power of 2
D. There is no effect on the reaction rate as the order with respect to one reactant is zero

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.5 Question 5

For the A tier, this question was answered correctly by 61.49% students with CR(TA) of 3.7. For the R tier, 52.24% students gave the correct reason with CR(TR) of 3.8. For the B tier, 46.27% students provided both the correct answer and correct reason with CR(TB) of 3.92. The difficulty level of the question was considered *fair* with a DL of 0.53. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Option D (remains constant) is the most popular wrong answer and was chosen by 18.21% students with a CR(TA) of 3.1. In order to obtain Answer D students might assume that there is no effect on the reaction rate due the rate being zero-order with respect to CO. This is supported by the fact that Reason D (there is no effect on the reaction rate as the order with respect to one reactant is zero) was selected by 10.75% students with a CR(TR) of 3.25. Students' carelessness in reading the question could also explain this mistake. However, option C is the most popular wrong reason and was selected by 23.28% students with CR(TR) of 2.82.

Correct answer- wrong reason (CAWR) combination

Among students providing this combination, Q5-CB was selected by the highest number of students (17.91%) with CR(TB) of 2.4. This *spurious* misconception falls in the *weak_false positive* category. Those students understood that the higher the concentration, the higher the rate. However, they did not realize that this is not the case in a zero-order reaction. Q5-CC was selected by 5.07% students with CR(TB) of 3.31. In order to obtain the correct answer using reason C ("*The overall order of reaction is 2, therefore an increase in the concentration of both reactants increases the rate by the power of 2*") students either made an arithmetical mistake or guessed the correct answer.

Wrong answer- wrong reason (WAWR) combination

Q5-DD was only chosen by 1.19% students, but the value of its CR(TB) is the highest among these erroneous combinations. Students assume that the reaction rate will remain constant as the order with respect to one of the reactants is zero. It is possible that students believe that if the order with respect to one reactant is zero, when the concentration is raised to the power zero we obtain the number 1 and so the rate is unchanged. The value of CR(TB) of 3.54 confirms that this misconception is *genuine* and falls into the *moderate* category. Another misunderstanding is uncovered by the slightly higher fraction of students (2.29%) selecting Q5-AC with CR(TB) of 2.6. These students believe that the reaction rate will increase by a factor of 36 because the overall order of reaction is 2, therefore an increase in the concentration of both reactants increases the rate by the power of 2. This group of students was not aware that an increase or the decrease in concentration of a zero-order reactant does not affect the reaction rate. They assumed that the effect of changing the concentration of both reactants (whether second or zero order) on a reaction rate is the same. The percentage of students showing this combination is very small, but previous findings as reported by Cakmakci

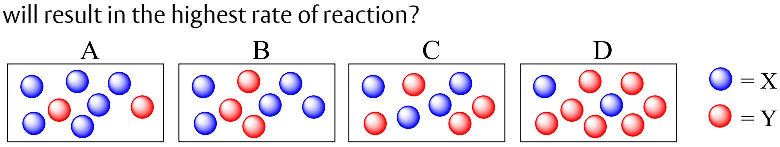
(2010) and Kirik and Boz (2012) suggest this misconception is significant and should be noted. Cakmakci (2010) found many students believe that the increase in concentration of a reactant increases/decreases the reaction rate of a zero-order reaction. Besides, Cakmakci and Aydogdu (2011) and Kirik (2012) revealed some students generalize that the reaction rate decreases as reaction progresses and ignore the fact that the rate of a zero-order reaction is constant.

The most popular misconception in this question is shown by 35.22% students selecting Q5-BC with CR(TB) of 2.75. By assuming that "the overall order of reaction is 2, therefore an increase in the concentration of both reactants increases the rate by the power of 2", they should choose option A as the correct answer. Arithmetical error in doing the calculation could be the reason for this mistake. Students' errors in doing calculations regarding reaction rate was also found by Chairam et al. (2009).

5.3.6. Question 6

The purpose of this question is to identify students' understanding of how an increase in concentration of first and second order reactants affects the rate.

For a hypothetical reaction: X + Y → Products, the rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



Answer: B

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. It has the highest concentration of the reactant which is 2nd order
B. The concentrations of both reactants are the same, therefore the ratio of collisions is more favourable
C. Both 1st and 2nd order reactants determine the rate
D. The concentration of Y is much higher than the concentration of X and this leads to the reaction being completed faster

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.6 Question 6

18.51% students with CR(TA) of 3.7 answered the question correctly in the A tier. For the R tier, 20.60% students gave the correct reason with CR(TR) of 3.3. For the B tier, 10.75% students provided the correct answer with CR(TB) of 3.57. The difficulty level of the question was considered *difficult* with a DL of 0.17. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Option A is the most popular wrong answer and was chosen by 40% of students with CR(TA) of 3.4. In order to choose this wrong answer students may have simply chosen the reaction mixture in which the concentration of the second-order reactant is the highest, knowing that the reaction is second order in X. This analysis is supported by the fact that reason A was also selected by the highest number of students (41.19% students). In addition, students show strong confidence in their reason as confirmed by the value of CR(TR) of 3.3. The confidence rating confirms that students experienced *moderate* misconception.

Wrong answer- correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, Q6-AC was selected by 3.88% students with CR(TA) of 3.62. Q6-CC was also selected by the same number of students with CR(TB) of 3.08. These students realised that both reactants must be considered when doing the calculation. However, error in the calculation could be the reason for this mistake. The high value of their confidence ratings excludes the possibility of *guesswork*.

Correct answer- wrong reason (CAWR) combination

Among students showing this combination, Q6-BA with the reason "It has the highest concentration of the reactant which is 2nd order" is the most preferred. This combination was selected by 5.37% students with CR(TB) of 3.61. This demonstrates that students understand the relevance of the second-order reactant concentration in the rate equation but have ignored the effect of the other reactant.

Wrong answer- wrong reason (WAWR) combination

Q6-AA was selected by the highest percentage of students (31.04%) with CR(TB) of 3.38. These students' reasons confirmed that they have failed to consider the concentration ratio between the second-order and first-order reactants. The number of molecules of X (second-order reactant) in option A is 6, while in option B it is 5. However, the number of molecules of Y (first-order reactant) in option A is 2, while in option B it is 3. By substituting these numbers in the equation $R = k[X]^2[Y]$, the rate for option A is 72*k* while for option B is 75*k*. Unfortunately, many students only focused on the number of molecules of the second-order reactant without doing a mathematical calculation based on the rate equation. This must be ascribed to informed *guesswork* in the absence of any calculation.

Another *genuine* misconception is revealed by the 10.45% of students who selected Q6-CB with CR(TB) of 2.87. These students assumed that when the concentration of two reactants involved in a reaction is the same this will lead to a higher reaction rate because the collision ratio of molecules is more favourable. The confidence rating confirms that this is a *genuine* misconception and falls in the *moderate* category. Q6-DD was also selected by 7.76% students with CR(TB) of 3.0. These students believed that when the concentration of a reactant is significantly in excess compared to the concentration other reactants, the reaction is going to be completed faster. This *genuine* misconception could be due to confusing the terms reaction rate and reaction time.

5.3.7. Question 7

The purpose of this question is to identify students' ability to express the equation for half-life from the integrated rate law equation. The integrated rate law is provided in the question and students were asked to derive the expression for the half-life of a zero-order reaction. This question is equivalent to Q2 but demands higher mathematical skills than the former equivalent question.

The integrated rate law for a reaction can be expressed as $[A]_t = [A]_0 - kt$. If $[A]_0$ is the initial concentration, $[A]_t$ is the concentration at particular time, *t*, and *k* is the rate constant, then the expression of half-life for this reaction is....

A. $t½ = \frac{[A]_t}{2k}$ **B $t½ = \frac{[A]_0}{2k}$** C. $t½ = \frac{0.693}{k}$ D. $t½ = -\frac{[A]_0}{k}$

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The concentration of A at its half-life is twice its initial concentration
B. The concentration of A at its half-life is a half of its initial concentration
C. The concentration of A at its half-life is same as its initial concentration

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.7 Question 7

47.76% students with CR(TA) of 3.4 answered the question correctly in the A tier. For the R tier, 60.90% students gave the correct answer with CR(TR) of 3.2. For the B tier, 29.55% students provided the correct answer with CR(TB) of 3.46. The difficulty level of the question was considered *fair* with a DL of 0.46. The CR values suggest that students have higher confidence in answering more mathematical questions. The integrated rate law is provided in the question and students were asked to derive the expression for the half-life of a zero-order reaction. This question demands higher-level mathematical skills than the former equivalent question (Q2). However, a significant number of students answered the question correctly with quite a high confidence rating. This phenomenon again emphasizes that some students have good mathematical skills and are confident in solving algorithmic questions.

Most popular wrong answer and wrong reason

Because the main purpose of this question is to identify students' mathematical ability, all the distractors provided in the answer options are derived from a possible mathematical error in performing the calculation. Option C is the most popular wrong answer and was chosen by 27.16% with a CR(TA) of 3.57. Reason A is the most popular wrong reason and was chosen by 16.12% of students with CR(TR) of 2.67. The high number of students selecting reason A "*the concentration of A at its half-life is twice its initial concentration*" indicates at least two misunderstandings. Firstly, it indicates a lack of understanding of the meaning of half-life. Secondly it suggests students have difficulty converting verbal statements to mathematical operations and vice versa. This implies that this skill should be practised. As stated by Hoban, Finlayson, and Nolan (2013), there is a belief that students' ability to convert from a mathematical statement to chemical behaviour and vice versa is one of the fundamental aspects for success in physical chemistry.

5.3.8. Question 8

The purpose of this question is to investigate students' understanding of the half-life of a first-order reaction. This question is equivalent to Q18. Q18 is displayed pictorially, while this question is in algorithmic format.

Consider the first order reaction $X \rightarrow Y$ in which X molecules are converted to Y molecules. X is initially 2.4 mol dm^{-3} and after 10 minutes the concentration has dropped to 0.6 mol dm^{-3}. Calculate the concentration of X and Y after one half life.

A. X = 0.6 mol dm^{-3} & Y = 1.8 mol dm^{-3} B. X = 0.9 mol dm^{-3} & Y = 1.5 mol dm^{-3}

C. X = 0.3 mol dm^{-3} & Y = 2.1 mol dm^{-3} **D. X = 1.2 mol dm^{-3} & Y = 1.2 mol dm^{-3}**

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question

A. **The concentration of X at its half-life is a half of its initial concentration**

B. The concentration of X is a half of its concentration at 10 minutes

C. The concentration of X that react is a half the concentration that react between 0 and 10 minutes

D. The half-life is reached at 10 minutes

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.8 Question 8

For the A tier, this question was answered correctly by 45.67% students with CR(TA) of 3.2. For the R tier, 37.31% students gave the correct answer with CR(TR) of 2.9. For the B tier, 28.06% students provided the correct answer with CR(TB) of 3.2. The difficulty level of the question was considered *fair* with a DL of 0.37. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was chosen by 27.16% students with a CR(TA) of 3.05. To arrive at this wrong answer, both groups of students might simply assume that the half-life of the reaction is 10 minutes. Reason B is the most popular wrong reason and was selected by 25.07% students with CR(TR) of 2.57. Those students believed that after one half-life the concentration of X is a half of its initial concentration at 10 minutes. As a result, they assumed that after one half-life the concentration of X has dropped to 1.2 mol dm^{-3}. This *spurious* misconception falls into the *weak* category.

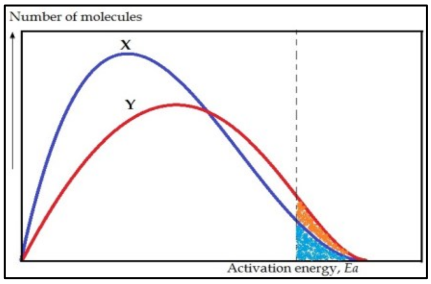
Wrong answer- wrong reason (WAWR) combination

5.67% students selected Q8-CB with CR(TB) of 2.34. Those students believed that the concentration of reactant X after one half-life is a half of its concentration at 10 minutes. As 0.6 mol dm^{-3} of [X] remained after 10 minutes, then those students assumed that the concentration of X after one half-life is 0.3 mol dm^{-3}. The CR confirms this *spurious* misconception and falls in the *weak* category. Another fraction of students (3.58%) selected Q8-BC with CR(TB) of 2.75. These students believed that the amount of X that reacts is a half the amount that reacts between 0 and 10 minutes. As the 1.8 mol dm^{-3} of [X] reacted in 10 minutes, then those students assumed that the concentration of X after one half-life is 0.9 mol dm^{-3}. The CR confirms this *genuine* misconception and falls in the *moderate* category. However, both misunderstandings may be rooted in students' lack of understanding of the meaning of half-life even they memorize the literal definition of it. This is demonstrated by students selecting Q8-AB (9.85%) and Q8-AC (8.66%) with CR(TB) of 2.89 and 2.86 respectively. These students assumed that the half-life is 10 minutes.

5.3.9. Question 9

The purpose of this question is to identify students' ability in interpreting diagrams showing the distribution of kinetic energies of molecules at different temperatures.

The Maxwell-Boltzmann distribution curves below describe the distribution of the kinetic energies of molecules.



X and Y represent the same reaction carried out at a different temperature where X is lower than Y. Which statement below is correct?

A. X has a higher rate of reaction than Y
B. Y has a higher rate of reaction than X
C. Both reactions have the same rate
D. There is insufficient information to determine the relative rates

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. This reaction has the higher activation energy
B. The value of *k* and the number of molecules of both reactants are unknown
C. **The higher the temperature, the higher the number of molecules with the activation energy (*Ea*)**
D. The higher the temperature, the higher the activation energy (*Ea*)
E. This reaction has the lower activation energy
F. The value of activation energy does not determine the rate

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.9 Question 9

50.45% students with CR(TA) of 3.54 answered the question correctly in the A tier. For the R tier, 31.94% students gave the correct reason with CR(TR) of 3.21. For the B tier, 22.99% students provided the correct combination with CR(TB) of 3.51. The difficulty level of the question was considered *fair* with a DL of 0.35. The CR values suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was chosen by 34.03% students with a CR(TA) of 3.2. Reason E is the most popular wrong reason and was selected by 17.01% students with CR(TR) of 3.26. Those students assumed that X has a higher rate as they assumed it has the lower activation energy (*Ea*).

Wrong answer- correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, Q9-AC was selected by the highest number of students, 5.67% with a CR(TB) of 2.71. An inability to interpret the plot must again be the reason for this mistake. This finding assumes that students did not understand that the shaded areas above the dashed line represent the number of molecules of each reaction that possess the activation energy. The CR confirms that this is a *spurious* misconception and falls in the *weak_false negative* category.

Correct answer- wrong reason (CAWR) combination

Of students selecting the correct answer but the wrong reason, Q9-BE was selected by 9.85% students with a remarkable value of CR(TB) of 3.64. Reason E "*this reaction has the lower activation energy*" was also considered as the most popular wrong reason. This feature indicates a major weakness of students in understanding and interpreting the diagram as mentioned above. Students' difficulty in interpreting the diagram is also illustrated by 7.76% students selecting Q9-BD with CR(TB) of 3.35. Those students did not recognize that even though both X and Y reactions are carried out at different temperatures, the *Ea* values of both reactions are same. This CAWR combination also reveals students' misconception that the higher the temperature, the higher the activation energy.

Wrong answer- wrong reason (WAWR) combination

7.76% students exhibited a misconception relating to the relationship between reaction rate and activation energy by choosing Q9-AA. Those students argued that X has a higher reaction rate because it has a higher activation energy. These students believed the higher the activation energy, the higher the rate. The confidence rating of students with CR(TB) of 3.02 supports this *genuine* misconception and falls in the *moderate* category. This finding shows an opposite result to the one that was revealed by Kolomuç and Tekin (2011) in which students believed that the probability of molecular collisions is minimized in a reaction with a higher activation energy.

Misunderstanding due to inability in interpreting the diagram was shown by 6.57% students selecting Q9-AE. Those students believed that X has a higher rate than Y as X has the lower activation energy. This WAWR combination implies the following possibilities. Firstly, those students did not realize that the red and blue shaded areas next to the dashed line represent the number of molecules produced in each reaction. By assuming that both reactions were conducted in the same duration (t), they should realize that the numbers of these molecules represent the rate of the reactions. Therefore, students were expected to understand that Y has the higher reaction rate. Secondly, those students assumed that X has a higher activation energy. In the dashed line that represents activation energy, the red line (Y) is located above the blue line (X).

The positions of the blue and red lines representing X and Y reactions respectively in the diagram may cause students to assume that X has the lower activation energy. It is clearly stated in the diagram that horizontal axis represents the *Ea* while the vertical axis represents the number of molecules. Therefore, in the dashed line point, the Ea of X and Y are the same but the number of molecules between both are different. Actually, it is scientifically correct that the lower the activation energy, the higher the rate. However, the *Ea* values of both reactions as represented in the diagram are the same. The different rates of both reactions are caused by the different temperatures. Justi and Gilbert (1999) asserted that teachers generally presented the diagram of Maxwell-Boltzmann distribution without any explanation to help students to understand the influence of temperature on reaction rate.

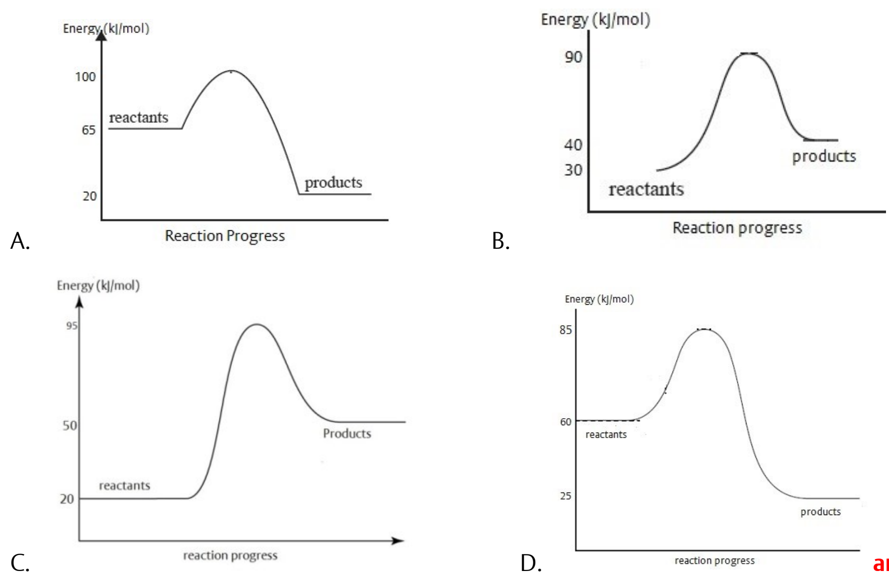
Similar research published by Orgill and Crippen (2010) showed the way in which first semester general chemistry students interpreted diagrams to solve a question about electromagnetic radiation. In this study, students were asked to determine the shortest wavelength of the emission of electromagnetic radiation from a series of electron transitions. Even though the energy level diagram provided was sufficient to answer the question, most students, including those who gave the correct answer, implemented the Rydberg equation to answer the question quantitatively (Orgill & Crippen, 2010). LaDue, Libarkin, and Thomas (2015) stressed the high importance of using visual interpretations to assess students' deep understanding.

Another misunderstanding uncovered in this question is that the different of reaction rate between X and Y reactions cannot be interpreted from the graph as the information presented in the graph is insufficient. This *genuine* misconception is shown by 5.97% students selecting Q9-AF with CR(TB) of 3.15. Other students also assumed that the value of *Ea* does not influence the rate of a reaction. This *spurious* misconception is shown by a small fraction of students (3.28%) with CR(TB) of 2.32. The same misconception is also experienced by 2.39% student selecting Q9-DF with CR(TB) of 2.69.

5.3.10. Question 10

The purpose of this question is to identify students' ability to interpret diagrams the *Ea* values and consider those values to compare the rates of each reaction.

Consider four reactions as described in the energy profile of *Ea* and ΔH below. Assuming that all four reactions are carried out at the same temperature and have the same Arrhenius factor A, which reaction is the slowest....?



answer: C

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The reaction has the highest energy in its transition state
B. The reaction has the highest activation energy
C. The reaction has the lowest energy in its transition state
D. The reaction has the lowest activation energy
E. The reaction is exothermic
F. The reaction is endothermic

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.10 Question 10

For the A tier, this question was answered correctly by 49.85% students with CR(TA) of 3.2. For the R tier, 40% students gave the correct reason with CR(TR) of 3.2. For the B tier, 27.16% students provided the correct combination with CR(TB) of 3.31. The difficulty level of the question was considered *fair* with a DL of 0.39. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was chosen by 17.91% students with a CR(TA) of 3.3. These students might believe that the value of the activation energy of the reaction as represented by option A is 80 kJ/mol (by assuming the *Ea* value = 100 – 20 kJ/mol). This is actually the activation energy of the reverse reaction.

Reason A is also the most popular wrong reason and was selected by 11.94% students with CR(TR) of 2.58. These students believed that the reaction with the highest energy of the transition state is the slowest one.

Wrong answer – correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, Q10-AB was selected by the highest number of students (6.27%) with a CR(TB) of 3.26. These students might believe that the value of the activation energy of the reaction represented by option A is 80 kJ/mol (assuming the E_a value = 100 – 20 kJ/mol) which is actually the activation energy of the reverse reaction. Q10-DB was selected by a smaller number of students (2.69%) but with a higher CR(TB) of 3.39. Both misunderstandings fall in the *moderate_false negative* category.

Correct answer – wrong reason (CAWR) combination

Of students selecting the correct answer but the wrong reason, Q10-CA and Q10-CF were selected by the highest number of students, (5.07% for both) with CR(TB) of 2.57 and 2.76 respectively. Those selecting CA believed that the reaction with the highest energy at the transition state is the slowest one. However, this answer combination reveals at least two weaknesses. Firstly, that the absolute energy of the transition state defines the rate of a reaction. The activation energy in an energy profile is derived from the difference between the energy of the reactants and the energy of the transition state. Therefore, a reaction with a high energy in the transition state does not necessarily have the highest activation energy. Sanger (2000) stated that many students misinterpret chemical drawings. Appropriate guidance needs to be used when teaching to help students in interpreting drawings (Sanger, 2000). Secondly, answer C is not the one that has the highest energy in the transition state. This phenomenon can only be explained by students' carelessness. This finding supports the one published by Tastan et al. (2010) & Kolomuç and Tekin (2011) in which some students confused the concept of the intermediate and the activated complex.

Those students selecting CF actually chose a correct statement that the energy profile of correct answer C demonstrates that the reaction is an endothermic one. However, those students assumed that being endothermic is the reason why it is the slowest reaction. This *genuine* misconception is shown by 5.07% students with CR(TB) of 2.76. The converse wrong assumption, i.e that an endothermic reaction is faster than an exothermic one has also been uncovered previously (Cakmakci, 2010; Kolomuç & Tekin, 2011; Sözbilir, Pınarbaşı, & Canpolat, 2010; Yalçınkaya et al., 2012).

Wrong answer- wrong reason (WAWR) combination

Q10-DE is the most popular wrong combination (4.78%) with CR(TB) of 3.44. These students believed that an exothermic reaction is the slowest reaction. This *genuine* misconception falls in the *moderate* category. The opposite assumption that an exothermic reaction is faster than an endothermic one was also uncovered by many researchers (Cakmakci, 2010; Cakmakci & Aydogdu, 2011; Kolomuç & Tekin, 2011; Sözbilir et al., 2010; Taştan-Kırık & Boz, 2012; Yalçınkaya et al., 2012).

2.39% students selecting Q10-AA with CR(TB) of 2.94 believed that the slowest reaction is the one with the highest energy in its transition state. As discussed above, those students did not understand that a reaction with a high energy in the transition state does not necessarily have the highest activation energy. The students also did not understand that the slowest reaction in this context is determined by the value of *Ea* and not the value of energy in the transition state. This assumption is in contrast to the assumption revealed by 1.49% students selecting Q10-DD with CR(TB) of 2.5. The last group believed that the slowest reaction is that the one has the lowest energy in its transition state.

Gegios, Salta, and Koinis (2017) stated that incomplete explanation in school textbooks could also be one of the reasons students' weaknesses in interpreting those diagrams. The diagrams presented in the question are basically very similar to diagrams which are presented in many school textbooks. The diagrams are not accompanied by sufficient explanation and the magnitude of the reaction enthalpy is not included (Gegios et al., 2017). Glazer (2011) stated that students often get into difficulty to determine correctly two points that confine an interval in a diagram. To help students to obtain a comprehensive understanding, some features including lines and energy levels should be clearly explained (Gegios et al., 2017).

5.3.11. Question 11

The purpose of this question is to identify students' understanding of the successive half-lives of a second-order reaction.

> The decomposition of nitrogen dioxide to nitric oxide and oxygen takes place by second order kinetics:
>
> $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$
>
> At time, t = 10 s the pressure of NO_2 is 80 torr and after 5 seconds the pressure has dropped to 40 torr. Determine the time at which the pressure of NO_2 is 20 torr.
>
> A. 17.5 *s* B. 20 *s* **C. 25 *s*** D. 30 *s*
>
> State the confidence rating of your answer
> 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
>
> Which one of the following options is the reason for your answer to the question?
> A. The value of each successive half-life is half the preceding one
> B. The value of t½ is constant
> C. The rate of disappearance of this sample increases with decrease in concentration
> D. **The value of each successive half-life is twice the preceding one**
>
> State the confidence rating of your answer
> 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.11 Question 11

For the A tier, this question was answered correctly by 19.10% students with a CR(TA) of 3.14. For the R tier, 11.94% students gave the correct reason with a CR(TR) of 2.9. For the B tier, only 4.18% students provided the correct combination with CR(TB) of 2.82. This question is equivalent to Q3 but is displayed in algorithmic format here. The difficulty level of the question was considered *difficult* with a DL of 0.12. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Answer B is the most popular wrong answer and was chosen by 48.96% students with a CR(TA) of 3.3. As in Q3, in order to obtain Answer B students have assumed that this is a first-order reaction and the half-life is constant. This again suggests students are familiar with the concept of constant half-life in a first-order reaction but are not used to expressions for half-lives in reactions with different orders. This wrong answer is consistent with the most popular wrong reason which is Reason B and was chosen by 40% students with a CR(TR) of 3.01.

Wrong answer- wrong reason (WAWR) combination

Among students showing this combination, Q11-BB was selected by the highest number of students (25.07%) with CR(TB) of 3.19. These students believe that the value for the half-life of a reaction is constant. As the reaction here is second order, this assumption is a *genuine* misconception and falls in the *moderate* category. This again demonstrates that students are generally familiar with the half-life of first-order reaction. Students often apply the concept of constant half-life of first-order reaction to reactions of other orders. Q11-AA was also selected by 10.75% students with CR(TB) of 3.38. These students believed that the value of each successive half-life is half the preceding one. This misconception is also *genuine* and falls in the *moderate* category.

5.3.12. Question 12

The purpose of this question is to identify students' ability to determine the rate law based on the mechanism, particularly a mechanism with a fast-initial step.

The formation of HI(g) follows the reaction $H_2 + I_2 \rightarrow 2HI$. This reaction may occur with the following mechanism:

$$I_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2I \qquad \text{fast}$$

$$I + I + H_2 \xrightarrow{k_2} 2HI \qquad \text{slow}$$

The overall rate law of this reaction is....

A. Rate = $k_2[I]^2[H_2]$ B. Rate = $k\frac{[HI]^2}{[I]^2[H_2]}$ **C. Rate = $k_2\frac{k_1}{k_{-1}}[I_2][H_2]$** D. Rate = $k_1[I_2] - k_{-1}[I]^2$

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The rate law is obtained directly from the slow step in the mechanism
B. The rate law is obtained from the fast step in the mechanism
C. The rate law is obtained from the law of mass action
D. The rate law is obtained from the slow step by considering any intermediates in preceding steps

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.12 Question 12

20.30% students with CR(TA) of 3.18 answered the question correctly in the A tier. For the R tier, 25.67% students gave the correct reason with CR(TR) of 2.8. For the B tier, 8.66% students provided the correct combination with CR(TB) of 3.24. The difficulty level of the question was considered *difficult* with a DL of 0.18. The CR values suggest that students' scientific understanding falls into the *moderate* category.

Reaction mechanisms are included in A-level chemistry in the UK and the chemistry syllabus for senior high school in Indonesia. Secondary school students in both countries are taught that the slow step in a reaction is the rate-determining step. However, the syllabuses do not seem to include the method for determining the overall rate law from the reaction mechanism. This factor explains why many students cannot answer this question correctly.

Most popular wrong answer and wrong reason

Answer B is the most popular wrong answer and was chosen by 45.97% students with a CR(TA) of 3.33. Reason A is the most popular wrong reason and was chosen by 33.43% students with CR(TR) of 3.02. Those students believed that the rate law is obtained directly from the slow step in the mechanism.

Wrong answer – wrong reason (WAWR) combination

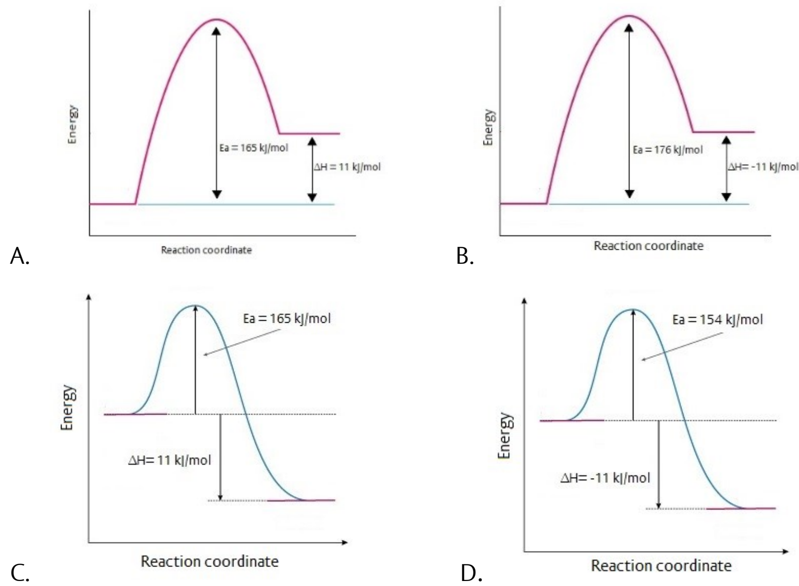
Several misunderstandings are uncovered by this question. Firstly, 14.03% of students selected Q12-AA with CR(TB) of 3.03. These students remembered that the rate law is obtained directly from the slow step in the mechanism but have failed to consider the previous fast step and how this affects the rate. The CR(TB) confirms this is a *genuine* misconception and falls in the *moderate* category.

Another group of students (8.06%), with CR(TB) of 2.74, selected Q12-BC and assumed that the rate law is obtained from the law of mass action. The CR(TB) confirms that this misunderstanding is a *spurious* misconception and falls in the *weak* category. This finding is in keeping with results published by Kıngır and Geban (2012) & Turányi and Tóth (2013). An interesting phenomenon revealed by 15.82% students selecting Q12-BA with a CR(TB) of 3.36. This WAWR combination demonstrates two *genuine* misconceptions. Firstly, those students assumed that the rate law is obtained directly from the slow step in the mechanism. Those students ignored the previous step which is a fast step when deriving the rate law. They did not realize that in a mechanism which involves two steps (a fast step precedes a slow one), the fast step must be considered in deriving the rate law. Secondly, those students believed that the rate law of the reaction is Rate = $k\frac{[\mathrm{HI}]^2}{[\mathrm{I}]^2[\mathrm{H_2}]}$. This incorrect answer is obtained from "$\mathrm{I} + \mathrm{I} + \mathrm{H_2} \xrightarrow{k_2} 2\mathrm{HI}$". This incorrect answer again shows that students are confused between the rate law and the law of mass action.

5.3.13. Question 13

The purpose of this question is to identify students' ability to determine the energy profile that represents an exothermic reaction. Students were also asked to identify the *Ea* value of the reaction from the energy profile.

The reaction $NO_2(g) + NO_3(g) \rightarrow N_2O_5(g)$ with $\Delta H = 11$ kJ mol^{-1} has the activation energy 165 kJ mol^{-1}. The graph below that represents the energy profile for the **reverse reaction** is....



Answer: D

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?
A. The reverse reaction is endothermic and its activation energy value is lower
B. The reverse reaction is exothermic and its activation energy value is lower.
C. The reverse reaction is endothermic and its activation energy value is higher
D. The reverse reaction is exothermic and its activation energy value is higher

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.13 Question 13

For the A tier, this question was answered correctly by 25.67% students with CR(TA) of 3.5. For the R tier, 31.64% students gave the correct reason with a CR(TR) of 3.1. For the B tier, 19.40% students provided the correct reason with CR(TB) of 3.42. The difficulty level of the question was considered *difficult* with a DL of 0.26. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was chosen by 39.40% with a CR(TA) of 3.47. In order to obtain Answer A students have assumed that the reverse reaction is an endothermic reaction. Carelessness in reading the question could be the reason for this wrong answer. The phrase "**reverse reaction**" was displayed in bold font in order to prevent students from ignoring it. This wrong answer is consistent with the most popular wrong reason which is Reason C and was chosen by 32.54% students with a CR(TR) of 3.4.

Wrong answer – correct reason (WACR) combination

Of students selecting the correct reason but wrong answer, Q13-CB was selected by 4.48% students with CR(TB) of 3.1. Those students might have got into difficulty determining the *Ea* value of the reaction from the energy profile. Q13-AB was selected by 4.48% students with CR(TB) of 2.87. Q13-BB was selected by 3.28% students with CR(TB) of 3.18. These two combinations could be as a result of students' difficulty in differentiating between the energy profiles of endothermic and exothermic reactions.

Correct answer – wrong reason (CAWR) combination

Of students selecting the correct answer but wrong reason, Q13-DA was selected by 1.79% students with CR(TB) of 3.42. Q13-DC was selected by 1.19% students with CR(TB) of 3.25. These two combinations could also be a result of students' difficulty in determining the *Ea* value. Q13-DD was selected by 2.99% students with a CR(TB) of 2.8. This combination could be a result of students' difficulty in differentiating between the energy profile of an endothermic and exothermic reaction and also in determining the *Ea* value of the reaction from the energy profile.

Wrong answer- wrong reason (WAWR) combination

19.10% students selected Q13-AC with a CR(TB) of 3.7. A similar misconception was also revealed by 8.36% students selecting Q13-BC with CR(TB) of 3.21. This *genuine* misconception that falls into the *moderate* category indicates several points. Firstly, students may have difficulty in determining whether a reaction is endothermic or exothermic, even though the sign of the ΔH value indicates it. The ΔH value clearly shows that the forward reaction is endothermic, therefore the reverse reaction must be exothermic. Therefore, based on the energy profile given, options C and D are the only two options to be considered. An error here could be due to carelessness in reading the question, so the student probably did not realize that the question was concerned with the reverse reaction. However, this possibility was anticipated by using **bold font** for the term "reverse reaction" in the question. Secondly, students' weaknesses in interpreting a chemical diagram were also confirmed. Students should understand that in the diagram for the energy profile of an exothermic reaction, the potential energy of the product is located at a lower level than the potential energy of the reactant as shown in the C and D diagrams. Consequently, this leads to a negative value for ΔH. In addition, those students might also not understand the meaning of the sign (whether + or -) of the ΔH value regarding the direction of enthalpy change in the reaction. This finding confirms that an understanding of chemical kinetics relies on a sound understanding of other related topics such as thermodynamics. This has been reported by Cakmakci and Aydogdu (2011). A good understanding of chemical kinetics requires an integrated conceptual understanding of some fundamental ideas such as the particulate nature of matter, the kinetic molecular theory and dynamic aspects of chemical reactions (Cakmakci, 2010; Justi, 2002). Thirdly, students' difficulty in deriving the value of the activation energy from the energy profile is also confirmed. Those students assumed that the value of the activation energy for the reverse reaction is higher.

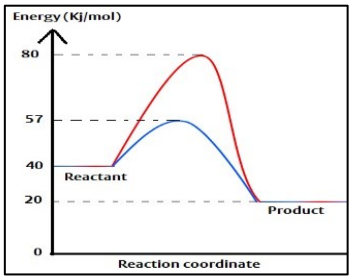
The influence of an incomplete explanation in chemistry textbooks as discussed in Q10 could also one of the reasons for students' misconceptions in this question. Referring to students difficulty in differentiating the energy profile between exothermic and endothermic reactions, Gegios et al. (2017) stated that in many textbooks the diagram for an exothermic reaction is depicted without an additional explanation that the diagram for an endothermic reaction is different from it. In addition, in the whole chapter on chemical kinetics, the energy diagrams generally only depict exothermic reactions (Gegios et al., 2017). A parallel presentation as suggested by Bowen and Roth (2002) of the energy profiles between endothermic and exothermic reactions is highly recommended because it would facilitate students to compare and contrast both types of energy profiles, to identify the differences and similarities and finally to lead students to a better understanding (Gegios et al., 2017).

5.3.14. Question 14

The purpose of this question is to identify students' understanding of the activation energy and mechanism of a catalyzed (blue line) and an uncatalysed (red line) reaction pathway from a plot.

For the A tier, this question was answered correctly by 43.88% students with CR(TA) of 3.9. For the R tier, 37.91% students gave the correct reason with CR(TR) of 3.3. For the B tier, 22.39% students provided the correct combination with CR(TB) of 3.77. The difficulty level of the question was considered *fair* with a DL of 0.35. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

The energy profile below describes a catalysed and an uncatalysed pathway for a given reaction.



The value of the activation energy of the catalysed reaction is....

A. 60 kJ mol^{-1} B. 40 kJ mol^{-1} C. 37 kJ mol^{-1} **D. 17 kJ mol^{-1}**

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The activation energy of a catalysed and an uncatalysed pathway is the same, but the mechanisms are different
B. The activation energy of a catalysed pathway is lower than an uncatalysed one and the mechanisms are the same
C. **The activation energy of a catalysed pathway is lower than an uncatalysed one and the mechanisms are different**
D. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are the same
E. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are different
F. The mechanism of a reaction is only changed if the temperature increases

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.14 Question 14

Most popular wrong answer and wrong reason

Answer C is the most popular wrong answer and was chosen by 22.39% with a CR(TA) of 3.29. In order to obtain answer C, students subtract the transition state energy of the uncatalysed pathway from the transition state energy of the catalysed pathway. Reason B was the most popular wrong reason and was chosen by 23.41% students with CR(TR) of 3.2. Those students did not realize that a catalyst provides an alternative mechanism for a reaction.

Wrong answer – correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, 4.78% students selected Q14-BC with CR(TB) of 2.78. These students believe that the value of the activation energy of the catalyzed reaction is 40 kJ mol^{-1}. These students confused the value of the uncatalysed reaction with the activation energy value for the catalysed one.

Correct answer – wrong reason (CAWR) combination

Of students selecting the correct answer but the wrong reason, Q14-DB is the most popular combination and was selected by 15.52% students with CR(TB) of 3.64. These students believed that a catalyst lowers the activation energy without providing a new mechanism. They assumed that the mechanism of a catalysed pathway and an uncatalysed one are the same. The CR(TB) value confirms this as a *genuine* misconception and falls in the *strong_false positive* category. This misunderstanding is in keeping with ones that have been published previously. Many students realize that a catalyst decreases the activation energy, but do not realize that by lowering the activation energy, a new mechanism or reaction pathway is provided (Cakmakci, 2010; Cakmakci & Aydogdu, 2011; Kirik & Boz, 2012; Yalçınkaya et al., 2012).

Wrong answer- wrong reason (WAWR) combination

Q14-AA was selected by only a small fraction of students (0.90%) but has a remarkable CR(TB) of 4.0. These students assumed that the value of the activation energy for the catalyzed reaction is 60 kJ mol^{-1}. These students incorrectly calculated the value of the activation energy as the difference between the energy of the activated complex and the energy of the products. These students also believed that the activation energy of a catalysed and an uncatalysed pathway are the same, but the mechanisms are different. This *genuine* misconception which falls in the *strong* category is a unique finding of this study. Generally, the results reported by previous researchers showed that students understood that the activation energies of both pathways are different, but they did not realize that the mechanisms for both pathways are different as well.

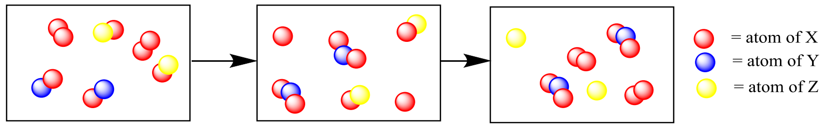
5.67% students selected Q14-BE with CR(TB) of 3.18. These students showed a *genuine* misconception by considering that the value of the activation energy for an uncatalyzed pathway is lower than the value for the catalysed one. However, students understood correctly that the mechanisms of the two pathways are different.

5.3.15. Question 15

The purpose of this question is to identify students' ability to identify the catalyst in a hypothetical reaction that is displayed pictorially.

For the A tier, this question was answered correctly by 40.30% students with CR(TA) of 3.6. For the R tier, 42.09% students gave the correct reason with CR(TR) of 3.7. For the B tier, 28.08% students provided the correct combination with CR(TB) of 4.02. The difficulty level of the question was considered *fair* with a DL of 0.37. The confidence ratings suggest that students' scientific understanding for the A and R tiers falls into the *moderate* category. Yet, the confidence rating of the B tier falls into the *strong* category.

The following diagram depicts an imaginary two step mechanism of a reaction.



Based on the representation above, the substance that acts as a catalyst is….

A. X B. XZ **C. X_2** D. XY

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer
A. **The substance does not undergo a permanent chemical change and is reformed in the final product**
B. The substance is formed in one elementary reaction and consumed in the next
C. The substance increases the rate without being involved chemically in the reaction
D. The substance is not present in the final product

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.15 Question 15

Most popular wrong answer and wrong reason

Answer B is the most popular wrong answer and was chosen by 29.25% with a CR(TA) of 3.34. Reason C is the most popular wrong reason and was chosen by 18.81% students with CR(TR) of 3.14. Those students assumed that a catalyst only increases a rate without being involved chemically in the reaction.

Wrong answer – correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, Q15-AA was selected by 5.67% students with CR(TB) of 3.08. Q15-BA was selected by 5.07% students with CR(TB) of 3.35. The last group of students believed that XZ is the catalyst. This answer is surprising because XZ is clearly not reformed in the last step although the correct reason states that the catalyst is reformed. This finding is in keeping with the 3.28% students who chose Q15-DA with CR(TB) of 2.91 and assumed "XY", which also is not reformed in the reaction, to be the catalyst.

Correct answer – wrong reason (CAWR) combination

Of students selecting the correct answer but the wrong reason, Q15-CB was selected by 3.58% students with CR(TB) of 2.67. These students understood correctly that X_2 is the catalyst. These students' incorrect reason that the substance is formed in one elementary reaction and consumed in the next does not agree with their correct answer unless they have misinterpreted the diagram or guessed at the answer. Meanwhile 3.88% students with CR(TB) of 2.81 selected Q15-CC and assumed the catalyst is not involved in the reaction chemically, thus showing a *genuine* misconception which falls in the *moderate_false positive* category.

Wrong answer – wrong reason (WAWR) combination

3.88% students selected Q15-AB with CR(TB) of 2.73 and considered “X” as the catalyst in this reaction because X is formed in one elementary reaction and consumed in the next. These students are confused between the nature of a catalyst and an intermediate. The confidence rating shows that this is a *spurious* misconception and falls in the *weak* category.

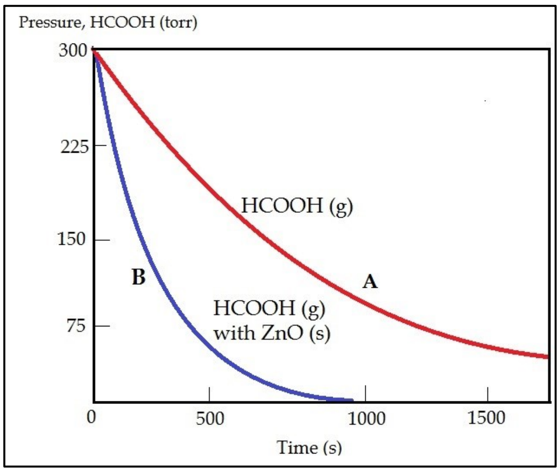
Another misconception already reported in the literature is that a catalyst increases the rate without being chemically involved in the reaction. This *genuine* misconception was revealed by 8.96% students who selected Q15-BC with CR(TB) of 3.35. This finding supports the one published by Yalçınkaya et al. (2012) and Kıngır and Geban (2012). Meanwhile, 2.39% students selected Q15-DD with CR(TB) of 3.0 and believed that “XY” is a catalyst because it is not obtained in the final product. The confidence rating of this *genuine* misconception falls in the *moderate* category. This finding is unique to this study.

5.3.16. Question 16

The purpose of this question is to identify students’ understanding of the role of a catalyst upon the reaction rate from a plot of pressure versus time and to investigate students’ understanding of a heterogeneous catalyst.

For the A tier, this question was answered correctly by 53.73% students with CR(TA) of 3.4. For the R tier, 41.19% students gave the correct reason with CR(TR) of 3.5. For the B tier, 31.34% students provided the correct combination with CR(TB) of 3.73. The difficulty level of the question was considered *fair* with a DL of 0.42. The confidence ratings suggest that students’ scientific understanding falls into the *moderate* category.

The variation in partial pressure of HCOOH for the decomposition of formic acid $HCOOH(g) \rightarrow CO_2(g) + H_2(g)$ in the gas phase as a function of time at 838 K is described in the graph below.



A graph of the partial pressure of HCOOH versus time is shown as the red curve, A. Assuming that ZnO(s) is the catalyst, when a small amount of solid ZnO is added, the partial pressure of HCOOH versus time varies as shown by the blue curve, B. Based on this information, which is the correct statement below?

A. This is an example of homogeneous catalysis and the rate of B is higher than the rate of A
B. This is an example of heterogeneous catalysis and the rate of B is higher than the rate of A
C. This is an example of homogeneous catalysis and the rate of A is higher than the rate of B
D. This is an example of heterogeneous catalysis and the rate of A is higher than the rate of B

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. HCOOH, CO_2 and H_2 are in the same phase and the presence of ZnO increases the rate
B. HCOOH and ZnO are in different phases and the presence of ZnO decreases the rate
C. HCOOH, CO_2 and H_2 are present in the same phase and the presence of ZnO decreases the rate
D. **HCOOH and ZnO are in different phases and the presence of ZnO increases the rate**

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.16 Question 16

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was chosen by 14.33% with CR(TA) of 2.56. This wrong answer clearly indicates students' confusion between homogeneous and heterogeneous catalysts. Reason B is the most popular wrong reason and was chosen by 20.30% students with CR(TR) of 3.12.

Wrong answer – correct reason (WACR) combination

Within this combination, 2.09% students with CR(TB) of 3.07 selected Q16-AD thus showing a misunderstanding over the difference between homogeneous and heterogeneous catalysts. Meanwhile, 2.39% students selected Q16-DD with a CR(TB) of 3.0. This fraction of students understands the difference between homogeneous and heterogeneous catalysis, but they have difficulty in interpreting the plot. Their assumption that the rate of A is higher than the rate of B may be as a result of difficulty in interpreting the plot.

Correct answer – wrong reason (CAWR) combination

Of students selecting the correct answer but the wrong reason, 8.66% students selected Q16-BA with CR(TB) of 2.95. These students understand correctly that the presence of ZnO increases the rate. That HCOOH, CO_2 and H_2 are present in the same phase is a correct statement. However, this statement does not imply that the reaction is an example of using a heterogeneous catalyst. Those students did not realize that the terms homogenous and heterogenous catalyst are defined based on whether the catalyst exists in the same phase as the reactants or in a different phase.

Q16-BC was selected by 6.27% students with CR(TB) of 2.57. Those students believed that the presence of ZnO decreases the rate. The CR value confirms that this misconception is *spurious* and falls in the *weak_false positive* category. In addition, the selected incorrect answer and selected incorrect reason are inconsistent. Those students have stated that reaction B (with the catalyst, ZnO) is faster than reaction A (without catalyst). However, their incorrect reason that ZnO (the catalyst) decreases the rate confirms this inconsistency. This inconsistency emphasizes that this misconception could be *guesswork*.

Wrong answer – wrong reason (WAWR) combination

5.37% students selected Q16-DB with CR(TB) of 3.64. These students correctly recognize that the reaction is an example of heterogeneous catalysis, but again assume that the presence of a catalyst decreases the rate. An inability to interpret the diagram correctly could explain this *genuine* misconception.

4.48% students selected Q16-CC with CR(TB) of 2.57. These students showed a *lack of knowledge* in stating that the presence of a catalyst decreases the rate. This *spurious* misconception is a new finding in the topic of catalysis to date. Another interpretation shown by this fraction of students is that the rate of reaction A is higher than the rate of reaction B. Students' inability to interpret the graph may be the root of this misunderstanding. Both reactions (the one that is represented by the red curve, A without ZnO(s) and the one represented by the blue curve, B with ZnO(s)) have the same pressure of HCOOH, 300 torr at $t = 0$ *s*. However, at $t = 500$ *s*, for example, the pressure of B (about 25 torr) is much lower than the pressure of A (about 180 torr). Thus, it is clear that the rate of B is higher than that of A.

5.3.17. Question 17

The purpose of this question is to identify students' ability to determine the rate law based on the mechanism, specifically a mechanism with a slow initial step. This question explores similar concepts to those in Q12, but this question involves a mechanism with a slow initial step.

The reaction of nitrogen dioxide and carbon monoxide $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ may occur according to the following mechanism:

Step 1: $NO_2(g) + NO_2(g) \xrightarrow{k_1} NO_3(g) + NO(g)$ slow

Step 2: $NO_3(g) + CO(g) \xrightarrow{k_2} NO_2(g) + CO_2(g)$ fast

If k is the overall rate constant, the rate law for this reaction is....

A. Rate = $k[NO_2][CO]$ **B. Rate = $k[NO_2]^2$** C. Rate = $k[NO_3][CO]$ D. Rate = $k\frac{[NO][CO_2]}{[NO_2][CO]}$

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. **Step 1 is the rate determining step**
B. Step 2 is the rate determining step
C. The rate law is obtained directly from the overall reaction equation
D. The rate law is derived from the law of mass action

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.17 Question 17

For the A tier, this question was answered correctly by 35.22% students with CR(TA) of 3.2. For the R tier, 32.24% students gave the correct reason with CR(TR) of 3.3. For the B tier, only 23.88% students provided the correct combination with CR(TB) of 3.38. The difficulty level of the question was considered *fair* with a DL of 0.30. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was chosen by 26.27% students with a CR(TA) of 3.33. Reason C is the most popular wrong reason and was chosen by 42.09% students with CR(TR) of 3.12. These wrong answers and wrong reasons suggest that these students believed that the rate law is obtained directly from the overall reaction equation rather than by a consideration of the individual steps in the reaction.

Wrong answer – correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, Q17-AA was selected by 3.88% students with CR(TB) of 2.81. Q17-CA was selected by 2.99% students with CR(TB) of 3.3. Those students have a correct knowledge that the slow step is a rate determining step. However, they still cannot use the knowledge to select the correct answer.

Correct answer – wrong reason (CAWR) combination

Of students selecting the correct answer but wrong reason, Q17-BC is the most preferred and was selected by 8.06% students with CR(TB) of 2.76. Those students believed that the rate law is obtained directly from the overall reaction equation. This *genuine* misconception falls in the *moderate_false positive* category. In this question, coincidentally this misconception helped those students to select the correct answer. However, this will not be transferable when the overall reaction equation does not align with the experimentally determined rate law. A possible reason for this phenomenon is that examples of rate laws given in chemical kinetics' teaching often do align with the overall reaction equation.

Wrong answer – wrong reason (WAWR) combination

17.91% students chose Q17-AC with CR(TB) of 3.63 suggesting they believe that the rate law is obtained directly from the overall reaction equation rather than by a consideration of the individual steps in the reaction. The CR(TB) confirms that this misunderstanding is a *genuine* misconception and falls in the *moderate* category.

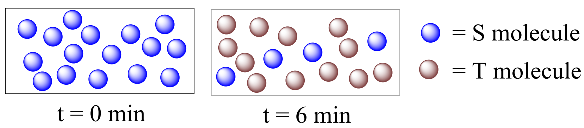
Although the reaction mechanism indicates that the rate law only relies on step 1 (slow step), by choosing Q17-CB with CR(TB) of 2.92, a small fraction of students (1.79%) believe that the fast step is the rate-determining step (RDS). This *genuine* misconception falls in the *moderate* category. Another small fraction of students selecting Q17-DD assumed that the rate law is derived from the law of mass action. The CR(TB) of 2.79 confirms that this is a *genuine* misconception and falls in the *moderate* category. The same misunderstanding has been published by Kıngır and Geban (2012).

7.76% students selected Q17-DB with CR(TB) of 3.6. This wrong answer exhibits two unscientific understandings. Firstly, students assumed that step 2 which is a fast step is a rate-determining step. Secondly, by selecting the wrong reason, $\text{Rate} = k\,\frac{[\text{NO}]\,[\text{CO}_2]}{[\text{NO}_2][\text{CO}]}$, implies that the rate law is obtained from the law of mass action. The CR(TB) confirms that this misconception is *genuine* and falls in the *moderate* category. Kıngır and Geban (2012) & Turányi and Tóth (2013) published the same findings. 11.94% students selected Q17-DC with CR(TB) of 3.04. These students derived the rate law directly from the overall reaction equation. These findings are consistent with the previous findings discussed in Q12.

5.3.18. Question 18

The purpose of this question is to identify students' understanding of the relationship between the concentration of a first-order reactant at its half-life and the concentration remaining after a particular time. This question was provided pictorially. This question is equivalent to Q8 which is displayed in algorithmic format.

Consider the first order reaction S → T in which S molecules are converted to T molecules.



How many S (blue) molecules and T (brown) molecules are present at the half-life?

A. Blue = 4 and brown = 12   B. Blue = 6 and brown = 10   C. Blue = 2 and brown = 14   **D. Blue = 8 and brown = 8**

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The number of S molecules is a half of its initial number

B. The number of S molecules is a half of its number at 6 minutes

C. The number of S molecules that react is a half the number that react between 0 and 6 minutes

D. The half-life is reached at 6 minutes

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

Figure 5.18 Question 18

37.31% students with CR(TA) of 3.3 answered the question correctly in the A tier. For the R tier, 31.04% students gave the correct reason with CR(TR) of 3.1. For the B tier, 23.58% students provided the correct combination with CR(TB) of 3.25. The difficulty level of the question was considered *fair* with a DL of 0.31. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category. The percentage of students giving the correct answer for this question (pictorial) is slightly lower than the percentage for Q8 (algorithmic). This implies that students have better understanding when answering the algorithmic question over the pictorial one.

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was chosen by 31.64% students with a CR(TA) of 3.35. This shows the same trend as the most popular wrong answer in Q8. Reason B is the most popular wrong reason and was selected by 22.99% with CR(TR) of 2.88. Those students believed that after one half-life the concentration of X is a half of its initial concentration at 6 minutes. This shows a similar misconception to in Q8.

Wrong answer – correct reason (WACR) combination

Of students selecting the correct reason but the wrong answer, Q18-AA and Q18-CA were selected by 2.99% students with CR(TB) of 3.3 for both. This indicates that those students generally only remember the definition that at the half-life there is a phrase "*half the initial number*" without fully understanding it.

Wrong answer – wrong reason (WAWR) combination

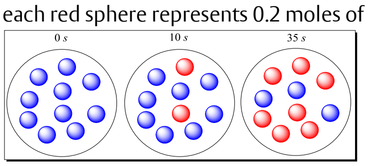
Q18-AB was selected by the highest number of students (10.15%) with CR(TB) of 3.16. Q18-AC was selected by 8.36% students with CR(TB) of 3.02. Meanwhile, 7.76% students selected Q18-AD with CR(TB) of 3.17. Those students may simply consider $t = 6$ minutes as the half-life. This *genuine* misconception could be caused by their lack of understanding of the meaning of half-life. 3.28% students selected Q18-BC with CR(TB) of 2.55. These students may think that the S molecules decrease to 12 (from 16 to 4 = 12) in 6 minutes. So, the number of S molecules that react is half the number that react between 0 and 6 minutes. Again, this shows an incorrect approach to solving the problem. This misunderstanding is a *spurious* misconception and falls in the *weak* category. 6.57% students selected Q18-CB with CR(TB) of 3.02. These students must have considered that the half-life referred to in the question was represented by the time at which the concentration of S had further dropped by a half.

In summary, the results suggest that many students fail to understand the true implication of the meaning of "the half-life of a reaction". They simply memorize the definition, but are unable to implement the theory. In teaching chemical kinetics, it is suggested that teachers ensure students consolidate their knowledge by practising different types of examples.

5.3.19. Question 19

The purpose of this question is to identify students' understanding of the change in concentration of reactants or products per unit of time. This question was provided pictorially.

The hypothetical reaction G → H is depicted pictorially below. Each blue sphere represents 0.2 moles of G and each red sphere represents 0.2 moles of H, and the container has a volume of 1.00 L.



The number of moles of G and H respectively in the mixture after 32 *s* is….

A. 1.280 mol; 0.720 mol B. 0.544 mol; 1.456 mol **C. 0.720 mol; 1.280 mol** D. 1.456 mol; 0.544 mol

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. As time increases, the rate of conversion of G molecules to H molecules also increases
B. As time increases, the rate of conversion of G molecules to H molecules decreases
C. The rate of conversion of G molecules to H molecules per second is a constant

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.19 Question 19

The figure in the question explains that the rate of conversion of G molecules to H molecules per second is a constant. This shows that the hypothetical reaction is zero-order because the rate is not affected by the change in concentration of the reactant. However, to arrive at this, students should understand how the concentration of the reactant changes over time. Using the formula that the rate is equal to the change in concentration per unit of time, the rate of this reaction is a constant over time at 0.04 mol $L^{-1}s^{-1}$.

40.60% students with CR(TA) of 2.8 answered the question correctly in the A tier. For the R tier, 27.16% students gave the correct reason with a CR(TR) of 2.8. For the B tier, 10.75% students provided the correct answer with CR(TB) of 3.08. The difficulty level of the question was considered *difficult* with a DL of 0.26. The confidence ratings suggest that students' scientific understanding falls into the *moderate* category.

Most popular wrong answer and wrong reason

Answer B is the most popular wrong answer and was selected by 30.45% students with a CR(TA) of 2.36. These students may have determined the rate based on the number of G molecules remaining at 35 s. So, $rate = \frac{d[\mathrm{G}]}{dt} = \frac{0.6}{35} = 0.017\ mol.s^{-1}$. Therefore, at t = 32, the amount in moles of G = 32 x 0.017 = 0.544 mol. Students appear to be confused about which concentration should be used in the equation, whether it should be the concentration of the reactant that has been used-up or the concentration remaining. Reason B is the most popular wrong reason and was selected by 29.25% students with a CR(TR) of 2.8. This implies that students assume the reaction rate decreases with time for all reactions and they do not appreciate the difference for a zero-order reaction.

Wrong answer – wrong reason (WAWR) combination

8.96% students selected Q19-BA with CR(TB) of 2.23. As explained above, those students who selected answer B might determine the rate based on the concentration of G remaining at 35 s. This is a strong indication that students seem to be confused about which concentration to use in the equation. Such confusion commonly happens within Indonesian students as observed by the author in teaching chemical kinetics. This is supported by the finding that those students believed that as time increases, the rate of conversion of G molecules to H molecules increases in this reaction. This finding shows a similar misunderstanding to that published by previous researchers. For example, some students assumed that the increase in concentration of a reactant always increases the reaction rate (Kıngır & Geban, 2012; Tastan et al., 2010; Van Driel, 2002). To avoid this typical misunderstanding in the future, the word “generally” should be emphasized in teaching about factors that affect reaction rate.

Another misunderstanding uncovered is that the reaction rate always decreases as time increases. This misunderstanding is opposite to the one mentioned above. This misunderstanding is confirmed by 3.28% students who selected Q19-DB with CR(TB) of 2.73. This similar misconception is shown by 3.88% students selecting Q19-AB with CR(TB) of 2.65. These *spurious* misconceptions fall in the *weak* category. The decrease in reaction rate with time is observed in a first-order and second order reaction. Making the general statement that the rate of reaction always decreases with increase in time shows a knowledge gap. In addition, as discussed above, Reason B is the most preferred wrong reason. This implies that students assume the reaction rate decreases with time for all reactions and they do not appreciate the difference for a zero-order reaction. To avoid this typical misconception, teachers should stress that the term ‘zero-order’ implies that the rate does not depend upon the concentration and therefore does not change as the concentration of reactant decreases. The similar misconception is also shown by 8.66% students selecting Q19-BB with CR(TB) of 2.53. Those students believed that as time increases, the rate of a zero-order reaction decreases. However, these students should select whether answer A or D which is consistent with the wrong reason that the rate of reaction decreases over time. If the rate of a zero-order reaction decreases over time, the number of G molecules at 32 *s* will be higher than 0.720 mol. This conflicting combination of wrong answer with wrong reason implies that often students do not have a deep understanding of many concepts but have simply memorized them.

5.3.20. Question 20

The purpose of this question is to identify students’ ability to express the rate of reaction in terms of change in concentration of either reactants or products.

For the A tier, this question was answered correctly by 12.24% students with CR(TA) of 3.1. For the R tier, 9.55% students gave the correct reason with CR(TR) of 2.8. For the B tier, only 2.99% students provided the correct combination with CR(TB) of 3.2. The difficulty level of the question was considered *difficult* with a DL of 0.08. The confidence ratings suggest that students’ scientific understanding falls into the *moderate* category.

The decomposition of N_2O_5 in a solvent occurs according to the following equation $N_2O_5 \rightarrow 2NO_2 + ½ O_2$
In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is the correct expression of the average reaction rate?

A. Rate $= \frac{d[N_2O_5]}{dt} = 0.001\ M\ min^{-1}$
B. Rate $= \frac{d[NO_2]}{dt} = 0.001\ M\ min^{-1}$
C. Rate $= \frac{d[O_2]}{dt} = 0.0005\ Mmin^{-1}$
D. Rate $= -\frac{d[NO_2]}{dt} = -0.002\ Mmin^{-1}$

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?
A. O_2 is produced twice as fast as N_2O_5 is consumed
B. NO_2 is produced a half as fast as N_2O_5 is consumed
C. The rate law can only be expressed by the rate of disappearance of N_2O_5
D. N_2O_5 is consumed twice as fast as NO_2 is produced
E. NO_2 is consumed twice as fast as N_2O_5 is consumed
F. O_2 is produced a half as fast as N_2O_5 is consumed
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Figure 5.20 Question 20

Most popular wrong answer and wrong reason

Answer A is the most popular wrong answer and was selected by 47.22% students with a CR(TA) of 3.15. Reason C is the most popular wrong reason and was selected by 28.96% students with a CR(TR) of 2.51.

Wrong answer – wrong reason (WAWR) combination

18.21% students selected Q20-AC with CR(TB) of 2.94 and argued that the rate law expression can only be expressed in terms of the rate of disappearance of N_2O_5. This fraction of students did not realize that the rate of the chemical reaction can be expressed in terms of the rate of formation of products as well as the disappearance of reactants. Meanwhile, many of the students' responses reflected their inability to express the relative rates based on the balanced chemical equation. The CR(TB) confirms that this is a *genuine* misconception and falls in the *moderate* category. 7.16% students selected Q20-AD with CR(TB) of 2.96 and believed that: Rate= $\frac{d[N_2O_5]}{dt} = 0.001\ M\ min^{-1}$, because N_2O_5 is consumed twice as fast as NO_2 is produced. This is similar to the 5.67% students who selected Q20-BB with CR(TB) of 3.0 and believed that: Rate= $\frac{d[NO_2]}{dt} = 0.001\ M\ min^{-1}$, because NO_2 is produced half as fast as N_2O_5 is consumed. Another knowledge gap is shown by 2.69% of students with CR(TB) of 2.39 who selected Q20-DE. Those students were not aware of the meaning of the negative sign, therefore assumed that the NO_2 was consumed instead of being produced. Students' inability to convert verbal statements into mathematical operations and *vice versa* is one of the possible reasons for these *genuine* misconceptions.

In addition, the results show that some students believe the rate law can be derived from the stoichiometric equation – in the same way that the equilibrium constant can be obtained. This confusion may derive from the procedure they have learnt for expressing the equilibrium constant, when studying this concept, or it may derive from the knowledge that the rate of reaction can be expressed in terms of the different reactants and products, using the coefficients in the stoichiometric equation. Clearly the theory here is confusing until the student has a secure grasp upon the concepts.

5.4. CHAPTER SUMMARY

The item analysis results show that the quality of the FTDICK instrument is better than the prototype one. The average validity index of the FTDICK (0.451) is higher than the average of the prototype FTDICK (0.343). This confirms that the validity index of the FTDICK instrument is higher than the validity of the prototype one. In addition, the reliability indices of the FTDICK instrument are always higher than the reliabilities of the prototype one for all tiers. The reliability of the FTDICK instrument (0.911) falls into the *excellent* category while the prototype FTDICK (0.853) is in the *very good* category. These results imply that the FTDICK instrument is a valid and reliable instrument to investigate students' understanding of chemical kinetics.

Several students' misunderstandings including *genuine* and *spurious* misconceptions and confusion with chemical terminology are revealed in this study. Some of these misunderstandings concur with previous results published in the literature. Some novel findings are also revealed in this study. Some aspects of students' weaknesses including mathematical weaknesses, carelessness, and difficulty in interpreting diagrams affect their performances in answering questions. These weaknesses may not relate directly to students' understanding of chemical kinetics concepts, but the existence of these weaknesses influences students' performance in chemical kinetics in particular and in chemistry in general.

Students' confidence rating in answering questions is generally consistent with the DL of the questions. Students generally have high confidence when answering easy questions. In the same way, students' confidence rating is lower when answering difficult questions. Therefore, it can be concluded that students' confidence rating has a positive correlation with the DL level of questions.

This study also reveals that some students show a strong mathematical skill when solving algorithmic questions. However, they often can answer the chemical questions correctly by using a formulaic equation, but they don't always fully understand the concepts involved and use recall and parameter substitution to solve problems. Misconceptions uncovered in this study are presented in Table 5.8 below.

Table 5.8. The summary of students' misconceptions

No.	Misconception	Question	Category
1	The concentration of a reactant at its first half-life and second half-life is same	1	Genuine
2	The rate of a first-order reaction is constant over time	1	Genuine
3	The decrease in concentration of a first-order reactant increases the rate	1	Spurious
4	Making the generalization that the half-life of all reactions of any order is constant	1; 3; 18	Genuine
5	The rate of reaction always increases with decrease in concentration	3; 19	Genuine
6	Each successive half-life is half the preceding one	3	Genuine
7	The power of the reactants in the rate law is equal to the stoichiometric coefficients in the balanced equation	4	Genuine
8	Using the equilibrium-constant expression to derive the rate law	4; 12; 17	Genuine
9	An increase in concentration of a zero-order reactant increases/decreases the reaction rate.	5; 19	Genuine
10	The reaction rate will remain constant over time because the order with respect to one of the reactants is zero even though the other reactants' orders are not zero.	5	Genuine
11	If the overall order of a reaction is 2, regardless of the order of the reactants, an increase in the concentration of reactants increases the rate by the power of 2	5	Genuine
12	When the concentration of two reactants involved in a reaction is the same this will lead to a higher reaction rate because the collision ratio of molecules is more favourable	6	Genuine
13	When the concentration of a reactant is much greater than the concentration of other reactants, the reaction will be completed faster	6	Genuine
14	The concentration of a reactant at its half-life is twice its initial concentration	7	Genuine
15	The higher the activation energy, the higher the rate	9	Genuine
16	The value of activation energy does not influence the rate	9	Spurious
17	The higher the energy at the transition state, the slower the reaction rate	10	Genuine
18	An endothermic reaction is faster than an exothermic one	10	Genuine
19	An exothermic reaction is faster than an endothermic one	10	Genuine
20	The value of the half-life of a second-order reaction is constant	11	Genuine
21	The activation energy of a catalysed and an uncatalysed pathway is the same, but the mechanisms are different	14	Genuine, strong
22	A catalyst is a substance which is formed in one elementary reaction and consumed in the next.	15	Spurious
23	The catalyst increases the rate without being chemically involved in the reaction	15	Genuine
24	A catalyst is not obtained in the final product	15	Genuine
25	The presence of a catalyst decreases the rate	16	Genuine
26	The rate law is obtained directly from the overall rate equation rather than by a consideration of the individual steps in the reaction	17	Genuine
27	The fast step is the rate-determining step (RDS)	17	Genuine
28	The rate law is derived from the overall reaction equation	17	Genuine
29	An increase in concentration of a reactant always increases the reaction rate	19	Spurious
30	The reaction rate always decreases as time increases	19	Spurious

CHAPTER 6

COMPARISON OF STUDENTS' ABILITY TO SOLVE ALGORITHMIC AND PICTORIAL STYLE QUESTIONS

6.1 INTRODUCTION

6.1.1 Mathematical aspect of chemical kinetics

Physical chemistry, the branch that includes chemical kinetics, applies physical concepts and mathematical language in order to establish its principles (Atkins & Paula, 2010). Mathematical ability is required to learn and understand the subject. In many universities, chemistry students take a maths module that includes calculus in the first year. However, many students cannot apply their basic calculus knowledge to a chemical context (Hoban, Finlayson, & Nolan, 2013). Chemistry educators agree that many students experience difficulty with mathematics (Hoban et al., 2013). However, there is disagreement whether the difficulty is due to an inadequate knowledge of mathematics or to an inability to transfer mathematical knowledge into a chemical context (Potgieter, Harding, & Engelbrecht, 2008). Potgieter et al. (2008), Hoban et al. (2013) found that the cause is rooted in students' lack of knowledge of mathematics, rather than an inability to apply the knowledge. Meanwhile, Hewson (2011) stated that students' inability to translate mathematical knowledge to chemical behaviour is one of reasons for that difficulty.

In chemical kinetics, besides handling mathematical operations, students are also required to understand chemical concepts including terminology, definitions and chemical principles, and to interpret diagrams and relate kinetics to other topics such as thermodynamics (Justi, 2002). This implies that besides having a good understanding of the concepts students are also required to have sound mathematical skills to succeed in chemical kinetics. Students' proficiency in calculus is one of the factors that influences their performance in physical chemistry (Hahn & Polik, 2004; Nicoll & Francisco, 2001). However, both groups disagreed about the optimum number of mathematics modules a student should take. Nicoll and Francisco (2001) stated that there is no relationship between the number of mathematics modules taken and students' performance in physical chemistry, while Hahn and Polik (2004) reported a positive correlation between the two factors.

6.1.2 A definition of algorithmic and pictorial questions

Chemical concepts can be categorised when processed by three representations: macroscopic, microscopic and symbolic. To be successful in a chemistry course, students have to understand several chemical concepts in many modules. These concepts can be provided to students in different formats, two of which are algorithmic and conceptual (Costu, 2010; Mason, Shell, & Crawley, 1997). The algorithmic model tests students' proficiency in selecting the correct mathematical formula and using it to get a numerical answer, while the conceptual model tests students' proficiency in selecting appropriate ideas to solve a problem, and making the correct links between the three representations of chemical concepts (Costu, 2010). An algorithmic question generally requires students to manipulate a formula to compute a numerical answer, while a conceptual one requires students to interpret a diagram, plot or graph (pictorial based) or interpret a text (Nakhleh, 1993). The conceptual question provides an opportunity for students to apply critical thinking, while the algorithmic one generally only requires students to do multi-step "plug-and-chug" substitutions in order to arrive at the correct answer (Pushkin, 1998). Bowen and Bunce (1997) stated that conceptual understanding relies on students' ability to deal with chemical problems using the three levels of representations (macroscopic, microscopic, and symbolic).

Chemical kinetics can be understood on the microscopic level. Gabel (1999) found that when students received instructions using microscopic representations they demonstrated a better understanding of the macroscopic and symbolic representations over students who did not receive microscopic instructions. The study showed that chemistry instruction on the microscopic level improves students' ability to make the correct link between the three levels and enhances students' understanding of the chemical concepts (Gabel, 1999). The study conducted by Sanger (2000) corroborates the previous finding that students showed a better understanding of conceptual questions after receiving chemistry teaching that includes microscopic representations.

6.1.3 The difference between students' ability to solve conceptual and algorithmic questions

Two decades ago many chemistry educators focussed more on numerical questions when assessing their students under the assumption that students' success in answering numerical questions reflects the degree of their understanding of related chemical concepts (Bodner & Herron, 2002). Before this there had been some published work into students' problem-solving ability in the non-mathematical domain, particularly related to the concept of conceptual versus algorithmic understanding (Salta & Tzougraki, 2011).

Chemistry educators' interest in students' conceptual and algorithmic understanding was prompted by Nurrenbern and Pickering (1987) who found that many university students answered algorithmic questions correctly, but failed to answer equivalent conceptual ones (Sanger, 2000). Following Nurrenbern and Pickering's study, many other studies reported that some students solve algorithmic problems without fully understanding the concepts underlying the problem (BouJaoude, Salloum, & Abd-El-Khalick, 2004; Nakhleh & Mitchell, 1993; Pickering, 1990; Salta & Tzougraki, 2011; Smith & Metz, 1996; Yan & Subramaniam, 2016). Pickering (1990) found that students' weakness in answering conceptual questions is not an inherent lack of ability, but due to insufficient factual knowledge. Meanwhile, Cracolice, Deming, and Ehlert (2008) concluded that students' lack of scientific reasoning is the main reason for this inability to solve conceptual questions.

Pushkin (1998) stated that students' conceptual and algorithmic abilities can be improved by providing more opportunities for students to demonstrate both. Giving the same task in a microscopic representation can also help reveal students' misconceptions (Prilliman, 2014). Therefore, an investigation into students' ability to address the two styles of questions is timely (Mason et al., 1997). To identify students' ability to solve equivalent conceptual and algorithmic questions, a conceptual-algorithmic pair instrument has been implemented by previous researchers. Nurrenbern and Pickering (1987), pioneers of this area of research, used standard numerical questions for the algorithmic set and pictorial representations for the conceptual set. Nakhleh (1993) used numerical questions for the algorithmic set and drawings and text interpretation for the conceptual set. Costu (2010) and Salta and Tzougraki (2011) used common numerical questions for the algorithmic set and interpretation of text questions for the conceptual set. Meanwhile, Halakova, Zuzana, and Miroslav (2007) explored the use of verbal and pictorial questions.

In this (my) study, equivalent pictorial and algorithmic question pairs were used to identify students' ability in solving the two types of questions. The pictorial questions represent the conceptual set, while the numerical questions represent the algorithmic one. The use of pictorial questions to represent the conceptual set has been carried out by many previous authors such as Nurrenbern and Pickering (1987) in gas laws and stoichiometry, Pickering (1990) in gas laws; Sawrey (1990) in gas laws and stoichiometry; Nakhleh (1993) in gas laws and stoichiometry; Smith and Metz (1996) in acid and base chemistry; Mason et al. (1997) in density, stoichiometry, bonding, and gas laws; Sanger (2000) in pure substances and mixtures; Costu (2010) in solubility, chemical calculations, chemical equilibrium and radioactivity; Salta and Tzougraki (2011) in the law of conservation of matter; Sanger, Vaughn, and Binkley (2013) in gas laws, and others. In addition, the previous findings from Gabel (1999) and Sanger (2000) imply that students' ideas regarding the microscopic representation of chemical concepts generally represent students' conceptual understanding. The same finding is also revealed by LaDue, Libarkin, and Thomas (2015) that visual or pictorial assessment types can more truly reveal students' understanding. Similarly, Potgieter et al. (2008) strongly recommended the use of a pictorial approach in chemistry teaching and learning in order to improve students' conceptual understanding.

In this (my) study, the authors did not implement a separate instrument to assess whether students are preferentially algorithmic or conceptual problem solvers. Three equivalent algorithmic and pictorial question pairs were purposefully designed to be included in the final FTDICK instrument (Appendix G). These pairs of questions are: Q5-Q6[1]; Q11 – Q3 and Q8 – Q18. Q5, Q8 and Q11 represented algorithmic questions, while Q3, Q6 and Q18 represented pictorial questions.

6.2 AN ANALYSIS OF STUDENTS' SCIENTIFIC UNDERSTANDING WHEN ANSWERING ALGORITHMIC AND PICTORIAL QUESTIONS

A comparison of students' scientific understanding judged by their responses to the two types of questions is based on the percentage of students' correct answers to each type of questions as presented in Table 6.1 below.

Table 6.1. The percentages of students giving correct answers to algorithmic and pictorial questions

Q	Algorithmic (%)						Q	Pictorial (%)					
	A tier	CR(TA)	R tier	CR(TR)	B tier	CR(TB)		A tier	CR(TA)	R tier	CR(TR)	B tier	CR(TB)
Q5	61.49	3.7	52.24	3.8	46.27	3.92	Q6	18.51	3.7	20.60	3.3	10.75	3.57
Q11	19.10	3.1	11.94	2.9	4.18	2.82	Q3	25.97	3.2	16.12	2.9	10.75	3.08
Q8	45.67	3.2	37.31	2.9	28.06	3.2	Q18	37.31	3.3	31.04	3.1	23.58	3.25

Table 6.1 above depicts the results from the 3 algorithmic – pictorial question pairs: Q5-Q6, Q11-Q3 and Q8-Q18. In the Q_pair 1 (Q5 and Q6) the number of students getting the correct answer to the algorithmic question is higher than the number of students getting the correct answer to the pictorial question in all tiers. The same result is also shown by Q_pair 3 which are Q8 and Q18. This corroborates the findings of Salta and Tzougraki (2011) which concluded that students gave correct answers more frequently to algorithmic questions than conceptual ones in all topics tested which included density, stoichiometry, molarity and the gas laws. The same result was also found by Sawrey (1990). On the other hand, in the Q_pair 2 (Q11 and Q3) the number of students getting the correct answer to the pictorial question is higher in all the tiers. Overall though when all three question pairs are considered the number of students

[1] Q5 = question number 5 in the FTDICK instrument and represents an algorithmic question, while Q6= question number 6 in the FTDICK instrument and represents a pictorial question. This pattern is also applicable for Q11-Q3 and Q8-Q18

giving the correct answers to the algorithmic questions is higher than those giving the correct answers to the conceptual questions.

Table 6.1 also shows students' confidence ratings when answering algorithmic and pictorial questions. The CR(TA) mean of the algorithmic question is 3.3 while the mean of the pictorial one is 3.4. The CR(TR) mean of the algorithmic question is 3.2 while the mean of the pictorial one is 3.1. The CR(TB) mean of the algorithmic question is 3.3 while the mean of the pictorial one is 3.3. All these values show that students' scientific understanding falls in the *moderate* category and that for these questions their confidence is the same whether they are answering the question in algorithmic or pictorial format. This is at odds with the study by Potgieter et al. (2008) that found students' confidence in answering an algebraic/algorithmic question is higher than when answering the same question in graphical format. Due to the limited number of algebraic/algorithmic questions in this study, this result is not statistically robust enough to challenge the previous result published by Potgieter et al. (2008) above.

6.2.1 Detailed comparison of students' answer combinations to equivalent algorithmic and pictorial questions

Students' responses to these questions were also categorized based on the number of students giving particular combinations of answers to the algorithmic and pictorial questions. The frequencies are tabulated in Table 6.2. A correct answer to an algorithmic question was coded as A1 and a correct answer to a pictorial question was coded as P1. An incorrect answer to an algorithmic question was coded as A0 and an incorrect answer to a pictorial question was coded as P0. Thus, four possible combinations of responses for each pair of questions are possible and the results presented below.

Table 6.2. The number of students giving different combinations of responses to the algorithmic and pictorial questions (N=335)

	Algorithmic – pictorial pairs								
	Q5-Q6			**Q11-Q3**			**Q8-Q18**		
	A tier	R tier	B tier	A tier	R tier	B tier	A tier	R tier	B tier
A1P1	51	46	27	17	8	3	78	67	58
A1P0	155	129	128	47	32	11	75	58	36
A0P1	11	23	9	70	46	33	47	37	21
A0P0	118	137	171	201	249	288	135	173	220

A1P1: both algorithmic and pictorial correct; A1P0: algorithmic correct, pictorial incorrect;
A0P1: algorithmic incorrect, pictorial correct; A0P0: both algorithmic and pictorial incorrect

Table 6.2 shows that for the Q5-Q6 pair, the number of students getting both the R tier and the B tier incorrect for both types of presentations of questions (A0P0) is the highest. For the A tier the number of students obtaining the correct answer for the algorithmic presentation (A1P0) is the highest. For all tiers, the number of students getting the algorithmic question correct (A1P0) is significantly higher than the number getting the pictorial question correct (A0P1). This corroborates the findings previously published by Nakhleh (1993). She found that in four topics investigated (out of 5) i.e. the gas laws, balancing chemical equations, limiting reagent, and density, a higher number of students obtained the correct answer for the algorithmic question and an incorrect answer for the conceptual one than students who obtained a correct answer for the conceptual question but incorrect answer for the algorithmic one.

For the Q8-Q18 pair, the number of students who obtained the wrong answers for both types of questions (A0P0) in all tiers is higher than any other combination of responses. This suggests students struggle with the concepts no matter how the question is presented. The number of students getting the correct values for the algorithmic question (A1P0) is higher than the number obtaining incorrect values for the pictorial one (A0P1) in all the tiers. The same results were also found by Nakhleh and Mitchell (1993) that 41.7% chemistry students had a low conceptual ability but high algorithmic ability, while 5% students had a high conceptual ability but a low algorithmic one. Another published study revealed that 10% of students had a high ability in both algorithmic and conceptual questions; 65% students had a high algorithmic ability and low conceptual ability; 0% student had a high conceptual ability but low algorithmic ability and 25% students had a low ability in both algorithmic and conceptual questions (Mason et al., 1997). The same results were also published by Cracolice et al. (2008), Nakhleh (1993), Pickering (1990), Salta and Tzougraki (2011) and Sawrey (1990).

For the Q11-Q3 pair, the proportion of students getting both the algorithmic and conceptual questions wrong (A0P0) is the largest and greater than any other combination of responses in all the tiers. The proportion of students getting both algorithmic and conceptual questions correct (A1P1) is the lowest in all tiers, again suggesting that most students struggled with this concept no matter how it was presented. For this question pair, the number of students getting the algorithmic question wrong but the conceptual question correct (A0P1) is greater than the inverse situation (A1P0) for all the tiers. This is at odds with previously published findings as discussed above as most previous studies have found that students are generally more successful at solving algorithmic questions compared to conceptual ones. The reason for this odd result could be the use of the pressure of $NO_2(g)$ in the algorithmic type question (Q11) rather than the more familiar concentration term in the pictorial type (Q3). This is similar to the questions given in the preliminary study. One question involved a first-order reaction in the aqueous phase, while another question involved a first-order reaction in the gas phase. The number of students giving a correct answer to the former question is higher than that to the latter one. In the former question, the amount of reactant was presented as a concentration with a unit of moldm^{-3}, while in the latter question it was presented as a pressure in units of torr. As a result, many students did not realize that the integrated first-order rate law, $\ln[A]_t = \ln[A]_0 - kt$, can be applied in answering the latter question by substituting the concentration, [A], by pressure (P).

In most studies, the number of students answering the algorithmic questions correctly is higher. Nakhleh (1993) found only a small fraction of students attained a higher conceptual grade over the algorithmic grade. Stamovlasis, Tsaparlis, Kamilatos, Papaoikonomou, and Zarotiadou (2005) investigated Greek students' responses to questions in the Greek national examination and categorised the questions in terms of *simple-algorithmic*, *demanding-algorithmic* and *conceptual*. They showed that students' ability to answer *simple-algorithmic* questions correctly was better than their ability to answer *conceptual* ones, whereas students' performance in *demanding-algorithmic* questions was lower than their performance in *conceptual* ones. In a separate study a small fraction of students showed better performance in conceptual questions compared to algorithmic ones (Nakhleh & Mitchell, 1993).

6.3 STATISTICAL TESTS ON STUDENTS' ABILITY TO ANSWER ALGORITHMIC AND PICTORIAL QUESTIONS

Comparative statistics of students' ability to answer algorithmic and pictorial questions are described based on the results of Wilcoxon Signed-Rank test and Spearman Rho (ρ) test. These are nonparametric tests and are alternatives to the paired t-test and Pearson's product-moment correlation respectively which are parametric statistics. Those are appropriate as one of the assumptions for the parametric test, i.e. normal distribution of data, was not met.

6.3.1 Tabulation of students' correct answers for the two types of questions

Table 6.3 shows the mean values of students' correct answers. The highest mean score that can be achieved is 1 as each correct answer is given a score of 1 and an incorrect answer a score of 0. The table reveals that the mean scores in algorithmic questions are generally higher than the mean scores in pictorial ones. 6 responses (out of 9) including Q5_A; Q5_R: Q5_B; Q8_A; Q8_R and Q8_B from algorithmic questions have higher mean scores than the mean scores of the equivalent conceptual questions (Q6_A; Q6_R; Q6_B; Q18_A; Q18_R and Q18_B). Meanwhile, the others 3 responses including

Q11_A; Q11_R and Q11_B have higher mean scores for the pictorial questions compared to the responses for the equivalent algorithmic questions (Q3_A: Q3_R; Q3_B).

Table 6.3 Descriptive statistics of students' answers to algorithmic and pictorial questions

	Descriptive Statistics (N = 335)			
	Algorithmic	**Mean**	**Pictorial**	**Mean**
Q_pair 1	Q5_A	0.61	Q6_A	0.19
	Q5_R	0.52	Q6_R	0.21
	Q5_B	0.46	Q6_B	0.11
Q_pair 2	Q11_A	0.19	Q3_A	0.26
	Q11_R	0.12	Q3_R	0.16
	Q11_B	0.04	Q3_B	0.11
Q_pair 3	Q8_A	0.46	Q18_A	0.37
	Q8_R	0.37	Q18_R	0.31
	Q8_B	0.28	Q18_B	0.24
	Average	**0.34**	**Average**	**0.22**

The average mean scores of each algorithmic question (0.34) is higher than the average mean scores of each pictorial one (0.22). The difference between the scores for the two types of questions is quite significant. This implies that students' ability in solving algorithmic questions is better than their ability in answering pictorial questions. This result is in line with previous findings as mentioned above (Cracolice et al., 2008; Nakhleh, 1993; Nakhleh & Mitchell, 1993; Niaz, 1995; Pickering, 1990; Salta & Tzougraki, 2011; Sawrey, 1990; Zoller, Lubezky, Nakhleh, Tessier, & Dori, 1995).

Table 6.4 below gives a comparison of students' correct answers to algorithmic and pictorial questions. In the A tier for Q_pair 1, 155 students had a higher score for the algorithmic question than the pictorial one. Only 11 students had a higher pictorial score and 170 students had the same score in each type of question. The overwhelming number of students getting the correct answer to the algorithmic questions compared to the equivalent pictorial ones is also corroborated by the higher mean score from the algorithmic questions (0.61) compared to the pictorial ones (0.19). In the R tier, 129 students had a higher score for the algorithmic questions compared to the pictorial ones. Only 23 students had a higher pictorial score and 183 students had an equal score in both types of questions. The mean scores for the two types of questions (0.52 algorithmic; 0.21 pictorial) also confirm the discrepancy. For the B tier, 128 students had a higher algorithmic score than a pictorial score. Only 9 students had a higher pictorial score and 198 students had an equal score in both types of questions. The large difference in the number of students getting the correct answer in the two types of questions is supported by the significant difference in the mean scores (0.46 for algorithmic; 0.11 for pictorial).

Table 6.4 Rankings of students' answers to algorithmic and pictorial questions

Question pair	Rank		N
Q_pair 1	Q6_A - Q5_A	Negative Ranks	155
		Positive Ranks	11
		Ties	169
	Q6_R - Q5_R	Negative Ranks	129
		Positive Ranks	23
		Ties	183
	Q6_B - Q5_B	Negative Ranks	128
		Positive Ranks	9
		Ties	198
Q_pair 2	Q3_A - Q11_A	Negative Ranks	47
		Positive Ranks	70
		Ties	218
	Q3_R - Q11_R	Negative Ranks	32
		Positive Ranks	46
		Ties	257
	Q3_B - Q11_B	Negative Ranks	11
		Positive Ranks	33
		Ties	291
Q_pair 3	Q18_A - Q8_A	Negative Ranks	75
		Positive Ranks	47
		Ties	213
	Q18_R - Q8_R	Negative Ranks	58
		Positive Ranks	37
		Ties	240
	Q18_B - Q8_B	Negative Ranks	36
		Positive Ranks	21
		Ties	278

Negative Ranks: score for algorithmic questions is higher
Positive Ranks: score for pictorial questions is higher
Ties: scores for algorithmic and pictorial questions are equal

For Q_pair 2, in the A tier, 47 students had a higher algorithmic score than a pictorial one. However, 70 students had a higher pictorial score and 218 students had an equal score in both types of questions. The mean score for the pictorial question (0.26) is only slightly higher than the mean score for the algorithmic one (0.19). For the R tier, 32 students had a higher algorithmic score than a pictorial one. However, 46 students had a higher pictorial score and 257 students had an equal score in the two types of questions. As in the previous tier, the difference in mean score between the two types of questions is quite small (0.12 for algorithmic; 0.16 for pictorial). For the B tier, 11 students had a higher algorithmic score than a pictorial score. However, 33 students had a higher pictorial score and 291 students had an equal score in the two types of questions. The mean score of algorithmic questions (0.04) in this tier is also lower than the mean score of the pictorial one (0.11). Both are very low.

For Q_pair 3, in the A tier, 75 students had a higher algorithmic score than a pictorial one. However, 47 students had a higher pictorial score and 213 students had an equal score in the two questions. The mean score of the algorithmic question (0.46) is only slightly higher than the mean score of the pictorial one (0.37). For the R tier, 58 students had a higher algorithmic score than a pictorial one. However, 37 students had a higher pictorial score and 240 students had an equal score in the two types of questions. The mean score in the two types of questions is almost equal with 0.37 for the algorithmic question and 0.31 for the pictorial one. For the B tier, 36 students had a higher algorithmic score than for the pictorial one. However, 21 students had a higher pictorial score and 278 students had an equal score in the two types of questions. The mean score for the two types of questions is also almost equal with 0.28 for the algorithmic question and 0.24 for the pictorial one.

Overall, the results from students' responses to algorithmic and pictorial questions as presented in Table 6.1 – Table 6.4 confirm that students generally have a higher performance in algorithmic style questions than in pictorial ones. This is in agreement with previously published studies (Bilgin, 2006; BouJaoude et al., 2004; Cracolice et al., 2008; Halakova et al., 2007; Mason et al., 1997; Nakhleh, 1993; Nakhleh & Mitchell, 1993; Niaz, 1995; Pickering, 1990; Salta & Tzougraki, 2011; Sawrey, 1990; Zoller et al., 1995).

6.3.2 The difference in students' ability in the two types of questions

As explained above, the Wilcoxon Signed-Rank Test was implemented in order to investigate whether students' ability in algorithmic questions is significantly different from their ability in answering pictorial questions. Table 6.5 below shows the statistical difference in students' ability in the two types of questions in each question pair for each tier.

Table 6.5 Wilcoxon statistical test of students' answers to algorithmic and pictorial questions

	Q_Pair 1			Q_Pair 2			Q_Pair 3		
	Q5_A/Q6_A	Q5_R/Q6_R	Q5_B/Q6_B	Q3_A/Q11_A	Q3_R/Q11_R	Q3_B/Q11_B	Q18_A/Q8_A	Q18_R/Q8_R	Q18_B/Q8_B
Z	-11.18	-8.60	-10.17	-2.13	-1.59	-3.32	-2.54	-2.16	-1.99
Sig. (2-tailed)	0.000	0.000	0.000	0.033	0.113	0.001	0.011	0.031	0.047

Table 6.5 shows that in the column headed "Q_pair 1", the Z scores of Q5_A/Q6_A (for A tier); Q5_R/Q6_R (for R tier) and Q5_B/Q6_B (for B tier) are very low with -11.18, -8.60 and -10.17. The *p*-values of all three pairs are 0.000 and less than 0.05. These figures imply that in this question pair, students' ability in algorithmic questions is significantly different to their ability in pictorial ones. The mean scores in the two types of questions as presented in Table 6.3 above confirm this difference. The same conclusions are also revealed from the column headed "Q_pair 3". The *p*-values of all tiers are less than 0.05 demonstrating the significant difference between students' ability in the two question types. This confirms that students' ability in algorithmic questions is better than their ability in pictorial ones. A similar statistically significant result was also shown by Nakhleh (1993), Niaz (1995), Zoller et al. (1995), Salta and Tzougraki (2011), Halakova et al. (2007) and Cracolice et al. (2008).

Meanwhile, in the column headed “Q-pair 2”, the Z scores of Q3_A/Q11_A (for A tier) and Q3_B/Q11_B (for B tier) are -2.13 and -3.32 respectively. The *p*-values of the tiers are 0.033 and 0.001 respectively (both lower than 0.05). This implies that students' ability in algorithmic questions is statistically different from students' ability in pictorial ones. However, for Q3_R/Q11_R (also in the column headed “Q-pair 2”), the Z score is -1.59 and the *p*-value is 0.133 (higher than 0.05). This shows that students' ability in this algorithmic question is not statistically different from the algorithmic one. The mean scores (Table 6.3) for these two types in this pair show a higher score for the pictorial questions (0.16 over 0.12). However, the difference mean score between the two types of questions is insufficient to claim that students' ability in pictorial questions is better than their ability in algorithmic ones.

The majority of the statistical results displayed above demonstrate a significant difference in terms of students doing better in algorithmic questions as shown by six pairs: i.e. Q5_A/Q6_A; Q5_R/Q6_R; Q5_B/Q6_B; Q18_A/Q8_A; Q18_R/Q8_R; Q18_B/Q8_B. The opposite result is only shown for two pairs including Q3_A/Q11_A and Q3_B/Q11_B. Therefore, it can be concluded that, as in previously reported studies, students who participated here exhibited better ability in answering algorithmic questions and giving reasons for their answers, over pictorial ones.

6.3.3 The correlation between students' ability in the two types of questions

The correlation between students' ability to correctly answer algorithmic questions and their ability to answer pictorial questions were calculated statistically using Spearman Rho (ρ) correlation as presented in Table 6.6 below.

Table 6.6 Spearman Rho correlation of students' ability to answer algorithmic and pictorial questions (N=335)

	Q_Pair 1			Q_Pair 2			Q_Pair 3		
	Q5_A/Q6_A	Q5_R/Q6_R	Q5_B/Q6_B	Q3_A/Q11_A	Q3_R/Q11_R	Q3_B/Q11_B	Q18_A/Q8_A	Q18_R/Q8_R	Q18_B/Q8_B
ρ	0.203	0.147	0.200	0.007	0.039	0.072	0.259	0.376	0.561
Sig.	0.000	0.007	0.000	0.905	0.478	0.188	0.000	0.000	0.000

Table 6.6 demonstrates that in the column headed “Q_pair 1”, the Spearman Rho (ρ) coefficients of Q5_A/Q6_A (for A tier); Q5_R/Q6_R (for R tier) and Q5_B/Q6_B (for B tier) are positives but quite low at 0.203; 0.147 and 0.200 respectively. The *p*-values of the three tiers (0.000; 0.007 and 0.000 respectively) are lower than 0.05 meaning that students' ability in algorithmic questions is correlated significantly with students' ability in pictorial ones. However, the ρ-values confirm that the correlation is very weak. This means that when students answer the algorithmic question correctly, the possibility of answering the equivalent pictorial one correctly is low and vice versa. This corroborates

with the previous finding that students' success in answering algorithmic questions is not a guarantee of success in answering equivalent conceptual ones (Zoller et al., 1995). Zoller et al. (1995) revealed that from the 5 groups they investigated and from all participants combined, the only significant correlation between students' ability in the two types of questions was for one group only which was Purdue university students.

In the column headed "Q_pair 2", the Spearman Rho (ρ) coefficients of Q3_A/Q11_A (for A tier); Q3_R/Q11_R (for R tier) and Q3_B/Q11_B (for B tier) are positives but remarkably low at 0.007; 0.039 and 0.072 respectively. The *p*-values of the three tiers (0.905; 0.478 and 0.188 respectively) are higher than 0.05 meaning that students' ability in algorithmic and students' ability in pictorial questions is not correlated significantly. This is similar to the previously published findings that students' ability in conceptual and algorithmic questions are independent of each other (Costu, 2010; Stamovlasis et al., 2005).

In the column headed "Q_pair 3", the Spearman Rho (ρ) coefficient of Q8_A/Q18_A (for A tier); Q8_R/Q18_R (for R tier) and Q8_B/Q18_B (for B tier) are positives and slightly higher than the previous two pairs with 0.259; 0.376 and 0.561 respectively. The *p*-values of the three tiers are all 0.000 meaning that the students' ability in algorithmic and pictorial questions is correlated significantly. The ρ-values confirm that the correlation is still weak. This means that when students answer the pictorial questions correctly, the possibility of answering the equivalent algorithmic ones correctly is not really related. The converse finding was revealed by Niaz (1995) who showed there is a relationship between students' ability in answering algorithmic and conceptual questions.

6.4 STUDENTS' MISCONCEPTIONS SHOWN BY ANSWERING ALGORITHMIC AND PICTORIAL QUESTIONS

The comparison of students' misconceptions when answering the two types of questions presented here is based on the combinations of students' wrong answer – wrong reason selections in equivalent questions. A detailed description of students' misconceptions has been discussed in Chapter 5. The criteria used to classify a response as a misconception and to be highlighted in this comparison are:

1. The percentage of students exhibiting the misconception is greater than 5% or
2. The percentage of students exhibiting the misconception is less than 5%, and CR(TB) is greater than 3.5

6.4.1 Q_Pair 1

This pair involves Q5 which is an algorithmic-type question and Q6 which is a pictorial-type question. Both questions are intended to investigate students' ability to determine the effect of concentration changes on the reaction rate. Q5 focusses on the change in concentration of reactants that are zero and second-order while Q6 involves first and second-order reactants.

In both questions, students were required to carry out a calculation which involved raising the concentration of the reactant by the appropriate power dependent upon its order in the chemical reaction. Student responses resulted in different classifications for the difficulty level of each question. The difficulty level of Q5 was considered *moderate*, while Q6 was considered *difficult*. Meanwhile, the confidence ratings suggest that students' scientific understanding falls into the *moderate* category for both questions. In addition, the results revealed students made simple mathematical errors when carrying out both calculations. The frequency of students displaying unscientific understanding is presented in Table 6.7 below.

Table 6.7 Frequency of students' unscientific understanding in Q_pair 1

Type	WAWR	N, %	CR(TB)	Criteria
Algorithmic (Q5)	Q5_BB	6.27	3.1	*Genuine* misconception (*moderate*)
	Q5-BC	35.22	2.75	*Genuine* misconception (*moderate*)
	Q5-DD	1.19	3.54	*Genuine* misconception (*moderate*)
Pictorial (Q6)	Q6-AA	31.04	3.38	*Genuine* misconception (*moderate*)
	Q6-CB	10.45	2.87	*Genuine* misconception (*moderate*)
	Q6-DA	2.09	3.71	*Genuine* misconception (*moderate*)
	Q6-DD	7.76	3.0	*Genuine* misconception (*moderate*)

WAWR = Wrong answer – wrong reason combination indicating misconception

Table 6.7 demonstrates that misconceptions arise in both types of questions. The frequency of students' misconceptions in Q6, the pictorial-style question, is slightly higher than the frequency in Q5, the algorithmic question. The highest frequency is shown in Q5 with N = 35.22%, while the highest confidence rating is shown in Q6 with CR(TB) = 3.71. All misconceptions in this Q_pair 1 are *genuine* and fall in the *moderate* category. In Q5, the students' misconception is mainly related to the dependence of reaction rate on concentration for a zero-order reactant. Meanwhile, in Q6, the students' main misconception is when the concentration of two reactants involved in a reaction is the same this will lead to a higher reaction rate because the collision ratio of molecules is more favourable. Students' carelessness in interpreting the pictorial representation was also one of the main reasons for students' incorrect answers.

6.4.2 Q_Pair 2

This pair involves Q11 which is an algorithmic-style question and Q3 which is a pictorial question. Both questions were intended to investigate students' understanding of the successive half-lives of a second-order reaction. The difficulty level of both questions is *difficult* and the confidence ratings fall into the *moderate* category. The frequency of students displaying unscientific understanding is presented in Table 6.8 below.

Table 6.8 shows that misconceptions exist in the two types of questions. The frequency of students' misconceptions within Q3 representing the pictorial question is higher than the frequency of students' misconceptions in Q11 representing the algorithmic question. The most common wrong answer and wrong reason combination is found for Q11, the algorithmic question, with a value of 25.07%. The highest confidence rating in the wrong answer wrong reason combination is found for Q3, the pictorial question, with a CR(TB) of 4.0. All misconceptions in Q11 are *genuine* and fall in the *moderate* category. Meanwhile, in Q3, one misconception is *spurious* and falls in the *weak* category, while the misconception with the CR(TB) = 4.0 is *genuine* and falls in the *strong* category. The other five misconceptions are *genuine* and fall in the *moderate* category. In both questions, students made the same mistake. The most popular wrong answer and wrong reason arose when students believed this to be a first-order reaction with a constant half-life.

Table 6.8 Frequency of students' misconceptions in Q_pair 2

Type	WAWR	N, %	CR(TB)	Criteria
Algorithmic (Q11)	Q11-AA	10.75	3.38	*Genuine* misconception (*moderate*)
	Q11-AB	5.97	3.28	*Genuine* misconception (*moderate*)
	Q11-BA	12.84	3.19	*Genuine* misconception (*moderate*)
	Q11-BB	25.07	3.11	*Genuine* misconception (*moderate*)
	Q11-BC	5.07	2.97	*Genuine* misconception (*moderate*)
Pictorial (Q3)	Q3-AA	8.36	2.84	*Genuine* misconception (*moderate*)
	Q3-AB	6.87	2.7	*Spurious* misconception (*weak*)
	Q3-AC	4.78	3.53	*Genuine* misconception (*moderate*)
	Q3-BA	9.25	3.32	*Genuine* misconception (*moderate*)
	Q3-BB	22.09	3.13	*Genuine* misconception (*moderate*)
	Q3-BC	10.75	3.01	*Genuine* misconception (*moderate*)
	Q3-DC	0.60	4.0	*Genuine* misconception (*strong*)

WAWR = Wrong answer – wrong reason combination indicating misconception

6.4.3 Q_Pair 3

In this pair, Q8 is in algorithmic format and Q18 is in pictorial format. Both questions were intended to investigate students' understanding of the relationship between concentration of a first-order reactant at its half-life and the concentration remaining after a particular time. The difficulty level of both two questions is *moderate* and the confidence ratings fall into the *moderate* category. The frequency of students showing unscientific understandings is presented in Table 6.9 below.

Table 6.9 Frequency of students' misconceptions in Q_pair 3

Type	WAWR	N, %	CR(TB)	Criteria
Algorithmic (Q8)	Q8-AB	9.85	2.89	*Genuine* misconception (*moderate*)
	Q8-AC	8.66	2.86	*Genuine* misconception (*moderate*)
	Q8-CB	5.67	2.34	*Spurious* misconception (*weak*)
Pictorial (Q18)	Q18-QAB	10.15	3.16	*Genuine* misconception (*moderate*)
	Q18-AC	8.36	3.02	*Genuine* misconception (*moderate*)
	Q18-AD	7.76	3.17	*Genuine* misconception (*moderate*)
	Q18-CB	6.57	3.02	*Genuine* misconception (*moderate*)

WAWR = Wrong answer – wrong reason combination indicating misconception

Table 6.9 demonstrates that misconceptions exist in both types of questions. The frequency of students' misconceptions in Q18, the pictorial question is slightly higher than the frequency in Q8, the algorithmic question. There is no especially high wrong answer wrong reason combination here. The highest frequency is found for Q18 with a value of 10.15% and a CR(TB) of 3.17. All misconceptions in Q18 are *genuine* and fall in the *moderate* category, while one misconception in Q8 is *spurious* and *falls* in the weak category.

6.5 CHAPTER SUMMARY

In this study, students' ability in answering both algorithmic and pictorial questions is investigated using three algorithmic-pictorial pair questions. In two question pairs, the number of students getting the correct answer to the algorithmic question is higher. This is in line with many previous studies which have shown that students' ability in algorithmic questions is better than their ability in pictorial questions. To ensure that the difference in the number of students giving the correct answer in the two types of questions in each pair is significant, statistical analysis using the Wilcoxon Signed-Rank Test was conducted. The statistical tests confirm that students' ability in the two types of questions is significantly different. This implies that in the two question pairs, students' ability in algorithmic questions is better than students' ability in pictorial questions.

The opposite result was shown in one question pair. In this pair, the number of students getting the correct answer for the pictorial-style question is higher than the number getting the correct answer for the algorithmic one. A statistical test was again conducted using the Wilcoxon Signed-Rank Test. The statistical test confirms that students' ability in the two types of questions is not significantly different. This implies that there is not enough evidence to conclude that students' ability in pictorial questions in this particular question pair is better than their ability in algorithmic questions.

Referring to the statistical results, a robust conclusion in this study “students’ ability in algorithmic questions is better than students’ ability in pictorial questions” is statistically proven. This implies that the finding in this study is in keeping with previous findings.

In addition, the correlation of students’ ability between the two types of questions was statistically investigated using Spearman Rho (ρ) correlation. The result shows that students' ability to solve algorithmic questions is weakly correlated to their ability to solve pictorial questions. This means that when students answer the algorithmic question correctly, the chance of answering the equivalent pictorial one correctly is low. Similarly, when students answer the pictorial question correctly, the chance of answering the equivalent algorithmic one correctly is also low. So far, only a few studies in this area have been carried out to test the statistical correlation between students’ ability in algorithmic and in conceptual/pictorial questions. Therefore, extension work regarding this correlation should be considered in future studies.

It was found that students' confidence ratings when giving a correct answer to an algorithmic question are equal to their confidence when giving a correct answer to a pictorial question. This is at odds with findings published by Potgieter et al. (2008) who showed that students' confidence in answering algebraic/algorithmic questions is higher than when answering graphical questions. However, students more frequently show misconceptions when answering pictorial questions than algorithmic ones. This phenomenon could be a result of students’ inability to identify the relevant information from a pictorial representation such as graph, diagram or table. In addition, mistakes in converting information obtained from a pictorial representation into chemical behaviour may account for misconceptions.

The results of this study imply that promoting students' ability in algorithmic and conceptual type questions is still timely. Chemistry educators are strongly recommended to frequently use pictorial representations when explaining chemical concepts in the class. More importantly, students should be trained in how to identify critical information from a pictorial representation and to transfer this information into chemical behaviour. The use of some learning strategies to improve the visual processing skills of students could be helpful. In addition, practice should be given by including pictorial questions in chemistry tests.

The effect of pictorial representations in chemistry textbooks on students' understanding must be taken into account. Figure 6.1 below describes some diagrams that explain the concept of successive half-lives for a first-order reaction. These diagrams are captured from several general chemistry textbooks.

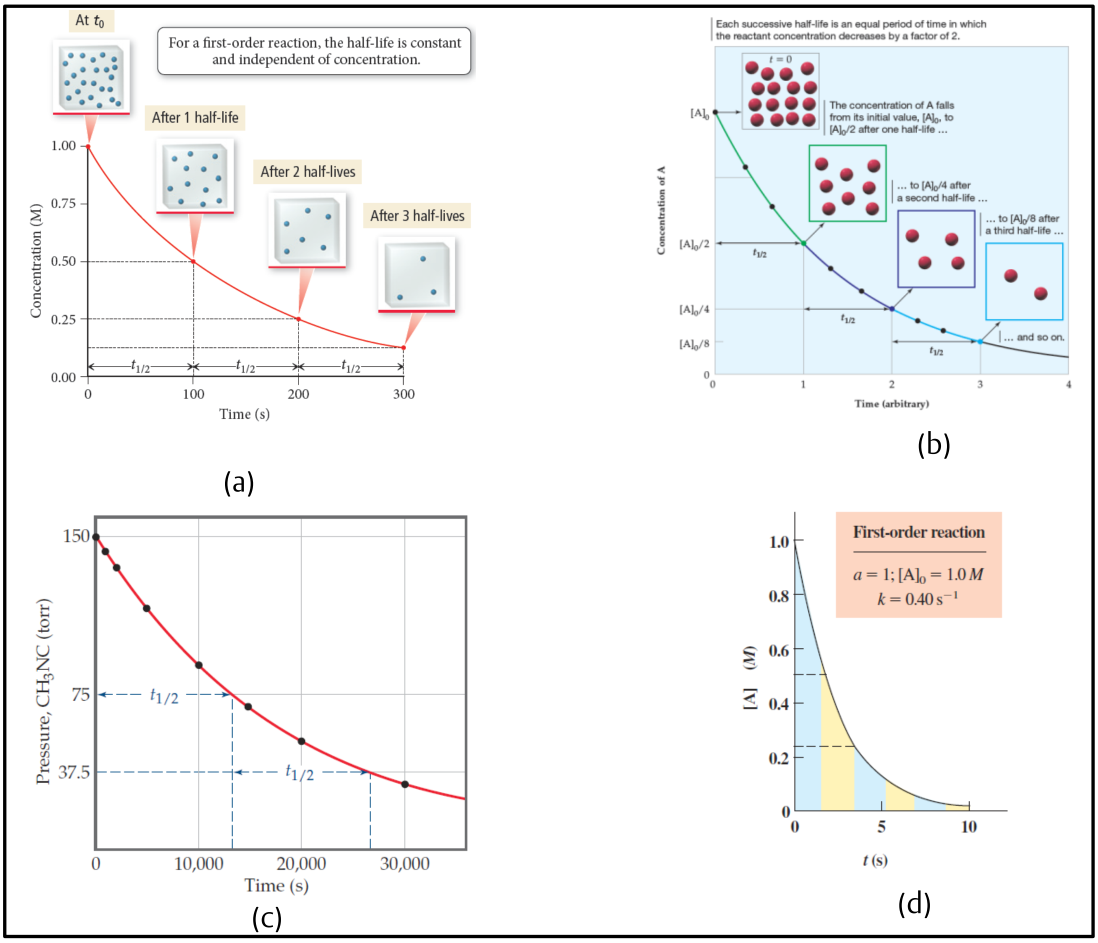


Figure 6.1. Diagrams from chemistry textbooks describing concentration of a reactant as a function of time for a first-order reaction. Source, (Brown et al., 2017; McMurry, Fay, & Robinson, 2016; Tro, 2017; Whitten et al., 2014)

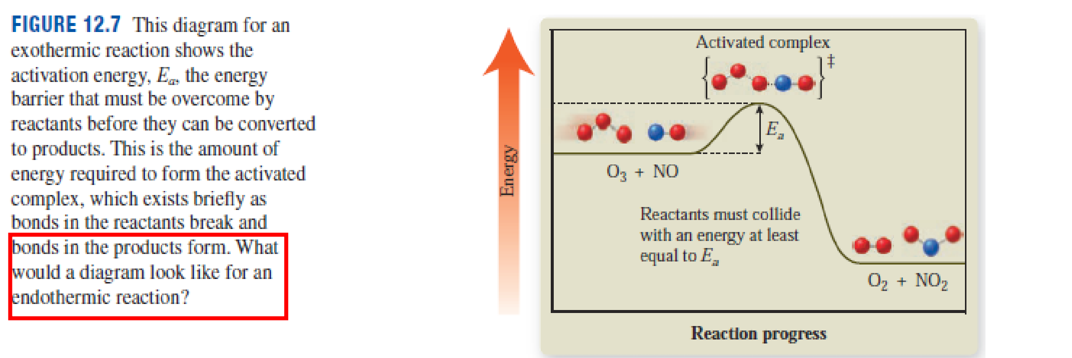
Diagrams (a) and (b) in the Figure 6.1 present a very clear description regarding the successive half-lives of a first-order reaction. In each half-life, the plots in both diagrams depict clearly how the concentration of the reactant is a half of the previous one. The plots of concentrations or amount against time (t) are matched and more understandable for students. For instance, in the (a) diagram, students should understand that after 2 half-lives (at 200 seconds), the concentration of the reactant is 0.25 M. In addition, the pictorial representations on both diagrams depicting the concentration of reactants in each half-life will enhance students' understanding.

Meanwhile, in the (c) diagram, the plot of pressure against time (t) does not help the students to make the link between the two. For instance, students find it difficult to work out exactly what is the t½ when the pressures are 75 torr and 37.5 torr. The diagram in (d) is even worse. Students will get into difficulty working out both the concentration and time at each half-life. In addition, pictorial representations of concentration are also not given in both (c) and (d) diagrams. Therefore, both diagrams may not help students' understanding of the concept of successive half-lives.

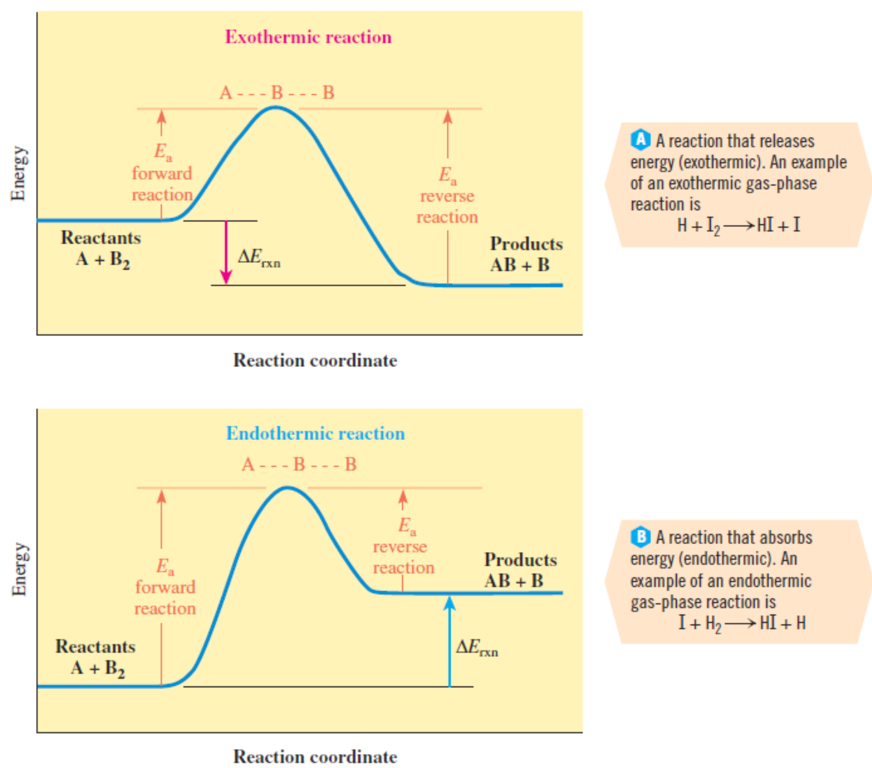
Another example is described in Figure 6.2 below. The figure describes some diagrams which are presented when explaining activation energy, temperature and rate.

In the (a) diagram, the energy profile for an exothermic reaction is provided while the energy profile for endothermic one is not presented. As stated in the text highlighted with the **red box**, the authors seem to want to challenge students to figure out independently the energy profile of the endothermic reaction. Actually, this is a good way to stimulate students' analytical thinking, but the role of a textbook is to provide the explanations not to undermine the confidence of students. However, educators must ensure that their students can work out the correct energy profile of an endothermic reaction otherwise, students may get into difficulty and assume that the energy profile for an exothermic reaction is transferable to an endothermic one.

This analysis is strengthened by a study of school textbooks in Greece. The study revealed that there are some verbal explanations and pictorial presentations in chemical kinetics concepts that do not help students to gain a better conceptual understanding (Gegios, Salta, & Koinis, 2017). These imply that some pictorial representations in chemistry schoolbooks need to be critically evaluated and possibly revised.



(a). source: Bauer, Birk, and Marks (2010)



(b). source: Whitten, Davis, Peck, and Stanley (2014)

Figure 6.2. Diagrams describing energy profiles of endothermic and exothermic reactions

Meanwhile, in the (b) diagram, the energy profiles of both endothermic and exothermic reactions are presented in parallel. This will help students to differentiate correctly between the energy profiles of exothermic and endothermic reactions.

CHAPTER 7

A COMPARISON OF INDONESIAN AND UK STUDENTS' RESPONSES TO THE FTDICK

7.1 INTRODUCTION

The United Nations (UN) and many international organizations have been focused on bridging the gap between developed and developing countries in many areas including education (McNeely, 1995; Woodward, Drager, Beaglehole, & Lipson, 2001). For this reason, many government and non-government organizations from developed countries provide support and opportunities for developing countries to improve in all aspects, particularly in education. For example, the United Stated provides the Fulbright Scholarship Programme for students from other countries to study in the USA. The UK Government provides Chevening Scholarships and Chevening Fellowships. Formal relations between the UK and Indonesia were established in 1949. The UK has a strong interest in helping Indonesia to improve in many areas and also to promote a stable democracy in the South-East Asian region ("UK-Indonesia relations," 2010).

The Programme for International Student Assessment (PISA) revealed that among participating countries in 2015, the UK is ranked 15th and 27th in science and maths respectively, while Indonesia is far below with a ranking of 62nd in science and 63rd in maths (OECD, 2016). This international survey aims to evaluate the educational systems of many countries by testing the skills and knowledge of 15-year-old students. At the university level, the recent report of QS World University Rankings revealed that UK universities, along with the USA, dominate the top 50 universities in the world while the best Indonesian university sat at only 277th position ("QS World University Rankings of 2018," 2017). Although these survey results suggest that comparing Indonesian and UK students' understanding is not appropriate, there is evidence from the literature that such a comparison may be of value. Related research involving a comparison of students' understanding, particularly in chemistry between both countries has not been found in the literature.

However, an earlier study by Rahayu and Kita (2009) revealed that students from both Indonesia and Japan exhibited similar difficulties and misconceptions regarding electrolysis, electricity flow, the voltaic cell and electrode reactions. Japan also far out-ranked Indonesia in terms of the PISA results and QS World University Rankings. A cross-cultural study involving students from the UK, China, Singapore, New Zealand, Spain and the USA found that in general, students from the six countries had similar misconceptions (Tan et al., 2008). Another cross-cultural study involving students from

Nigeria, Japan and South Africa found that students' misunderstanding of the particulate nature of matter was consistent across the three countries (Onwu & Randall, 2006). These results imply that students' misunderstandings can be consistent over both developed and developing countries. As stated by Wan, Yanlan, and Hualin (2015), although their study only focused on China and the United States, the results can be also extended to other countries. Because previous research suggested that similar misunderstandings in certain areas are found internationally, it is appropriate to compare Indonesian and UK students' understanding in chemical kinetics.

A single study, focusing on only a small number of students in three universities from two countries is insufficient to represent a definitive global overview of students' understanding of chemical kinetics. However, comparing students' understanding between the two countries can provide a partial reflection of students' understanding of chemical kinetics globally. This also can provide a picture of students' understanding between a developed and a developing countries and importantly encourage knowledge dissemination particularly from developed to developing countries. Such a study can be of help to school/university staff in improving their teaching practice in chemical kinetics.

In the present study, Indonesian and UK university students' understanding was investigated and compared. Chemistry students from the 1st year of the State University of Malang and Haluoleo University, Indonesia and the University of Reading, UK participated in this study. The instrument used in this study was the FTDICK instrument and is attached in Appendix G.

7.1.1 Chemical kinetics in the secondary school curriculum of two countries

Although students surveyed in this study were in the 1st year of university, their knowledge of chemical kinetics is based on experiences in secondary school and the findings here should impact on the teaching at this level. The data were collected before the participants had experienced any chemical kinetics modules at the university level.

7.1.1.1 Chemical kinetics in the secondary school curriculum in Indonesia

In the Indonesian educational system, students typically complete three levels of formal education before they go to university. These levels are 6 years at elementary school (grade 1 – 6), 3 years at junior high school (grade 7-9) and 3 years at senior high school (grade 10-12). Elementary school is equivalent to primary education, while junior high school together with senior high school is equivalent to secondary education in the UK.

Chemistry in Indonesia is taught in junior high school as an integrated course which is combined with physics and biology and named "natural sciences". The document of basic and core competencies of natural sciences in Junior High School shows that chemical kinetics has not been encountered at this level (Kementrian Pendidikan dan Kebudayaan, 2013). Kementerian Pendidikan dan Kebudayaan is the Ministry of National Education and Culture which has recently been named Ministry of National Education.

At senior high school level, chemistry is taught as a separate course. According to the chemistry syllabus for senior high school, rates of reaction is taught at grade 11. The topic includes factors that affect reaction rates, the rate law, determining reaction order by the initial rate method, the integrated rate law and catalysis (Kementrian Pendidikan dan Kebudayaan, 2016).

7.1.1.2 *Chemical kinetics in the secondary school curriculum in the UK*

In the UK educational system, particularly in England and Wales students should complete two levels of education before they go to university. These levels are 6 years primary education and 5 plus 2 years of secondary education. Based on the Science programmes of study in the National Curriculum as documented by the Department of Education (2014) at Key Stage 4, chemical kinetics involves factors that influence the rate of reaction: temperature and concentration, changing the surface area of a solid reactant or a catalyst. At post 16, kinetics includes collision theory, Maxwell–Boltzmann distribution, catalysis, continuous and initial rate methods, rate-determining step, determination of rate equation (AQA, 2015; OCR, 2013).

It seems that the scope of chemical kinetics taught in secondary schools in the UK (England and Wales) and Indonesia is equivalent. This implies that students' experiences in chemical kinetics before university level can be assumed to be similar for the two groups of students. Therefore, comparing the understanding of students in the two groups is a reasonable exercise.

7.2 ITEM ANALYSIS RESULTS BETWEEN THE TWO GROUPS

7.2.1 Comparison of the Difficulty Level (DL)

The difficulty level of a question represents the number of students answering the question correctly. In the A tier (Table 7.1), none of the questions was considered *easy* for Indonesian students, while 6 questions (out of 20) were considered *easy* for UK students. Equivalent results are seen for the R tier. In the B tier, none of the questions was considered *easy* for Indonesian students, while results showed that 3 questions were *easy* for UK students.

Table 7.1. The number of *easy, moderate* and *difficult* questions in each tier for Indonesian and UK students

Students	**A Tier**			**R Tier**			**B Tier**		
	easy	**moderate**	**difficult**	**easy**	**moderate**	**difficult**	**easy**	**moderate**	**difficult**
Indonesia	0	11	9	0	7	13	0	2	18
UK	6	10	4	6	7	7	3	10	7

The number of *moderate* questions for both groups is almost same for the A (11 for Indonesia & 10 for UK students) and R tiers (7 for both groups). A big difference is shown in the B tier in which 10 questions were considered *moderate* for UK students, but only 2 questions were considered *moderate* for Indonesian students and the majority considered *difficult*.

Indonesian students considered 9 questions to be *difficult* in the A tier, while UK students only considered 4 questions as *difficult*. The percentage of questions in the *difficult* category increases significantly in the R and B tiers for both groups, yet Indonesian students still show higher numbers of *difficult* question in both tiers. 13 and 18 questions in the R and B tiers respectively were considered *difficult* for Indonesian students, while for UK students only 7 questions in each tier were considered *difficult*. To provide a clear comparison of the DL between the two groups, a graphical depiction for each tier is presented below (Figure 7.1).

Figure 7.1 below shows that the DL of 60% of the questions was either *moderate* or *difficult* for both Indonesian and UK students. 8 of those questions, i.e Q2, Q7, Q9, Q10, Q14, Q15, Q16 and Q19, were *moderate*, while 4 other questions, i.e. Q6, Q11, Q12 and Q20 were *difficult*.

Meanwhile, 40% questions in the A tier were categorized as being more difficult for Indonesian students than for UK students. More difficult in this context means the DL indices of those questions are lower among Indonesian students and result in different DL categories. Three of those questions including Q1, Q17 and Q18 were categorized as *difficult* for Indonesian students, but *easy* for UK students. Q3 and Q13 were considered *difficult* for Indonesian students, but *moderate* for UK students. A further three questions (Q4, Q5, and Q8) were considered *moderate* for Indonesian students, yet *easy* for UK students.

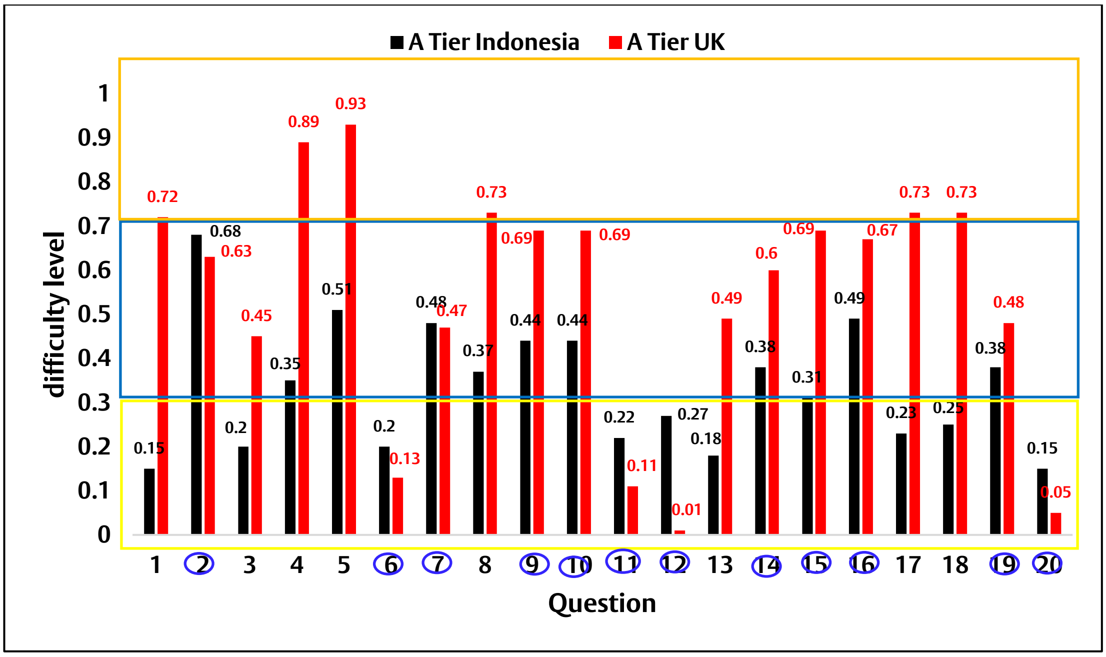


Figure 7.1 DL comparison between Indonesian and UK students in each question for A tier

: *Difficult* : *Moderate* : *Easy*

: Question with equal DL for the two groups

A slightly different percentage is shown for the R tier as presented in Figure 7.2 below. 55% of those questions were either *moderate* or *difficult* for the two groups. 4 questions including Q2, Q10, Q14, and Q16 were *moderate*, while 7 questions including Q3, Q6, Q11, Q12, Q18, Q19 and Q20 were *difficult*.

45% questions in the R tier were categorized as being more difficult for Indonesian students than for UK students. The meaning of more difficult is as explained above. Three questions including Q8, Q15 and Q17 were categorized *difficult* for Indonesian students, but *easy* for UK students. Meanwhile, Q1, Q9, and Q13 were *difficult* for Indonesian students but *moderate* for UK students. Three further questions (Q4, Q5, and Q7) were considered *moderate* for Indonesian students, but *easy* for UK students.

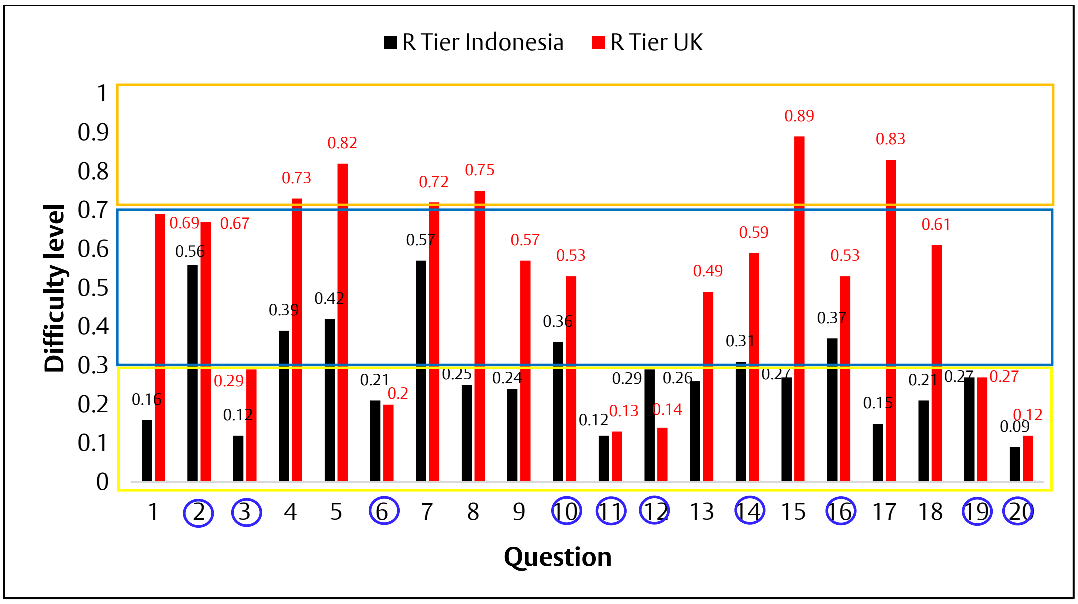


Figure 7.2 DL comparison between Indonesian and UK students in each question for R tier

: *Difficult* : *Moderate* : *Easy*

: Question with equal DL between the two groups

A significant difference is shown in the B tier as presented in Figure 7.3 below. 40% of those questions were either *moderate* or *difficult* for the two groups. Among these questions, only one question (Q2) was *moderate* and a further 7 questions including Q3, Q6, Q11, Q12, Q18, Q19 and Q20 were *difficult*.

60% questions in the B tier were categorized as being more difficult for Indonesian students than for UK students. Two questions including Q4 and Q17 were categorized *difficult* for Indonesian students, but *easy* for UK students. Q5 was considered *moderate* for Indonesian students, but *easy* for UK students. Meanwhile, 9 questions including Q1, Q7, Q8, Q9, Q10, Q13, Q14, Q15, and Q16 were considered *difficult* for Indonesian students, but *moderate* for UK students.

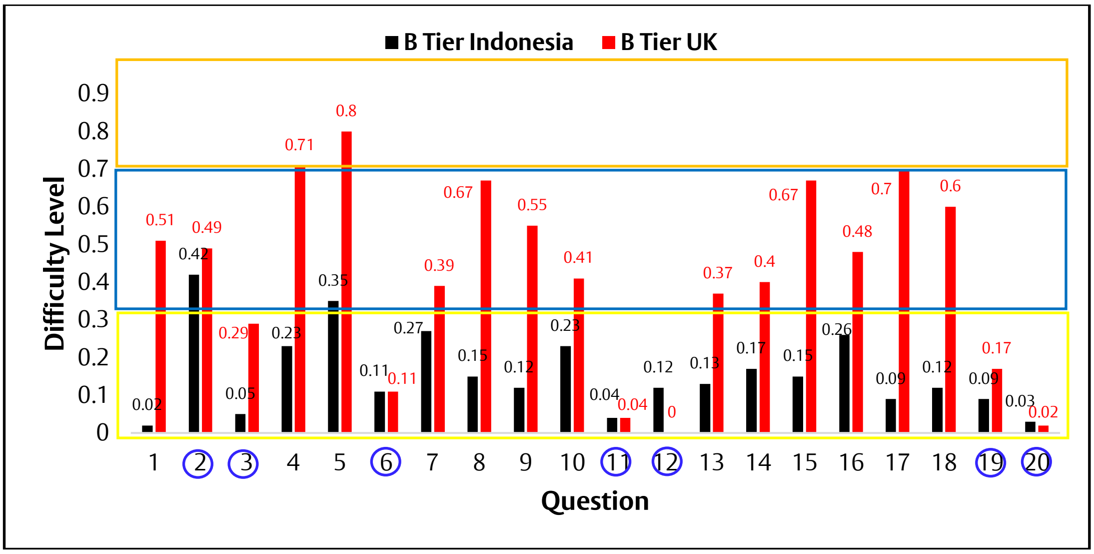


Figure 7.3 DL comparison between Indonesian and UK students in each question for B tier

: *Difficult* : *Moderate* : *Easy*

: Question with equal DL between the two groups

Q2 was considered to be *moderate* in all tiers (A, R and B tiers) for both Indonesian and UK students. When doing a calculation using the integrated rate law of a zero-order reaction, both groups of students made an error in doing selection and substitution. This suggests that improving students' mathematical ability in a chemical context is timely for both Indonesian and UK students.

Difficulty in transferring verbal statements to mathematical operations and carelessness are similar weaknesses shown by both Indonesian and UK students. This is reflected in the low DL indices of Q6 and Q20 in all tiers (A, R and B tiers) for both Indonesian and UK students. This suggests that encouraging students to practise such verbal to mathematical operations would be helpful for both Indonesian and UK students.

There is a large difference in DL indices for Q1 and Q8 for the two groups. Q1 and Q8 involve successive half-lives. These questions were classified as *easy* for UK students but *moderate* and *difficult* for Indonesian students in all tiers. Difficulty with terminology could be a cause of Indonesian students' problems with this topic. This is confirmed by a *genuine* misconception found for Indonesian students that for each successive half-life, the mass change in a first-order reaction is constant.

A similar trend is seen in the topic of rate law as shown in Q4 and Q17 in the A and B tiers. These questions were found to be *difficult* for Indonesian students but *easy* for UK students. However, misconceptions within this topic are found among both Indonesian and UK students.

Significant differences were also found for questions that involved identifying relevant information from a plot/drawing/graph (Q9, Q10, Q13, Q14 and Q16). UK students appear to be able to extract information from a diagram better than Indonesian students. This phenomenon is supported by students' difficulty, particularly Indonesian students in correctly identifying the value of *Ea* and determining the energy profile of endothermic and exothermic reactions from the plot. Misconceptions were also found in both groups, yet again the number of misconceptions experienced by Indonesian students was higher. For instance, only Indonesian students thought that the *Ea* of a catalysed and an uncatalysed pathway is the same.

7.2.2 Comparison of students' correct answers

Table 7.2 below shows that the average percentages of correct answers of UK students are higher than the average percentage of Indonesian students in all tiers. UK students have higher scores than Indonesian students for 70% questions in the A tier, 90% questions in the R tier and 85% questions in the B tier. In the A tier, the average percentage for Indonesian students is 33.39%, while for UK students it is 54%. In the R and B tiers, the average percentages for Indonesian students are 28.09% and 15.69% respectively, while for UK students the equivalent numbers are 53.31% and 41.92% respectively.

Significant differences in the percentage of correct answers for the two groups are shown in Q1, Q4, Q5, Q17 and Q18. The difference between the two groups in these questions is higher than 40%. In other questions, the difference between the two groups ranged from around 18% to 37%. The highest difference is shown in Q1 with values of 57.21%, 52.4% and 48.62% for the A, R and B tiers respectively. These results imply that UK students have a significantly better understanding of chemical kinetics concepts than Indonesian students.

Indonesian students showed slightly better grades for Q11 and Q20. Only in Q12 did Indonesian students perform significantly better than UK students. This question was the poorest for UK students, particularly in the A and B tiers. Only 1.2% students gave the correct answer in the A tier, while none of the students could answer the B tier correctly. Q12 asked for an expression of the rate law of a reaction and provided two steps of a reaction mechanism with one fast step and one slow step. The topic of reaction mechanisms is included in the A-level chemistry specification in the UK and the chemistry syllabus for senior high school in Indonesia. Secondary school students in both countries are taught that a slow step is the rate-determining step. However, the way to determine the overall rate law from the reaction mechanism is not covered in the UK. This explains why UK students cannot answer this question correctly. Surprisingly, although Indonesian students have equivalent teaching to UK students, they performed better in this question with the percentage of correct answers being 26.59%, 29.37% and 11.51% in the A, R and B tiers respectively. In Q11, Indonesian students also showed better grades than UK students, although the difference between the two groups is not as great as in Q12. In Q11, the percentage of Indonesian students giving the correct answer is slightly higher than the percentage of UK students. These figures suggest that Indonesian students are better in dealing with algorithmic questions rather than pictorial ones. A similar trend is also shown in Q6 & Q20 where there is a small difference percentage giving the correct answer in each group.

Table 7.2. The percentage of correct answer in the A, R and B tiers

	Indonesian students (N=252)						UK students (N=83)					
Q	**A tier**	**CR(TA)**	**R tier**	**CR(TR)**	**B tier**	**CR(TB)**	**A tier**	**CR(TA)**	**R tier**	**CR(TR)**	**B tier**	**CR(TB)**
1	15.08	3.8	16.27	2.83	1.98	3.8	72.29	3.8	68.67	3.5	50.60	3.6
2	67.86	3.7	55.56	3.4	42.06	3.9	62.65	3.0	67.47	2.4	49.40	2.8
3	19.84	3.5	11.90	3.2	4.76	3.8	44.58	2.7	28.92	2.6	28.92	2.8
4	35.32	4.3	39.29	3.4	23.41	4.0	89.16	3.9	73.49	3.5	71.08	3.7
5	51.19	3.7	42.46	3.7	35.32	4.0	92.77	3.8	81.93	3.9	79.52	3.9
6	20.24	3.9	20.63	3.6	10.71	3.8	13.25	2.6	20.48	2.6	10.84	2.8
7	48.02	3.8	57.14	3.4	26.59	3.9	46.99	2.2	72.29	2.7	38.55	2.6
8	36.51	3.3	25.00	2.9	15.08	3.5	73.49	2.9	74.70	2.9	67.47	3.0
9	44.44	3.5	23.81	2.8	12.30	3.1	68.67	3.6	56.63	3.8	55.42	3.8
10	43.65	3.4	35.71	3.4	22.62	3.6	68.67	2.7	53.01	2.8	40.96	2.8
11	21.83	3.2	11.51	3.1	4.37	2.9	10.84	2.6	13.25	2.4	3.61	2.7
12	26.59	3.2	29.37	3.0	11.51	3.2	1.20	3.0	14.46	1.7	0.00	0.0
13	17.86	3.9	25.79	3.5	13.49	4.0	49.40	3.0	49.40	2.6	37.35	2.8
14	38.49	4.0	30.95	3.4	16.67	3.9	60.24	3.7	59.04	3.2	39.76	3.5
15	30.95	3.5	26.59	3.4	15.08	4.1	68.67	3.9	89.16	3.9	67.47	4.0
16	49.21	3.6	37.30	3.5	25.79	3.9	67.47	3.1	53.01	3.3	48.19	3.4
17	22.62	3.5	15.48	3.5	8.73	3.9	73.49	3.0	83.13	3.3	69.88	3.2
18	25.40	3.6	21.03	3.5	11.51	3.8	73.49	3.0	68.67	2.7	60.24	2.9
19	38.10	2.9	27.38	2.9	8.73	3.1	48.19	2.6	26.51	2.6	16.87	3.0
20	14.68	3.3	8.73	3.4	3.17	3.8	4.82	1.3	12.05	1.3	2.41	1.0
Ave	**33.39**	**3.58**	**28.09**	**3.29**	**15.69**	**3.7**	**54.51**	**3.02**	**53.31**	**2.8**	**41.92**	**2.9**

Overall, the data show that UK students have a better understanding of chemical kinetics concepts than do Indonesian students. The data obtained in this study cannot explain the cause of the phenomenon. However, the information presented in Tables 7.3 and 7.4 below could be a reason for the difference in students' understanding between the two countries.

Table 7.3 The content of the chemistry syllabus for A-level in the UK. Source: AQA (2015).

AS Chemistry 7404 and A-level Chemistry 7405 AS exams May/June 2016 onwards. A-level exams May/June 2017 onwards. Version 1.1

3.1.5.2 Maxwell–Boltzmann distribution

Content	Opportunities for skills development
Maxwell–Boltzmann distribution of molecular energies in gases. **Students should be able to** draw and interpret distribution curves for different temperatures.	

3.1.5.3 Effect of temperature on reaction rate

Content	Opportunities for skills development
Meaning of the term rate of reaction. The qualitative effect of temperature changes on the rate of reaction. **Students should be able to** use the Maxwell–Boltzmann distribution to explain why a small temperature increase can lead to a large increase in rate.	**AT a, b, k and l** **PS 2.4 and 3.1** Students could investigate the effect of temperature on the rate of reaction of sodium thiosulfate and hydrochloric acid by an initial rate method. **Research opportunity** Students could investigate how knowledge and understanding of the factors that affect the rate of chemical reaction have changed methods of storage and cooking of food.
Required practical 3 Investigation of how the rate of a reaction changes with temperature.	

3.1.5.4 Effect of concentration and pressure

Content	Opportunities for skills development
The qualitative effect of changes in concentration on collision frequency. The qualitative effect of a change in the pressure of a gas on collision frequency. **Students should be able to** explain how a change in concentration or a change in pressure influences the rate of a reaction.	**AT a, e, k and i** Students could investigate the effect of changing the concentration of acid on the rate of a reaction of calcium carbonate and hydrochloric acid by a continuous monitoring method.

Table 7.4 The content of chemistry syllabus for senior high school in Indonesia. source: translated from the document of Kementrian Pendidikan dan Kebudayaan (2016).

Core competencies	Topics	Teaching activities
3.6 Understanding collision theory to explain the dependence of reaction rate on temperature and concentration 3.7 Determining the order of reaction and rate constant from experimental data 4.6 Safe storage of chemicals 4.7 Designing and doing an experiment, making conclusions and presenting experimental results regarding factors that affect reaction rate and order of reaction	Reaction rate and factors that affect reaction rates: • The definition of reaction rate • Collision theory • Factors that affect reaction rates • Rate law and determining rate law	• Observing some chemical reactions in daily life, i.e burning paper, burning Mg, fireworks, colour change on sliced apple and potato, rusting of iron • Understanding factors that affect reaction rate from teacher's explanation • understanding collision theory from teacher's explanation • designing and doing experiments regarding factors that affect reaction rate (concentration, physical states of reactants, temperature, and presence of catalysts) and reporting the results • discussing the way to determine the order of reaction • analysing experimental data to determine order of reaction • discussing the role of a catalyst • presenting the way to store chemicals in the laboratory

Table 7.3 above shows the chemical kinetics content of the A level chemistry syllabus in the UK. Table 7.4 shows chemical kinetics content for senior high school in Indonesia. Table 7.3 shows that practical work is always associated with theory for each concept except Maxwell-Boltzmann distribution. Table 7.4 shows that from 8 teaching activities only 1 activity involves practical work and this is depicted in red font. The absence of practical work means Indonesian students understand the concepts based only on teacher explanations and other nonpractical activities. As a result, concept acquisition of Indonesian students is only from theory teaching. Meanwhile, concept acquisition of UK students is from both theory and practical activities. Theory activity mostly engages students to be active intellectually, while practical activity engages students to be active both intellectually and physically. In the teaching of science including chemistry, practical/laboratory work incorporates both students' knowledge and creativity to investigate hypotheses (Chow, So, & Cheung, 2016). As stated by Swarat, Ortony, and Revelle (2012), students are more engaged with practical activities rather than theory-based activities. Similarly, young students enjoy chemistry lessons more by doing practical activities (Morais, 2015). Holstermann, Grube, and Bögeholz (2010) found that the quality of practical activity is highly affected by students' interest in that activity. All in all, students' positive attitude toward practical activity and its positive correlation with enhanced students' understanding have been uncovered by many studies (Chow et al., 2016; Swarat et al., 2012).

Arguably, what is interpreted from these syllabuses is not the only reason for the discrepancy of students' understanding between the two countries. How teachers implement the syllabus in the actual teaching and learning is also important and to be further explored. Other aspects of teaching including textbooks, school management, teaching methods, teachers' experiences and others could be factors that influence the discrepancy. However, this phenomenon can inform the Indonesian educational system that more time should be allocated for practical activities than has previously been done.

7.2.2.1 Comparing students' confidence rating in correct answers

Indonesian students generally showed higher confidence ratings (CR) when providing the correct answers than UK students. As shown in Figure 7.4 below, in the A Tier Indonesian students' CR as represented by the blue line are mostly higher than UK students' CR represented by the orange line, except for Q5, Q9 and Q15.

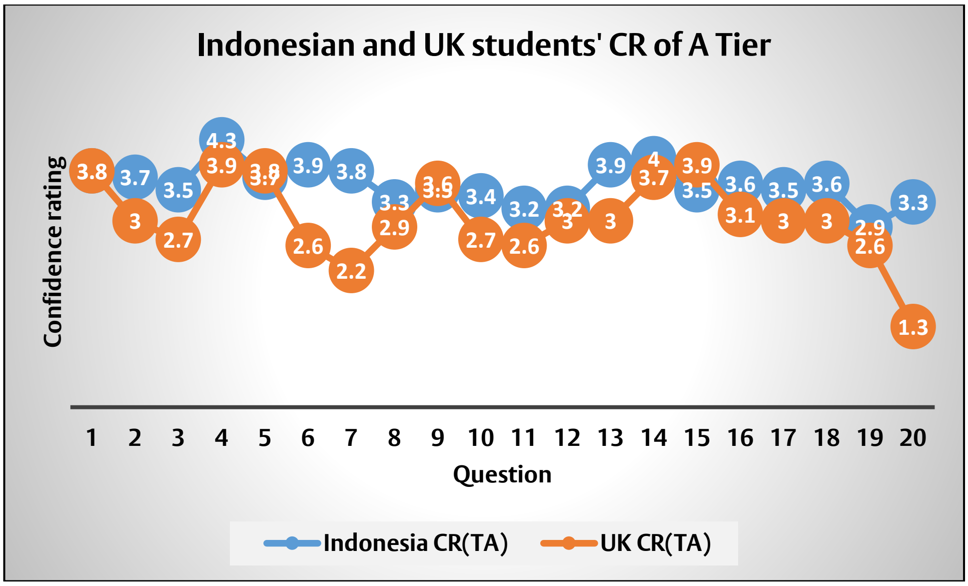


Figure 7.4 Indonesian and UK Students' CR when selecting the correct answer in the A tier

Figure 7.5 below also shows that in the R tier Indonesian students' CR represented by the blue line, are mostly higher than UK students' CR, as represented by the orange line, except for Q4, Q5, Q9 and Q15.

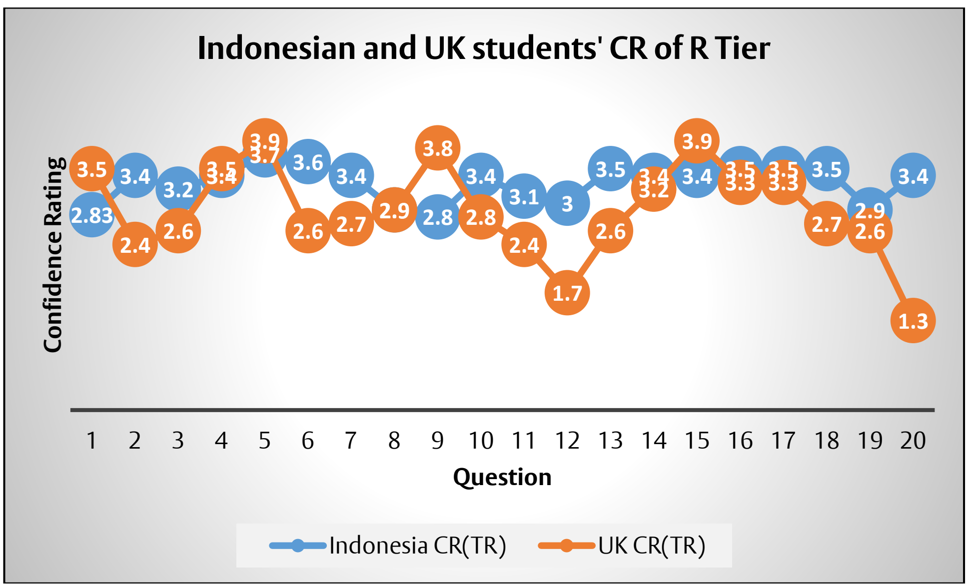


Figure 7.5 Indonesian and UK Students' CR when selecting the correct reason in the R tier

Similarly, Figure 7.6 below shows that in the B tier Indonesian students' CR as represented by the blue line are mostly higher than UK students' CR as represented by the orange line except for Q9.

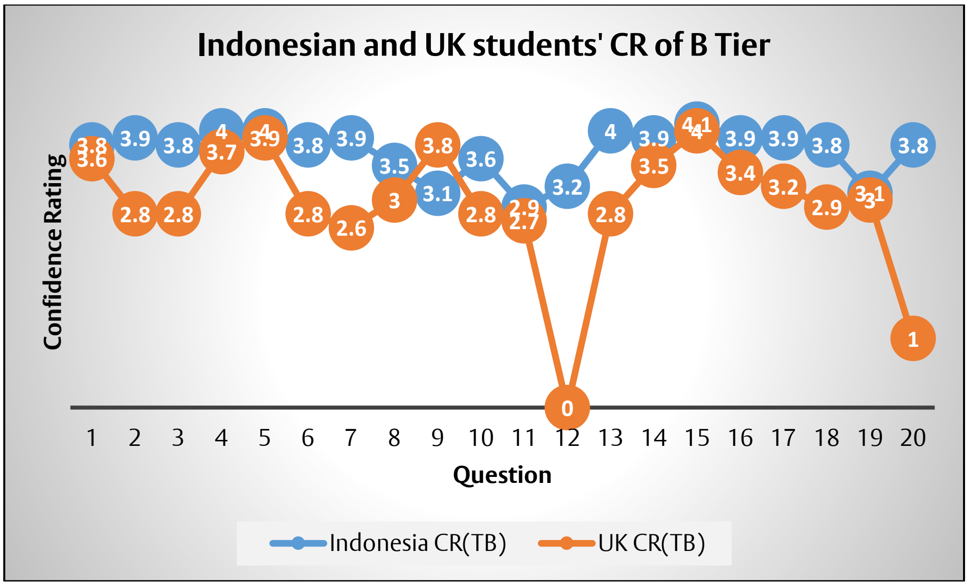


Figure 7.6 Indonesian and UK Students' CR when selecting the correct answer in the B tier

The average confidence ratings of Indonesian students when providing the correct answers in the A, R and B tiers are 3.58; 3.29 and 3.7 respectively. The average confidence ratings of UK students when providing the correct answers in the A, R and B tiers are 3.02; 2.8 and 2.9 respectively.

The highest difference in confidence ratings when providing the correct answers between the two groups is shown in Q20. Indonesian students' confidence ratings for this question are categorized as *moderate* with 3.3; 3.4 and 3.8 in the A, R and B tiers respectively. Meanwhile, UK students' confidence ratings for this question are categorized as *guesswork* with 1.3; 1.3 and 1.0 in A, R and B tiers respectively. Compared to other topics, chemical kinetics requires a more advanced mathematical ability. Therefore, chemistry students who may be aware of their weak mathematical ability will have low confidence in chemical kinetics topics. In a local survey, some chemistry students at the University of Reading stated they preferred organic chemistry rather than physical chemistry as they did not take maths at A' level. This may explain why UK students show a lower confidence than Indonesian students in answering chemical kinetics questions.

7.2.2.2 Comparing students' general confidence in chemistry

The mean of Indonesian and UK students' general confidence in chemistry as presented in Table 7.5 below shows a similar trend to their confidence in answering questions on chemical kinetics topics. Indonesian students' confidence ratings in all areas are higher than UK students'. The largest difference is shown in their confidence ratings in chemistry generally. Indonesian students' confidence ratings in this area fall in the *strong* category, while UK students' falls in the *moderate* category. In the others 3 areas, both Indonesian and UK students' confidence ratings fall in the *moderate* category.

The data in this study do not provide any evidence to explain the cause of this difference. Therefore, a more comprehensive study to reveal the cause of this difference needs to be conducted in the future.

Table 7.5 Comparison of the mean of Indonesian and UK students' general confidence in chemistry

Area of Chemistry	**Indonesian**	**UK**
Chemistry in general	3.92	3.21
Physical chemistry	3.17	2.95
Chemical kinetics as compared to other areas of chemistry	3.43	2.96
Chemical kinetics as compared to other areas of physical chemistry	3.47	3.19

7.3 STATISTICAL TESTS ON THE DIFFERENCE IN SCIENTIFIC UNDERSTANDING BETWEEN INDONESIAN AND UK STUDENTS

Comparative statistics of students' understanding of chemical kinetics between the two groups is interpreted based on the results of the independent t-test. The data are appropriate for parametric tests as they meet the assumptions of the independent t-test including normal distribution and the ratio level of data. The normality of data was interpreted based on the results of the Shapiro-Wilk Test and calculated using SPSS. Ghasemi and Zahediasl (2012) highly recommended the use of the Shapiro-Wilk test instead of Kolmogorov-Smirnov to compute the normality of the data. The results of the normality test are presented in Table 7.6 below.

Table 7.6. Normality test of data using the Shapiro-Wilk Test (df = 20)

	Statistic	**Sig.**
A tier_Indo	0.942	0.263
A tier_UK	0.878	0.017
R tier_Indo	0.944	0.282
R tier_UK	0.906	0.054
B tier_Indo	0.920	0.098
B tier_UK	0.937	0.214

A tier_Indo = Indonesian students' correct answer in A tier
R tier_UK = UK students' correct answer in the R tier
Same pattern applicable in the A tier_UK; R tier_Indo; B tier_Indo; B tier_UK

Table 7.6 shows that all the significance values (0.263; 0.282; 0.054; 0.098; 0.214) are greater than 0.05 except for the A tier_UK which is 0.017. This implies that all the data are normally distributed except those for the A tier_UK. As a result, the parametric independent t-test can only be implemented to compute the statistical difference of the R tier_Indo vs R tier_UK and B tier_Indo vs B tier_UK. Meanwhile, the statistical difference of the A tier_Indo vs A tier_UK is computed using a nonparametric test. The Mann-Whitney test is a nonparametric test which is equivalent to independent samples t-test.

The statistical difference between Indonesian students' correct answers and UK students' correct answers in the A tier (A_Indo vs A_UK) in the FTDICK instrument is shown in Tables 7.7 and 7.8 below.

Table 7.7. Rank table of Indonesian vs UK students correct answers in the A tier (N = 20)

Group	N	Mean Rank	Sum of Ranks
A_Indo	20	15.30	306.00
A_UK	20	25.70	514.00

Table 7.7 shows that A_UK students have a higher mean rank (25.70) than the mean rank of Indonesian students (15.30). This indicates that UK students obtain a higher percentage of correct answers in the A tier. To determine whether the difference in the mean rank between two groups is significant or not, the results from the Mann-Whitney test are presented in Table 7.8 below.

Table 7.8. Mann-Whitney test of Indonesian vs UK students' correct answers in the A tier

	Score
Mann-Whitney U	96.00
Wilcoxon W	306.00
Z	-2.81
Asymp. Sig. (2-tailed)	0.005

The table shows that the *p*-value for the A tier is 0.005 and lower than the critical value of 0.05. This means that the number of correct answers in the A tier given by UK students is significantly different than the number of correct answers given by Indonesian students. As previously shown by the higher mean rank of UK students, it can be concluded that UK students' understanding in the A tier is better than Indonesian students' understanding. A comparison of students' correct answers in the R and B tiers for the two groups is presented below.

Table 7.9. Descriptive statistics of Indonesian vs UK students' correct answers in the R and B tiers

	Group	Mean	Std. Deviation	Std. Error Mean
Score	R_Indo	28.10	13.45	3.01
	R_UK	53.31	25.30	5.66
	B_Indo	15.69	10.70	2.39
	B_UK	41.93	24.74	5.53

Table 7.9 above demonstrates the significant difference of Indonesian and UK students when giving the correct answers in the R and B tiers. In the R tier, the mean score of R_Indo (28.10) is lower than the mean score of R_UK (53.31). A similar difference is also shown in the B tier with 15.69 for B_Indo and 41.93 for B_UK. This means that the number of Indonesian students giving the correct answer in the R and B tiers is 28.10% and 15.69% respectively. Meanwhile, about half of UK students (53.31% and 41.93%) gave the correct answer in both tiers. To determine whether the difference in the mean

scores for the two groups is significant or not, the Independent sample t-test results are presented in Table 7.10 below.

Table 7.10. Independent sample t-test of Indonesian vs UK students' correct answers in the R and B tiers

	t		df		Sig. (2-tailed)	
	A	B	A	B	A	B
Equal variances assumed	-3.94	-4.35	38.00	38.00	**0.00**	**0.00**
Equal variances not assumed	-3.94	-4.35	28.94	25.87	**0.00**	**0.00**

t = the value of *t*-test
df = degree of freedom

A: R_Indo vs R_UK B: B_Indo vs B_UK

Table 7.10 shows that the significant values of R_Indo vs R_UK and B_Indo vs B_UK are both 0.00 and lower than the critical value of 0.05. This means that the number of correct answers in the R and B tiers given by UK students is significantly different than the number of correct answers given by Indonesian students. As previously shown by the higher mean score of UK students, it can be concluded that UK students' understanding in the R and B tiers is better than that of Indonesian students.

7.4 MISUNDERSTANDING OF CHEMICAL KINETICS CONCEPTS AMONG INDONESIAN AND UK STUDENTS

Indonesian and UK students' misunderstandings in chemical kinetics topics are investigated based on students' answers in the FTDICK instrument (Appendix G). These misunderstandings are revealed from students' answer in the A tier and R tiers separately. These misunderstandings are also revealed from the combination of answers from the A and R tiers simultaneously. This combination is simply called the B tier.

7.4.1 Students' most popular wrong answer and wrong reason

Most popular in this context means that the number of students selecting a specific wrong answer and wrong reason combination is higher than any other wrong answer and wrong reason combination. Table 7.11 below shows the most popular wrong answer (A tier) and wrong reason (R tier) of Indonesian and UK students along with their confidence ratings for each question.

Table 7.11. The percentage of students' most popular wrong answer and wrong reason for Indonesian and UK students

INDONESIA							UK						
Question	**Opt**	**Ans (%)**	**CR**	**OPT**	**Rea (%)**	**CR**	**Question**	**Opt**	**Ans (%)**	**CR**	**Opt**	**Rea (%)**	**CR**
1	C	33.33	3.5	C	28.97	2.89	**1**	C	22.89	3.4	B	20.48	2.9
2	D	11.90	3.1	C	18.65	3	**2**	D	18.07	1.7	C	13.25	1.8
3	B	56.75	3.4	B	40.48	2.9	**3**	A	31.33	2.4	A	30.12	2.3
4	C	41.27	3.9	B	30.95	3.3	**4**	C	6.02	2.6	B	13.25	2.4
5	D	23.41	3.1	C	27.38	2.8	**5**	B	3.61	3	C	10.84	2.9
6	A	33.33	3.6	A	35.32	3.4	**6**	A	60.24	3.1	A	59.04	3.1
7	C	34.13	3.7	A	18.65	2.9	**7**	A	19.28	2.7	A	8.43	1.4
8	A	32.14	3.0	B	31.35	2.6	**8**	A	12.05	3.7	C	8.43	1.6
9	A	41.27	3.3	E	21.03	3.3	**9**	D	14.46	2.4	F	15.66	2.5
10	A	19.84	3.4	D	12.30	2.8	**10**	A	12.05	3.0	A	12.05	2.1
11	B	49.60	3.5	B	45.24	3.1	**11**	B	46.99	2.8	A	46.99	2.7
12	B	46.83	3.5	A	21.43	3.1	**12**	A	45.78	2.6	A	69.88	2.9
13	A	49.21	3.6	C	40.87	3.4	**13**	C	25.30	2.8	D	21.69	2.2
14	C	26.98	3.3	B	23.41	3.3	**14**	A	16.87	3.3	B	32.53	2.9
15	B	35.32	3.4	C	23.41	3.2	**15**	A	15.66	3.4	C	4.82	2.8
16	D	17.06	3.6	B	23.81	3.2	**16**	A	19.28	2.1	A	28.92	2.3
17	A	32.54	3.4	C	53.57	3.2	**17**	C	8.43	2.4	C	7.23	2.2
18	A	39.68	3.4	B	28.17	3.0	**18**	B	9.64	2.1	C	14.46	1.8
19	B	32.94	2.5	B	30.56	2.8	**19**	B	22.89	1.7	A	33.73	2.0
20	A	47.22	3.5	C	28.17	2.7	**20**	A	40.96	2.0	C	31.33	1.9

Green shade: same answer and/or reason for Indonesian and UK students

7.4.1.1 The similarity in students' misunderstandings between the two groups

As depicted in Table 7.11 above, in most questions the majority of Indonesian and UK students chose the same most popular wrong answer and/or most popular wrong reason. In Q2, Q6 and Q20, the two groups showed the same popular wrong answer and wrong reason. By showing the same most popular wrong answer and wrong reason in Q2, this implies that both Indonesian and UK students made errors in doing simple mathematical calculations. However, the CR indices show that Indonesian students' misunderstanding falls in the *moderate* category, while UK students' misunderstanding falls in the *guesswork* category. In Q6, both Indonesian and UK students showed answer A and reason A as the most popular wrong answer and reason. This implies that both groups only focused on the number/concentration of second-order reactant without doing a calculation. This question is one of the few questions in which the number of UK students experiencing a misconception is higher than the number of Indonesian students. Misunderstandings of both groups fall into the *moderate* category. In addition, answer A and reason C of Q20 were the most popular wrong answer and wrong reason for both Indonesian and UK students. This implies that both groups did not realize that the rate of a chemical reaction can be expressed both in terms of the rate of formation of products and disappearance of reactants. Again, Indonesian students' misunderstanding falls in the *moderate* category, while UK students' misunderstanding falls in the *guesswork* category.

In Q1, Q8, Q10, Q11 and Q19, both Indonesian and UK students showed the same popular wrong answer. By showing the same popular wrong answer for Q1, it seems that both Indonesian and UK students are quite familiar with the correct concept that the time for successive half-lives in a first-order reaction is a constant. However, they incorrectly believed that the rate of decay and the mass change of sample are also constant during a first-order reaction. In Q10, both Indonesian and UK students might assume that the reaction with the highest energy at the transition state is the slowest one. In Q11, answer B is the most popular wrong answer for both groups. This implies that both Indonesian and UK students are familiar with the constant half-life in a first-order reaction. Both groups did not realize that this cannot be applied to reactions with different orders. Students' misunderstanding for both groups in those questions, apart from Q19, falls in the *moderate* category.

In Q4, Q5, Q7, Q12, Q14, Q15, and Q17, both Indonesian and UK students showed the same most popular wrong reason. The fact that both Indonesian and UK students showed the same most popular wrong reason for Q4 implies that they confused the rate-law concept with the equilibrium constant expression. However, the Indonesian students' misunderstanding is *genuine* and falls in the *moderate* category, while UK students' misunderstanding is *spurious* and falls in the *weak* category. In Q5, both groups were not aware that the increase or the decrease in concentration of a zero-order reactant does not affect the reaction rate. They assumed that the effect of changing the concentration of both reactants (whether second or zero-order) on the reaction rate is the same. Misunderstandings of both groups fall into the *moderate* category. In Q14, reason B is the most popular wrong reason for both groups of students. Both Indonesian and UK students correctly understood that the activation energy of a catalysed pathway is lower than that of an uncatalysed one, but they believed that the mechanisms for both reactions are the same. Misunderstandings of both groups also fall into the *moderate* category. In Q17, reason C was the most popular wrong reason for both groups. This implies that both sets of students confuse chemical kinetics concepts with chemical equilibrium.

7.4.1.2 The discrepancy of students' misunderstanding between the two groups

Table 7.11 above also shows that in many questions both Indonesian and UK students showed different most popular wrong answer and/or most popular wrong reason. In Q3, Q9, Q13, Q16 and Q18, the two groups gave different most popular wrong answers and wrong reasons.

For Q3, option B (30 *s*) is the most popular wrong answer for Indonesian students and was chosen by 11.90% students with a CR(TA) of 3.4. To obtain answer B students have to assume that this is a first-order reaction and the half-life is constant. This suggests Indonesian students are familiar with the constant half-life in a first-order reaction but are not used to expressions for half-lives in reactions with different orders. The most popular wrong reason for Indonesian students (reason B) was chosen by 40.48% students with a CR(TR) of 2.9. Meanwhile, answer A (25 *s*) is the most popular wrong answer for UK students and was selected by 31.33% students with a CR(TA) of 2.4. Answer A is obtained by assuming that each successive half-life is half the preceding one.

In Q9, answer A is the most popular wrong answer for Indonesian students and was chosen by 41.27% with a CR(TA) of 3.3. Reason E is the most popular wrong reason for Indonesian students and was selected by 21.03% students with CR(TR) of 3.3. This shows that Indonesian students did not understand that the shaded areas above the dashed line in the diagram represent the number of molecules in each reaction that possess the activation energy. Meanwhile, answer D is the most popular wrong answer for UK students and was chosen by 14.46% students with a CR(TA) of 2.4. Reason F is the most popular wrong reason for UK students and was selected by 15.66% with CR(TR) of 2.5. UK students believed that information provided in the question was insufficient to solve the problem. Indonesian students' misunderstanding is *genuine* and falls into the *moderate* category. Meanwhile, UK students' misunderstanding is *spurious* and falls into the *weak* category.

In Q13, answer A is the most popular wrong answer for Indonesian students and was chosen by 49.21% students with a CR(TA) of 3.6. The most popular wrong reason for Indonesian students is reason C and was chosen by 40.87% students with a CR(TR) of 3.4. Indonesian students might assume that the reverse reaction is an endothermic reaction due to carelessness in reading the question. Indonesian students' misconception is *genuine* and falls into the *moderate* category. Meanwhile, answer C is the most popular wrong answer for UK students and was chosen by 25.30% with CR(TA) of 2.8. Reason D is the most popular wrong reason for UK students and was chosen by 21.69% students with CR(TR) of 2.2. UK students understood correctly that the reaction was exothermic, but failed to determine the Ea value from the energy profile. UK students' misconception is *spurious* and falls into the *weak* category.

In Q16, answer D is the most popular wrong answer for Indonesian students and was chosen by 17.06% students with a CR(TA) of 3.6. Reason B is the most popular wrong reason for Indonesian students and was chosen by 23.81% students with CR(TR) of 3.2. Those students correctly recognized that the reaction is an example of heterogeneous catalysis, but assumed that the presence of a catalyst decreases the rate. Meanwhile, answer A is the most popular wrong answer for UK students and was chosen by 19.28% students with CR(TR) of 2.1. Those UK students show confusion between homogeneous and heterogeneous catalysis. Reason A is the most popular wrong reason for UK students and was selected by 28.92% students with CR(TR) of 2.3. This statement is correct factually but does not explain the reason for the correct answer. Therefore, it cannot be attributed as a misconception, but it still implies a knowledge gap related to defining homogeneous and heterogeneous catalysis.

In Q10, reason D is the most popular wrong reason for Indonesian students and was selected by 12.30% students with CR(TR) of 2.8. Those Indonesian students believed that the lower the activation energy, the slower the reaction. Meanwhile, reason A is the most popular wrong reason for UK students and was selected by 12.05% students with CR(TR) of 2.1. This wrong reason confirms that UK students believed a reaction with a high energy transition state has the highest activation energy.

In Q19, reason B is the most popular wrong reason for Indonesian students. The wrong reason was selected by 30.56% students with a CR(TR) of 2.8. It implies that those Indonesian students assumed the reaction rate decreases with time for all reactions and the students have not appreciated the different behaviour in a zero-order reaction. Meanwhile, reason A is the most popular wrong reason for UK students and was selected by 33.73% students with a CR(TR) of 2.0. This implies that those UK students assumed that reaction rate increases with time for all reactions and also don't appreciate the difference in behaviour in a zero-order reaction. However, Indonesian students' misconception is *genuine* and falls in the *moderate* category, while UK students' misconception is *spurious* and falls in the *weak* category.

7.4.1.3 Students' confidence ratings for the most popular wrong answer and wrong reason

Keeping in line with students' higher CR when giving a correct answer, Indonesian students generally also showed higher CR when providing wrong answers and wrong reasons than UK students. As shown in Figure 7.9 below, Indonesian students' CR when selecting the wrong answer as represented by the blue line are mostly higher than UK students' CR as represented by the orange line, except for Q8.

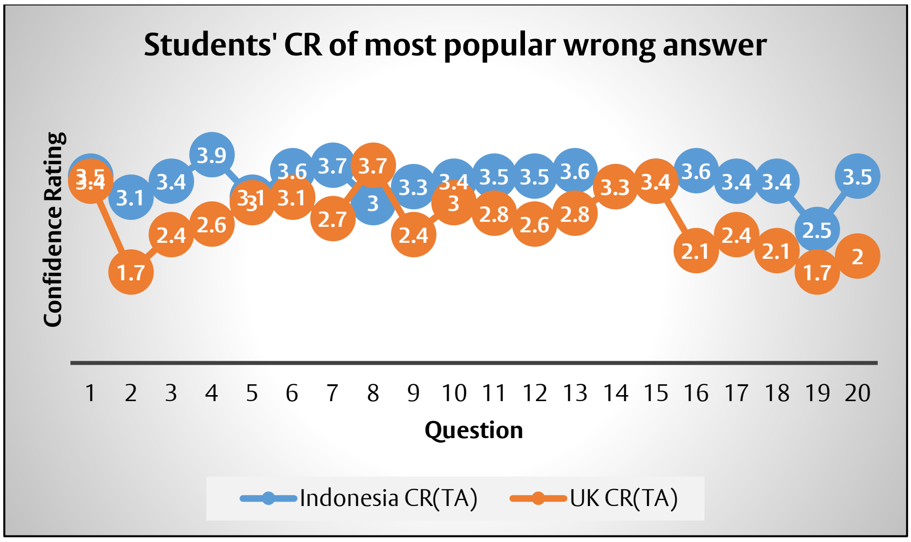


Figure 7.7 Indonesian and UK Students' CR when selecting the wrong answer

Figure 7.8 below also shows that Indonesian students' CR when selecting the wrong reason as represented by the blue line are mostly higher than UK students' CR as represented by the orange line, except for Q5.

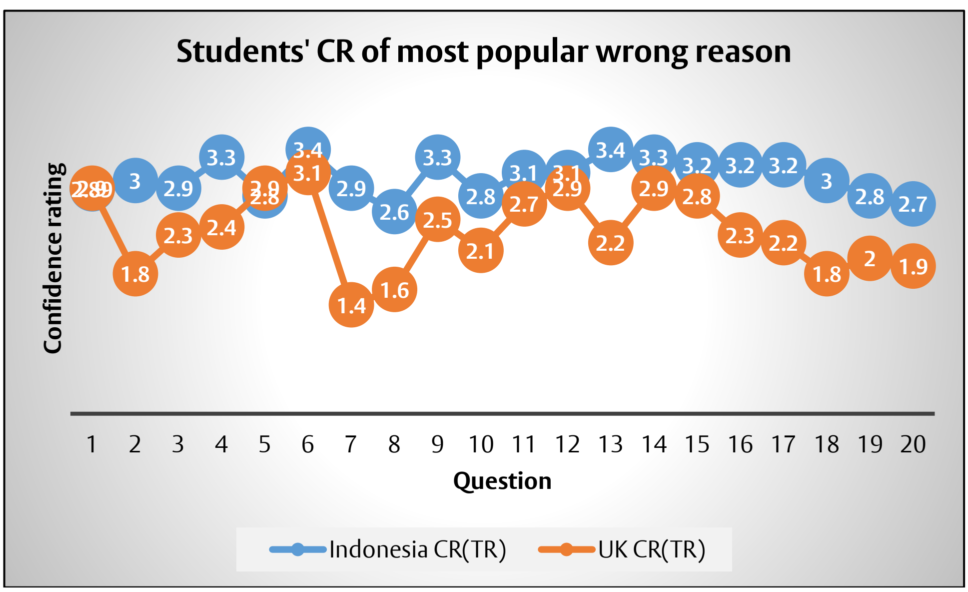


Figure 7.8 Indonesian and UK Students' CR when selecting the wrong reason

These facts imply that Indonesian students experienced more serious misconceptions than UK students.

7.4.2 Comparison of Indonesian and UK students' most prominent misconceptions

A most prominent misconception is determined based on either one or two criteria as explained below. Firstly, the number of students experiencing a misconception is ≥ 5% regardless of the CR value. Secondly, the value of students' CR who experienced the misconception is ≥ 3.5. The frequency of prominent misconceptions which exist among Indonesian and UK students is depicted in Figure 7.9 below.

Figure 7.9 shows clearly that Indonesian students harboured higher numbers of misconceptions than UK students. For each question, the frequency of prominent misconceptions of Indonesian students is always higher. A significant difference is shown in Q1, Q9, Q14 and Q20. In Q1, Indonesian students exhibited 8 prominent misconceptions while UK students showed only 1. This clearly indicates that Indonesian students suffered more misconceptions regarding the concept of successive half-lives than UK students. In Q9 and Q14, Indonesian students exhibited 7 prominent misconceptions in each question while UK students only 2. These indicate that Indonesian students suffered more misconceptions regarding the concept of activation energy than did UK students.

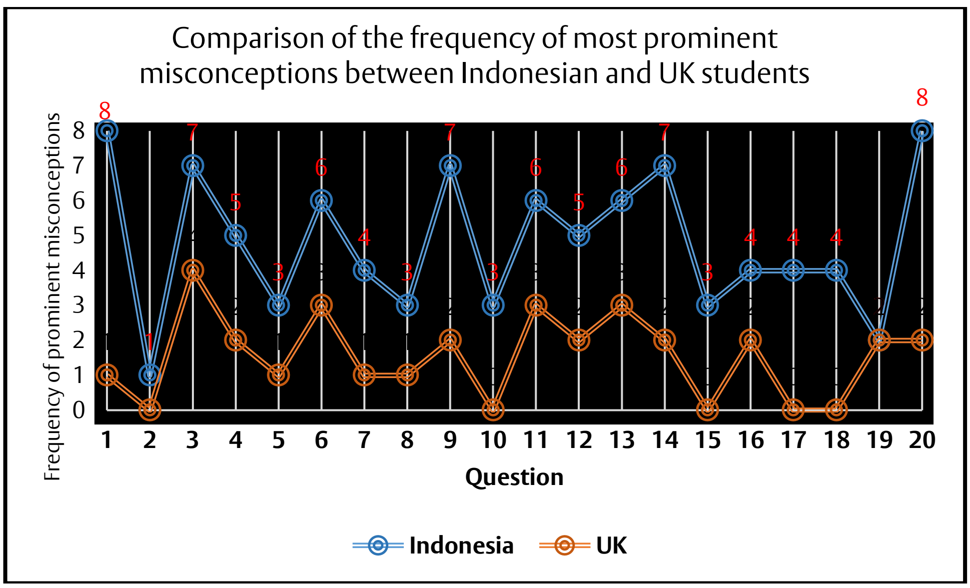


Figure 7.9 Comparison of prominent misconceptions between Indonesia and UK students

Q19 is the only question in which the frequencies of misconceptions between the two groups are the same. This implies that both Indonesian and UK students were confused regarding the terminology around "reaction rate" and "time of reaction".

Tables 7.12 and 7.13 below describe all the most prominent misconceptions among Indonesian and UK students. These misconceptions are revealed based on the combination of students' wrong answers and wrong reasons. A detailed description of Indonesian and UK students’ misconceptions is described for each question in the following.

Table 7.12 The percentage of Indonesian students giving the wrong answer – wrong reason

Question														
1			**2**			**3**			**4**			**5**		
WA-WR	N	CR(TB)		N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AA	11.51	2.76	AC	3.57	3.9	AA	5.16	3.4	AA	3.57	3.6	AC	5.56	2.93
AC	8.33	2.93				AB	5.56	3	CA	6.75	4.0	BC	7.14	2.8
BA	5.16	3				AC	5.56	3.8	CB	23.41	3.7	DD	10.32	3.6
BB	1.19	3.67				BA	9.92	3.4	DA	0.79	3.5			
BC	4.76	2.92				BB	27.38	3.2	DD	1.59	3.8			
CA	7.14	3.17				BC	13.10	3.1						
CB	5.95	3.07				DC	0.79	4						
CC	9.13	3.52												
Question														
6			**7**			**8**			**9**			**10**		
WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AA	22.62	3.6	AC	1.19	3.5	AB	12.30	2.9	AA	9.13	3.1	AD	2.38	3.6
AD	5.16	3	CA	4.37	3	AC	10.71	2.9	AD	5.95	3.3	AE	2.38	3.6
CB	10.32	3	CC	6.35	3.3	CB	6.75	2.5	AE	7.94	3.3	DE	6.35	3.44
CD	6.35	2.8	DA	1.59	3.8				AF	6.35	3.3			
DA	2.38	3.9							CD	1.19	3.7			
DD	8.33	3							DA	0.79	3.5			
									DE	0.40	4			
Question														
11			**12**			**13**			**14**			**15**		
WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AA	6.75	3.7	AA	6.75	3.5	AA	11.11	3.2	AA	1.19	4	BB	8.73	3.1
AB	7.54	3.3	AC	5.16	2.6	AC	25.40	3.7	AE	1.98	3.5	BC	11.11	3.4
BA	10.71	3.4	BA	11.51	3.6	AD	4.76	3.6	BA	1.19	3.8	BD	9.13	3.4
BB	26.98	3.2	BB	9.13	3.2	BA	1.59	3.5	BE	7.54	3.2			
BC	5.95	3	BC	9.52	2.9	BC	10.32	3.3	BF	1.19	3.5			
DB	1.19	3.5				CD	1.19	3.5	CB	5.95	3.3			
									CD	8.33	3.4			
Question														
16			**17**			**18**			**19**			**20**		
WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AB	5.56	3.3	AC	23.41	3.6	AB	13.49	3.2	BA	9.13	2.5	AB	7.14	2.9
CB	5.16	2.7	CC	5.56	2.9	AC	10.32	3.1	BB	8.73	2.6	AC	17.06	3.2
CC	5.56	2.6	DB	10.32	3.6	AD	9.13	3.4				AD	7.94	3.1
DB	6.35	3.8	DC	14.68	3.1	CB	8.33	3				AE	5.95	3.7
												BB	5.95	2.9
												BC	5.16	2.2
												BD	5.16	2.5
												DD	2.78	3.6

Table 7.13 The percentage of UK students giving the wrong answer – wrong reason

Question														
1			**2**			**3**			**4**			**5**		
WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AA	1.20%	3.5				AA	18.07%	2.3	AA	1.20%	4.5	BB	1.20%	3.5
						AB	10.84%	2.2	AB	1.20%	2.5			
						BA	7.23%	3						
						BB	6.02%	2.3						
Question														
6			**7**			**8**			**9**			**10**		
WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AA	56.63%	3.1	DB	15.66%	1.9	AD	2.41%	3.5	DB	6.02%	2.3			
CB	10.84%	2.6							DF	8.43%	2.6			
DD	6.02%	2.9												
Question														
11			**12**			**13**			**14**			**15**		
WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AA	22.89%	3.1	AA	36.14%	2.8	AA	6.02%	1.9	AC	6.02%	3.4			
BA	19.28%	2.8	BA	28.92%	3.1	BD	8.43%	2.5	BC	7.23%	2.5			
BB	19.28%	2.8				CD	8.43%	2.6						
Question														
16			**17**			**18**			**19**			**20**		
WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)	WA-WR	N	CR(TB)
AA	15.66%	2.2							BA	8.43%	1.5	AC	21.69%	2.3
CA	2.41%	3.5							BB	8.43%	2.2	DC	7.23%	1.7

7.4.2.1 Question 1

Q1-AA was selected by 11.51% Indonesian students with CR(TB) of 2.76. This shows that Indonesian students have a lack of knowledge of the concept of successive half-lives. This misconception was also found among UK students but for a very small number. Q1-CA was selected by 7.14% Indonesian students with CR(TB) of 3.17. Those Indonesian students believed that the first half-life and second half-life are the same concepts. A similar *genuine* misconception was shown by 5.16% Indonesian students selecting Q1-BA CR(TB) of 3.0. Q1-CD was selected by 3.97% Indonesian students with CR(TB) of 2.55. These Indonesian students believed that the rate of a first-order reaction increases as the concentration decreases.

Q1-AC was selected by 8.33% Indonesian students with CR(TB) of 2.93. In addition, 9.13% Indonesian students selected Q1-CC with CR(TB) of 3.52. These Indonesian students believed that for each successive half-life, the mass change of a first-order reactant is constant. This *genuine* misconception again shows that these Indonesian students are familiar with the correct concept that the half-life of a first-order reaction is constant. However, they are not aware that the mass change of a reactant that is first-order in the equation is not constant.

7.4.2.2 Question 2

Q2-AC was selected by 3.57% Indonesian students with CR(TB) of 3.9. Those students believed that the concentration of a second-order reactant at its half-life is the same as its initial concentration. This misconception is *genuine* and falls in the *moderate* category.

7.4.2.3 Question 3

Q3-BB is the most popular WAWR combination for Indonesian students and was selected by 27.38% students with CR(TB) of 3.2. This was also selected by 6.02% UK students with CR(TB) of 2.3. Indonesian and UK students were quite familiar with the concept of the half-life of a first-order reaction. However, those students did not realize that this concept does not apply to expressions for half-lives of reactions with different orders. The Indonesian students' misconception is *genuine* and falls in the *moderate* category, while the UK students' misconception is *spurious* and fall in the *weak* category.

Q3-BC was selected by 13.10% Indonesian students with CR(TB) of 3.1. Q3-AC was selected by 5.56% Indonesian students with CR(TB) of 3.8. These Indonesian students assumed that the rate always increases with a decrease in concentration of reactant. This misconception also exists among UK students.

Q3-AB was selected by 5.56% Indonesian students with CR(TB) of 3.0. This was also selected by 10.84% UK students with CR(TB) of 2.2. Q3-AA was selected by 5.16% Indonesian students with CR(TB) of 3.4. This was also selected by 18.07% UK students with CR(TB) of 2.3. These Indonesian and UK students assumed that each successive half-life is half the preceding one. The Indonesian students' misconception is *genuine* and falls in the *moderate* category, while the UK students' misconception is *spurious* and fall in the *weak* category.

7.4.2.4 Question 4

Q4-CB was selected by 23.41% Indonesian students with CR(TB) of 3.7. Those Indonesian students used the equilibrium-constant expression to derive the rate law. This phenomenon shows that Indonesian students often confuse concentrations at equilibrium with concentrations required for the rate law.

Q4-AA was selected by 3.57% Indonesian students with CR(TB) of 3.6. This was also selected by only 1.20% UK students with CR(TB) of 4.5. These Indonesian and UK students assumed that the power of the reactants in the rate law is equal to the stoichiometric coefficients in the balanced equation. The Indonesian students' misconception is *genuine* and falls in *the moderate* category, while the UK students' misconception is *genuine* and falls in the *strong* category.

7.4.2.5 Question 5

Q5-DD was selected by 10.32% Indonesian students with CR(TB) of 3.6. These Indonesian students assumed that the reaction rate will remain constant as the order with respect to one of the reactants is zero although the other reactants are not zero order.

Q5-AC was selected by 5.56% Indonesian students with CR(TB) of 2.93. These Indonesian students believe that the effect of changing concentration for both reactants (whether second or zero order) on a reaction rate is the same. The same misconception was found among UK students who selected Q5-BB with CR(TB) of 3.5.

7.4.2.6 Question 6

Q6-AA is the most popular WAWR combination for Indonesian students and was selected by 22.62% students with CR(TB) of 3.6. This was also selected by 56.63% UK students with CR(TB) of 3.1. These Indonesian and UK students have failed to consider the concentration ratio between the second-order and first-order reactants in the problem.

Q6-CB was selected by 10.32% Indonesian students with CR(TB) of 3.0. This was also selected by 10.84% UK students with CR(TB) of 2.6. These Indonesian and UK students assumed that when the concentration of two reactants involved in a reaction is the same this will lead to a higher reaction rate because the collision ratio of molecules is more favourable. The Indonesian students' misconception is *genuine* and falls in the *moderate* category, while the UK students' misconception is *spurious* and falls into the *weak* category.

Q6-DD was selected by 8.33% Indonesian students with CR(TB) of 3.0. This was also selected by 6.02% UK students with CR(TB) of 2.9. These Indonesian and UK students believed that when the concentration of a reactant is much greater than the concentration of other reactants, the reaction will be completed faster. This indicates that both Indonesian and UK students confused the meaning of reaction rate and reaction time.

7.4.2.7 Question 7

Q7-CC was selected by 6.35% Indonesian students with CR(TB) of 3.3. These Indonesian students believed that the concentration of a reactant at its half-life is the same as its initial concentration. Q7-CA was selected by 4.37% Indonesian students with CR(TB) of 3.0. These Indonesian students assumed that the concentration of a reactant at its half-life is twice its initial concentration.

7.4.2.8 Question 8

Q8-AB was selected by 12.30% Indonesian students with CR(TB) of 2.9. Q8-BC was selected by 4.37% Indonesian students with CR(TB) of 2.9. Q8-CC was selected by 3.17% Indonesian students with CR(TB) of 2.9. These wrong answer-wrong reason combinations indicate Indonesian students' lack of knowledge of the meaning of half-life even though they memorize the literal definition of it.

7.4.2.9 Question 9

Q9-AA was selected by 9.13% Indonesian students with CR(TB) of 3.1. This was also selected by 3.61% UK students with CR(TB) of 2.7. The Indonesian and UK students believed the higher the activation energy, the higher the rate. Indonesian students' misconception is *genuine* and falls in the *moderate* category, while the UK students' misconception is *spurious* and falls in the *weak* category.

Q9-DF was selected by 8.43% UK students with CR(TB) of 2.6. Those UK students believed that there is insufficient information to determine the relative rates because the value of the activation energy does not determine the rate.

7.4.2.10 Question 10

Q10-DE was selected by 6.35% Indonesian students with CR(TB) of 3.44. These Indonesian students believed that as the reaction is exothermic it will have the slowest rate. 3.17% Indonesian students selecting Q10-AA with CR(TB) of 2.94 believed that the slowest reaction is the one with the highest energy in its transition state.

7.4.2.11 Question 11

Q11-BB is the most popular WAWR combination and was selected by 26.98% Indonesian students with CR(TB) of 3.2. This was also selected by 19.28% UK students with CR(TB) of 2.8. These Indonesian and UK students believed that the value of the half-life of a second-order reaction is constant.

Q11-AA was selected by 6.75% Indonesian students with CR(TB) of 3.7. This was also selected by 22.89% UK students with CR(TB) of 3.1. These Indonesian and UK students believed that the value of each successive half-life for a second-order reaction is half the preceding one.

Q11-BC was selected by 5.95% Indonesian students with a CR(TB) of 3.0. These Indonesian students assumed that the rate of disappearance of a second-order reactant increases with a decrease in concentration.

7.4.2.12 Question 12

Q12-AA was selected by 6.75% Indonesian students with CR(TB) of 3.5. This was also selected by 36.14% UK students with CR(TB) of 2.8. Those Indonesian and UK students remembered that in determining the rate law for a multistep mechanism, the rate equation is based on the slow step for the reaction but failed to consider the previous fast step and how this affects the rate. The cause of this misunderstanding is that the theory that the slow step is the rate-determining step in a reaction has been taught to secondary school students in both Indonesia and the UK. However, the method of determining the overall rate law from the reaction mechanism provided has not been explained.

Q12-BA was selected by 11.51% Indonesian students with CR(TB) of 3.6. This was also selected by 28.92% UK students with CR(TB) of 3.1. In addition, Q12-BC was selected by 9.52% Indonesian students with CR(TB) of 2.9. This was also selected by 3.61% UK students with a very low confidence rating. These again show that both Indonesian and UK students inappropriately confused the concept of kinetics and chemical equilibrium.

7.4.2.13 Question 13

Q13-AC was selected by 25.40% Indonesian students with a CR(TB) of 3.7. In addition, Q13-BC was selected by 10.32% Indonesian students with a CR(TB) of 3.3. This indicates that these Indonesian students may have difficulty in determining whether a reaction is endothermic or exothermic, even when the sign of ΔH depicts this. This misunderstanding shows that those Indonesian students may have been careless when reading the question. Both groups had difficulty in interpreting the diagram for the reaction profile and made mistakes in judging the value of the activation energy.

7.4.2.14 Question 14

Q14-AA was selected by only a small fraction of Indonesian students (1.19%) but has a remarkable CR(TB) of 4.0. These Indonesian students believed that the activation energy of a catalysed and an uncatalysed pathway is the same, but that the mechanisms are different. Q14-BE was selected by 7.54% Indonesian students with a CR(TB) of 3.18. These Indonesian students assumed that the value of the activation energy for an uncatalyzed pathway is the same as the value of the catalysed one. Q14-CD was selected by 8.33% Indonesian students with CR(TB) of 3.4. These Indonesian students assumed that the activation energy of a catalysed pathway is higher than that of an uncatalysed one and that the mechanisms are the same.

7.4.2.15 Question 15

Q15-BC was selected by 11.11% Indonesian students with a CR(TB) of 3.4. These Indonesian students assumed that a catalyst increases the rate without being chemically involved in the reaction.

7.4.2.16 Question 16

Q16-DB was selected by 6.35% Indonesian students with a CR(TB) of 3.8. These Indonesian students assumed that the presence of a catalyst decreases the rate. A similar misconception was revealed by 5.56% Indonesian students with a CR(TB) of 3.3. In addition, these students got into difficulty in differentiating between homogeneous and heterogeneous catalysis.

7.4.2.17 Question 17

Q17-AC was selected by 23.41% Indonesian students with a CR(TB) of 3.6. These Indonesian students assumed that the rate law is obtained directly from the overall rate equation rather than by a consideration of the individual steps in the reaction. Q17-DB was selected by 10.32% Indonesian students with CR(TB) of 3.6. These Indonesian students assumed that fast step in a reaction is the rate-determining step.

7.4.2.18 Question 18

Q18-AB was selected by 13.49% Indonesian students with a CR(TB) of 3.6. In addition, Q18-AC was selected by 10.32% Indonesian students with a CR(TB) of 3.1. Q18-CB was selected by 8.33% Indonesian students with a CR(TB) of 3.0. These wrong combinations indicate that these Indonesian students only memorized the definition of the half-life of a reaction, but were unable to implement the theory.

7.4.2.19 Question 19

Q19-BA was selected by 9.13% Indonesian students with a CR(TB) of 2.5. This was also selected by 8.43% UK students with a CR(TB) of 1.5. These Indonesian and UK students calculated the rate based on the remaining concentration of reactant instead of the amount that had been used. Such confusion commonly occurs within Indonesian students as observed by the author when teaching chemical kinetics. They also believed that an increase in the concentration of a reactant always increases the reaction rate. This Indonesian students' misconception is *genuine* and falls in the *moderate* category, while the UK students' misconception is *spurious* and fall into *guesswork* category.

7.4.2.20 Question 20

Q20-AC was selected by 17.06% Indonesian students with a CR(TB) of 3.5. This was also selected by 21.69% UK students with a CR(TB) of 2.3. These Indonesian and UK students did not realize that the rate of a chemical reaction can be expressed in terms of the rate of formation of products and the disappearance of reactants. The number of UK students experiencing this misconception is higher, but Indonesian students' misconception is *genuine* and falls in the *moderate* category. Meanwhile, UK students' misconception is *spurious* and falls in the *weak* category.

Q20-AD was selected by 7.94% Indonesian students with a CR(TB) of 3.1. Another fraction of Indonesian students (5.95%) selected Q20-BB with a CR(TB) of 2.9. These indicate that these Indonesian and UK students experienced difficulty in converting verbal statements into mathematical operations and *vice versa*. However, Indonesian students’ misconceptions are *genuine* and fall in the *moderate* category. Meanwhile, UK students' misconceptions are *spurious* and fall in the *guesswork* category.

7.5 CHAPTER SUMMARY

The statistical test results show a significant difference between Indonesian and UK students' understanding of chemical kinetics concepts. The results reveal that UK students’ understanding of chemical kinetics is better than Indonesian students’ understanding.

The cause of the difference in students' understanding between the two groups is difficult to predict in this study. Future work to investigate possible causes could be a potential area for investigation. However, the authors recommend several suggestions that may help to enhance Indonesian educational system. These recommendations are discussed below.

First, more time should be allocated for practical work in the school chemistry curriculum in Indonesia. As discussed in the previous section, chemical kinetics teaching in Indonesia is dominated by theory-based activities. Based on the authors’ experiences, practical work in chemistry in secondary schools in Indonesia is carried out very rarely. Many secondary schools do not provide any practical activity for chemistry as a subject. Therefore, many students enter a university without any experience of working in a chemical laboratory. The absence of laboratory facilities and lack of incentives to teachers to conduct practical activities are the two major causes for this issue. In the UK, a survey was carried out across first year chemistry students at the University of Reading and the results presented in Figure 7.10 below. This shows that these students experienced at least 1hour practical activity in chemistry a week during their secondary education.

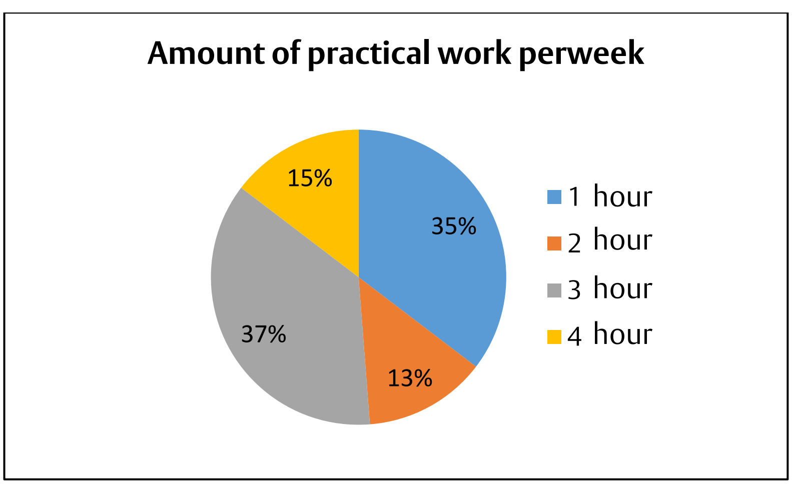


Figure 7.10. Amount of practical work per week among students at UoR in their secondary school (source: unpublished survey conducted by chemistry department, UoR).

Second, optimization of school inspection could be another way to improve the quality of teaching and learning. Both the Indonesian and UK educational systems provide an inspection board for inspecting schools and reporting the effectiveness of school services to policymakers. However, in the UK, inspection reports can be accessed publicly online. Whilst in Indonesia, the equivalent reports cannot be accessed by the wider community. Providing access to the wider community should be considered by policymakers in the Indonesian educational system in order to encourage schools to seriously consider the feedback of school inspectors.

Third, the number of compulsory subjects for secondary school students in Indonesia needs to be reconsidered. In the UK, at pre-university level, most pupils study 3 or 4 subjects at advanced level. Meanwhile, in Indonesia, there are 10-13 compulsory subjects for senior high school (pre-university education) students. This huge number of subjects obviously limits the allocated time for teaching each subject.

Fourth, the time allocated for chemistry in secondary schools in Indonesia is relatively limited. Grade X, XI and XII students are allocated 3, 4 and 4 hours respectively each week. This limitation is caused by the high number of compulsory subjects as discussed above.

Indonesian and UK students showed a similar aptitude in answering algorithmic and pictorial question. By comparing students' answers to equivalent algorithmic and pictorial questions such as Q5 – Q6, Q11 – Q3, Q8 – Q18, both Indonesian and UK students showed higher numbers of correct answer to the algorithmic questions than to the pictorial ones. This implies that both Indonesian and UK students have a better understanding of algorithmic questions than pictorial ones. The low scores for pictorial questions indicates inadequate conceptual knowledge.

Several misconceptions were uncovered among Indonesian and UK students. Some misconceptions are harboured by both Indonesian and UK students. Many other misconceptions were only demonstrated by Indonesian students. Indonesian students' misconceptions are mainly *genuine* and fall in the *moderate* category. Meanwhile, many UK students' misconceptions are mainly *spurious* and fall in the *weak* category. A summary of Indonesian and UK students' misconceptions is given in Table 7.14 below.

Table 7.14. Indonesian and UK students' misconceptions

Quest.	Misconception	Student	Category
1	Lack of knowledge of the concept of successive half-lives	Both	Genuine (moderate)
	First half-life and successive half-lives are the same	Both	Indonesian: genuine (moderate) UK: spurious (weak)
	The change in concentration/amount of a reactant in a first-order reaction is the same (constant) for every half-life	Indonesian	Genuine (moderate)
	the rate of first-order reaction increases as the concentration decreases	Indonesian	Spurious (weak)
2	The concentration of a second-order reactant at its half-life is the same as its initial concentration	Both	Indonesian: genuine (moderate) UK: spurious (weak)
3	Rate always increases with a decrease in concentration.	Both	Indonesian: genuine (moderate) UK: spurious (weak)
	Each successive half-life is half the preceding one	Both	Indonesian: genuine (moderate) UK: spurious (weak)
4	The rate law is derived from the law of mass action	Both	Genuine (moderate)
	The power of the reactants in the rate law is equal to the stoichiometric coefficients in the balanced equation	Both	Indonesian: genuine (moderate) UK: genuine (strong)
5	The reaction rate will remain constant if the order with respect to one of the reactants is zero even though the other reactants are not zero order	Both	Indonesian: genuine (moderate) UK: spurious (weak)
	The effect of changing the concentration of both reactants (whether second or zero order) on a reaction rate is the same	Indonesian	Genuine (moderate)
6	When the concentration of two reactants involved in a reaction is the same this will lead to a higher reaction rate because the collision ratio of molecules is more favourable	Both	Indonesian: genuine (moderate) UK: spurious (weak)
	When the concentration of a reactant is much greater than the concentration of other reactants, the reaction will be completed faster	Both	Genuine (moderate)
7	The concentration of a reactant at its half-life is twice its initial concentration	Indonesian	Genuine (moderate)
	The concentration of a reactant at its half-life is the same as its initial concentration.	Both	Indonesian: genuine (moderate) UK: spurious (guesswork)
9	The higher the activation energy, the higher the rate	Both	Indonesian: genuine (moderate) UK: spurious (weak)
	The value of activation energy does not determine the rate	Both	Indonesian: genuine (moderate) UK: spurious (weak)
10	An exothermic reaction is always faster than an endothermic reaction	Indonesian	Genuine (moderate)
	The slowest reaction is the one with the highest energy in its transition state	Indonesian	Genuine (moderate)
11	The value of the half-life of a second-order reaction is constant	Both	Genuine (moderate)
	The value of each successive half-life of a second-order reaction is half the preceding one	Both	Genuine (moderate)
	The rate of disappearance of second-order reactant increases with decrease in concentration	Both	Indonesian: genuine (moderate) UK: spurious (weak)

Quest.	Misconception	Student	Category
12	For a reaction with multistep mechanisms, the rate law is derived directly from the slow step.	Both	Genuine (moderate)
14	The activation energy of a catalysed and an uncatalysed pathway is the same, but the mechanisms are different.	Indonesian	Genuine (strong)
	The activation energy for the uncatalyzed pathway is same as that of the catalysed one	Both	Genuine (moderate)
	The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are the same	Both	Genuine (moderate)
15	A catalyst increases the rate without being chemically involved in the reaction	Both	Genuine (moderate)
	A catalyst is a substance formed in one elementary reaction and consumed in the next	Indonesian	Spurious (weak)
	A catalyst is a substance which is not obtained in the final product	Indonesian	Genuine (moderate)
16	The presence of a catalyst decreases the rate	Both	Indonesian: genuine (moderate) UK: spurious (weak)
17	The rate law is obtained directly from the overall rate equation rather than by a consideration of the individual steps in the reaction	Both	Genuine (moderate)
	The fast step is a rate-determining step	Indonesian	Genuine (moderate)
19	The increase in concentration of a reactant always increases the reaction rate	Both	Indonesian: genuine (moderate) UK: spurious (guesswork)
	The rate of reaction always decreases with the increase of time	Both	Indonesian: genuine (moderate) UK: spurious (weak)

CHAPTER 8
CONCLUSIONS AND IMPLICATIONS FOR TEACHING CHEMICAL KINETICS

8.1 CONCLUSIONS

The main goal of this study is to identify students' misconceptions of chemical kinetics concepts using a four-tier instrument (FTDICK). The results of this study point to several findings as formulated in the research questions. These findings are summarized below.

1. The FTDICK instrument is a valid instrument to investigate first-year students' misconceptions of chemical kinetics. This is shown by the validity and reliability indices of the instrument which fall in the *fair* and *excellent* categories respectively. This implies that the results obtained by using this instrument represent the students' actual misconceptions as well as students' understanding of chemical kinetics. The validity and reliability indices found for this FTDICK instrument show that it is rigorous and can be shared with chemistry educators at the university level. Within the limited time allocated in the curriculum, the instrument can help educators to identify students' misconceptions before their students embark on chemical kinetics topics at the university level. Educators can design more relevant and effective teaching if they aware of students' knowledge and misconceptions in advance.
2. This study reveals that first-year students' understanding of chemical kinetics is weaker than expected when they embark on university study. This is reflected in the fact that the number of students answering each question correctly is generally lower than 50% in all tiers. The number of students answering each question correctly is on average 38%, 34% and 22% in the A, R and B tiers respectively. Students' confidence ratings in many questions fall in the *moderate* category. In addition, as presented by the DL indices (Appendix J), many questions in the A and R tiers are considered *difficult*, most questions in the B tier are considered *difficult*.
3. Numerous misconceptions within chemical kinetics were revealed among first-year chemistry undergraduate students. Some typical misconceptions found are the following:
   - the concentration of a reactant at its first half-life and second half-life is the same
   - the higher the activation energy, the higher the rate
   - an exothermic reaction is faster than an endothermic one
   - the rate of a first-order reaction is constant over time

- the exponents of the reactant concentrations in the rate law is equivalent to the stoichiometric coefficients in the balanced equation
- an increase in concentration of a zero-order reactant increases the reaction rate
- when the concentration of one reactant is much greater than the concentration of other reactants, the reaction will be completed faster

Some of these misconceptions align with previous results published in the literature such as:

- the reaction rate always increases with the decrease in concentration of reactant
- the exponents in the rate law expression are directly obtained from the coefficients of the reactants in the balanced chemical equation
- an increase in temperature increases the rate of an endothermic reaction but decreases the rate of an exothermic one
- the rate law is obtained from the law of mass action.

Some novel misconceptions have been revealed in this study such as:

- when the concentration of two reactants involved in a reaction is the same a higher reaction rate results because the collision ratio of the molecules is more favourable
- even though a catalyst provides a new mechanism for a reaction, the activation energies of the catalysed and uncatalysed pathways are the same
- the catalyst increases the rate without being chemically involved in the reaction
- the value of the half-life of a second-order reaction is constant.

4. Not all misunderstandings uncovered in this study are classified as *genuine* misconceptions. This shows that inclusion of the confidence rating (CR) is timely in order to distinguish between a *genuine* and a *spurious* misconception. By assessing students' CR, an incorrect classification of a *spurious* misconception as a *genuine* misconception and vice versa can be avoided. Some of the *genuine* misconceptions discovered are that:

   - the first half-life and second half-life in a reaction are the same
   - when the concentration of a reactant is greater than the concentration of other reactants, the reaction will be completed faster
   - a catalyst is the substance which is not obtained in the final product
   - the rate law is derived from the law of mass action

   Meanwhile, some of the *spurious* misconceptions are that:

   - the decrease in concentration of a first-order reactant increases the rate

- the value of activation energy does not influence the rate
- the reaction rate always decreases as time increases

Educators should be aware of the misconceptions uncovered in this study. Otherwise, these misconceptions will persist (Barke, Hazari, & Yitbarek, 2009) as students embark on chemical kinetics studies at the university level. There is evidence that many students fail to integrate new concepts into coherent conceptual frameworks (Bodner, 1991; Herron & Eubanks, 1996; Nakhleh, 1992). Therefore, these misconceptions must be taken into account from the onset when planning a chemical kinetics course in order to lay sound foundations.

5. This study also showed that UK students have a better understanding of chemical kinetics concepts than do Indonesian students at the same level. This was indicated by the higher number of UK students than Indonesian students answering the questions correctly. The statistical test also confirmed the results from the questionnaire. The chemistry syllabus for secondary education in the UK shows that the time allocated for theory and practical activities are almost equal, while in Indonesia, theory teaching is more common than practical. This result may be used to persuade the Indonesian educational system to allocate more time for practical activity in chemistry.
6. Both Indonesian and UK students showed similar ability regarding algorithmic and pictorial questions. Both groups were more competent when answering algorithmic questions over pictorial questions. The lower ability of all students in pictorial questions indicates a poor conceptual understanding of chemical kinetics.
   Several misconceptions were found among Indonesian and UK students, such as that the rate law is derived from the law of mass action that describes the relationship between the concentrations of reactants and products. However, the number of misconceptions among Indonesian students was higher than among UK students. In addition, misconceptions among Indonesian students are generally *genuine*, while among the UK students they are generally *spurious*. Several misconceptions are found only for Indonesian students such as an exothermic reaction is always faster than an endothermic reaction, a catalyst is a substance which is not obtained in the final product and the fast step is a rate-determining step.
7. The confidence ratings (CRs) of Indonesian students when giving the correct answer in all tiers are generally higher than the equivalent UK students' CRs. However, the average CRs of both groups still falls in the *moderate* category. This implies that Indonesian and UK students' scientific understanding is approximately equivalent.

Scientific understanding means an understanding which is approved by the scientific community.

Indonesian students' CRs when giving the wrong answer are also higher than UK students' CRs in all tiers. The average of Indonesian students' CRs is 3.39 and 3.04 in the A and R tiers respectively. Meanwhile, the average of UK students' CRs is 2.66 and 2.33 in the A and R tiers respectively. These CRs indices imply that Indonesian students' misconceptions are *genuine* and fall in the *moderate* category. Meanwhile, UK students' misconceptions are *spurious* and fall in the *weak* category. It can be concluded that Indonesian students' misconceptions are more deeply rooted and therefore of more concern than UK students.

8. This study shows a positive correlation between students' general confidence and students' confidence in answering chemical kinetics questions. This implies that students who are confident in chemistry tend to have confidence in answering chemical kinetics questions. This finding is in line with the one published by Nicoll and Francisco (2001).

8.2 FACTORS THAT AFFECT STUDENTS' MISCONCEPTIONS

These misconceptions revealed can be attributed due to several reasons. Barke et al. (2009) found that students' misconceptions are caused by students' incorrect pre-concepts and inappropriate teaching and these are called school-made misconceptions. This study found that students' misconceptions can be caused by mathematical weakness, carelessness, difficulty in interpreting a table/diagram/graph and chemical terminology.

It is often mathematical difficulties that cause students to introduce errors. In particular, converting a verbal statement to a mathematical/algorithmic operation can create a major challenge for some students. This study also has revealed that many students show strong mathematical skills when solving an algorithmic question. However, often students can answer chemical questions correctly by using a formulaic equation, but they don't always fully understand the concepts involved and use recall and parameter substitution to solve problems. This is in line with the previous finding that many first-year students did not understand the derivation of various equations in chemical kinetics and how to implement the equations to do a calculation (Chairam, Somsook, & Coll, 2009) even though they may recall the actual equation.

Another factor that affects students' low performance in this study is their carelessness in reading/interpreting the question. For example, in one question many students only focused on the number of molecules of the second-order reactant and ignored the number of molecules of the first-order reactant without doing the required mathematical calculation. In several circumstances, students only focused on the mathematical operation without a sufficient conceptual understanding. For example, in another question, many students provided the correct mathematical expression for the rate law with respect to a particular reactant but failed to provide a negative or positive sign showing they did not fully understand the meaning of the relationship between change in concentration with time and rate.

Inability to identify relevant information from a diagram/graph or table indicates a poor conceptual understanding and leads to misconceptions. For example, in Figure 8.1 below, two reactions are represented as X and Y with the same activation energies. However, many students believed that X has a higher rate than Y as they thought X has the lower activation energy. Because the curve shown is lower for X than Y at the value of the activation energy, some students believed that the activation energy for X is lower and the reaction therefore faster.

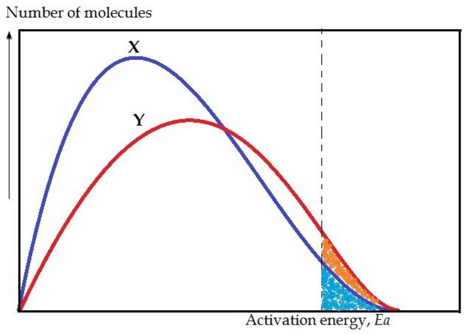


Figure 8.1 Maxwell-Boltzmann distribution of X and Y

Difficulty with chemical terminology is another factor that leads to students' misconceptions observed in this study. This difficulty leads to confusion between the precise meaning of terminologies. For instance, students confused the reaction rate and the time of reaction, the constant half-life of the first-order reaction, successive half-lives, rate law expression etc. Some students gave confused explanations about the meaning of reaction rate. In many concepts, students are only memorizing a scientific definition without having an adequate understanding of its conceptual meaning. For example, students correctly argued that the concentration of a reactant at its half-life is a half of its initial concentration. However, when the question was portrayed in a pictorial format, students got into difficulty. In addition, confusion between chemical kinetics and other topics such as chemical equilibrium and thermodynamics is also a cause of students' misconceptions. For instance, many students derived the rate law of a reaction by using the stoichiometric equation in the same way as they would derive the equilibrium constant expression.

8.3 IMPLICATIONS FOR TEACHING CHEMICAL KINETICS

The primary aim of this study is to use the results to inform and improve the quality of teaching and learning in chemical kinetics. Therefore, based on the results of this study, several suggestions for enhancing the teaching of chemical kinetics are presented below.

The study found that many students are more familiar with first-order reaction kinetics rather than those of any other orders. This leads to a better understanding and ability when answering questions about first-order reactions. This familiarity can be attributed to several factors. One possible reason is chemistry textbooks. Several general chemistry textbooks including Chang (2009), Kotz, Treichel, and Townsend (2012), McMurry, Fay, and Robinson (2016), Brown et al. (2017) and others show that among the three common reaction orders ($n = 0$, 1 and 2), the topic of first-order reactions always has the largest page allocation. In addition, the concept of first-order reactions also involves radioactive decay. Therefore, students' familiarity with this area of the topic is not surprising. To deal with this issue, an equal emphasis on all reaction orders is recommended within the time constraints allowed for teaching the syllabus.

Several students were found to believe that the exponents in the rate law expression are directly obtained from the coefficients of the reactants in the chemical equation. A possible reason for this is that examples of rate laws given in chemical kinetics' teaching often align with the coefficients in the balanced equation. To avoid this misconception, teachers should provide varied examples of rate laws in which the exponents in the experimentally determined rate law are not the same as the coefficient in the chemical equation. This can also be reinforced through practical work in which students determine the rate law from experimental data. As found by Chairam et al. (2009), practical work improves students' understanding of chemical kinetics. The same result was also found by Choi and Wong (2004) on the topic of acids and bases. A similar phenomenon is shown by the misconception that the rate law is obtained directly from the overall reaction equation. Again, this could be avoided if examples were used in which the rate law clearly cannot be obtained directly from the rate equation.

To address the misconception that an increase in concentration of a reactant always increases the reaction rate, the word "generally" should be used and emphasized when teaching factors that affect reaction rate. Meanwhile, to avoid the typical misconception that the reaction rate decreases with time for all reactions, chemistry educators should stress that the term 'zero order' implies that the rate does not depend upon the concentration and therefore the rate is constant through the reaction and does not change as the concentration of reactant decreases and/or increases.

Poor reasoning skills are another cause of students' misconceptions. Therefore, teaching strategies that can provide better opportunities for students to develop their reasoning skills such as learning cycle and guided inquiry are highly recommended (Cracolice, Deming, & Ehlert, 2008). Student-centred teaching such as inquiry-based practical chemistry was found to be effective in improving students' understanding of chemical kinetics (Chairam et al., 2009).

The study also showed that students have difficulty when interpreting drawings/graphs/plots. Therefore, more practice should be given in this area, for example by providing information in graphical or pictorial representations when appropriate. As found in Q13, students' inability to differentiate the energy profiles of exothermic and endothermic reactions could be because many textbooks only present the energy profile for an exothermic reaction. Therefore, parallel presentations of the energy profiles for both endothermic and exothermic reactions is highly recommended (Bowen & Roth, 2002). Many recent chemistry textbooks are illustrated by drawings and other pictorial representations in order to help students' reasoning. However, such representations are still limited in the secondary school textbooks in Indonesia. A similar phenomenon was also found in the school textbooks in Greece (Gegios, Salta, & Koinis, 2017).

Evidence from this study implies that students need appropriate guidance in order to interpret the information. The cognitive theory of multimedia learning suggests that conveying a verbal explanation which is accompanied by an appropriate picture rather than just a textual explanation contributes to students' robust understanding (Gegios et al., 2017). Assessment using diagrams and graphs is recommended to improve this skill.

As chemical terminology surrounding kinetics is confusing, chemistry educators are advised to provide clear definitions of relevant terms. Some terms have very similar names such as reaction rate and reaction time, rate law, rate expression and rate equation. Educators should ensure that each term is explained carefully to students. Barke et al. (2009) stated that misconceptions inculcated at school are due to incorrect use and understanding of chemical terminology and scientific language. Even chemistry educators can be lax with language in this area. Confusion that exists between some common everyday words and chemical terminologies is one of the barriers to chemistry teaching (Gabel, 1999) and can lead to misconceptions (Garnett, Garnett, & Hackling, 1995).

Poor mathematical ability may not be a direct factor affecting students' misconceptions. However, this issue is clearly a prominent barrier to teaching and learning and should be addressed. In Indonesian universities, maths for chemistry students is generally taught as an independent module. Students are expected to transfer their mathematical knowledge to a chemical context. In the University of Reading, there are dedicated maths for chemistry modules designed to help students perform simple calculations on chemistry topics both in mathematical and chemical contexts in an integrated manner. Such an example should be considered in Indonesian universities in order to improve chemistry students' ability in transferring mathematical knowledge to a chemical context.

Students' difficulty in converting verbal statements to mathematical operations and vice versa is another cause of misconceptions. This implies that more practice should be given in this area rather than simply providing an example where numbers should be simply slotted into the appropriate equation. Students' mathematical skills, logical thinking and interpreting information from verbal statements and diagrams are all essential elements for success in physical chemistry (Hoban, Finlayson, & Nolan, 2013).

8.4 FUTURE WORK

The results of this study found many students' misconceptions in chemical kinetics concepts. In consideration that the study involved only students from two universities in Indonesia and one university in the UK, further research covering more international students should be conducted. Involving students from other universities within the two countries would help in obtaining representative ideas of first-year chemistry students' understanding in chemical kinetics.

Further insight into this research would be to involve students from more countries. The following categories could be considered:

1. Students from countries that have many commonalities in term of language, culture and other social aspects such as Indonesia, Malaysia, and Brunei Darussalam
2. Students from the same region such as South East Asia countries
3. Students from developing countries

4. Students from developed countries

An international collaborative study with chemistry-education communities from other countries should be established in order to achieve that goal. By comparing the results of these further studies, a comprehensive view of first-year chemistry students' understanding will be transferable globally.

Future research in other physical chemistry topics such as chemical thermodynamics, chemical equilibrium, electrochemistry and other chemistry topics such as chemical bonding, acid-base theory could also be carried out. In addition, the methodology used in the research described here can be adopted for investigating first-year students' understanding in other areas including organic, inorganic, analytical chemistry and biochemistry.

In addition, further studies into how to overcome students' difficulties that may cause misconceptions are essential to be explored. For example, to deal with students' mathematical difficulties, investigating teaching approaches in some nations with strong maths performance such as Singapore, China, South Korea would be interesting. Most importantly, future work should involve using the FTDICK instrument in the actual teaching of chemical kinetics to empirically evaluate how the instrument can improve the quality of teaching in chemical kinetics at the university level.

In addition, dissemination of the results of this study to chemistry educators and policymakers is also essential. This is to ensure that these results are taken into account by chemistry practitioners particularly in Indonesia, in designing teaching, developing textbooks and other teaching materials. Agung and Schwartz (2007) stated that the limited number of published studies in Indonesia focusing on students' misconceptions in chemistry in particular, and the sciences, in general, may be the reason why educators and policymakers do not take these students' misconceptions into account. Similarly, Gegios et al. (2017) found that school textbooks in Greece are not influenced by the results of chemical education studies. Unfortunately, chemistry teachers rarely critically evaluate textbooks which are used in their chemistry classes. As a result, many of these textbooks do not help students to gain a better conceptual understanding (Gegios et al., 2017).

REFFERENCES

Adadan, E., & Savasci, F. (2012). An analysis of 16-17-year-old students' understanding of solution chemistry concepts using a two-tier diagnostic instrument. *International Journal of Science Education, 34*(4), 513-544.

Agung, S., & Schwartz, M. S. (2007). Students' understanding of conservation of matter, stoichiometry and balancing equations in Indonesia. *International Journal of Science Education, 29*(13), 1679-1702.

Airasian, P. W. (1994). *Classroom Assessment*. Singapore: Mcgraw-Hill.

Allen, M. J., & Yen, W. M. (2002). *Introduction to Measurement Theory*. Illinois: Waveland Press, Inc.

Anderman, E. M., & Anderman, L. H. (2009). Item analysis. In E. M. Anderman & L. H. Anderman (Eds.), *Psychology of Classroom Learning: An Encyclopedia* (Vol. 1, pp. 517-520). Detroit: Macmillan Reference USA.

AQA. (2015). *AS and A-Level Chemistry*.

Arikunto, S. (1993). *Dasar-Dasar Evaluasi Pendidikan*. Jakarta: PT Bumi Aksara.

Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2012). A three-tier diagnostic test to assess pre-service teachers' misconceptions about global warming, greenhouse effect, ozone layer depletion, and acid rain. *International Journal of Science Education, 34*(11), 1667-1686.

Atkins, P., & Paula, J. d. (2010). *Physical Chemistry*. New York: W. H. Freeman and Company.

Bain, K., Moon, A., Mack, M. R., & Towns, M. H. (2014). A review of research on the teaching and learning of thermodynamics at the university level. *Chemistry Education Research and Practice, 15*(3), 320-335.

Bain, K., & Towns, M. H. (2016). A review of research on the teaching and learning of chemical kinetics. *Chemistry Education Research and Practice, 17*(2), 246-262.

Barke, H.-D., Hazari, A., & Yitbarek, S. (2009). *Misconceptions in Chemistry, Addressing Perceptions in Chemical Education*. Berlin, Heidelberg: Springer-Verlag.

Bauer, R. C., Birk, J. P., & Marks, P. S. (2010). *Introduction to Chemistry: A Conceptual Approach, 2nd ed*. New York: McGraw-Hil.

Becker, N., & Towns, M. (2012). Students' understanding of mathematical expressions in physical chemistry contexts: An analysis using Sherin's symbolic forms. *Chemistry Education Research and Practice, 13*(3), 209-220.

Benson, D. L., Wittrock, M. C., & Baur, M. E. (1993). Students' preconceptions of the nature of gases. *Journal of Research in Science Teaching, 30*(6), 587-597.

Bilgin, I. (2006). The effects of pair problem solving technique incorporating Polya's problem solving strategy on undergraduate students' performance in chemistry/Los efectos de aplicación del método de resolución de problemas en pares y estrategia de Polya en el desempeño de los estudiantes universitarios en química. *Journal of Science Education, 7*(2), 101-106.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice, 5*(1), 7-74.

Bloom, B. S., Madaus, G. F., & Hastings, J. T. (1981). *Evaluation to Improve Learning*. New York: Mcgraw-Hill.

Bodner, G. M. (1991). I have found you an argument: the conceptual knowledge of beginning chemistry graduate students. *Journal of Chemical Education, 68*(5), 385.

Bodner, G. M., & Herron, J. D. (2002). Problem solving in Chemistry. In J. K. Gilbert, O. D. Jong, R. Justi, D. F. Treagust, & J. H. V. Driel (Eds.), *Chemical Education: Towards Research-based Practice* (pp. 235-266). Netherlands: Springer Netherlands.

BouJaoude, S., Salloum, S., & Abd-El-Khalick, F. (2004). Research report. *International Journal of Science Education, 26*(1), 63-84.

Bowen, C. W., & Bunce, D. M. (1997). Testing for conceptual understanding in general chemistry1. *The Chemical Educator, 2*(2), 1-17.
Bowen, G. M., & Roth, W.-M. (2002). Why students may not learn to interpret scientific inscriptions. *Research in Science Education, 32*(3), 303-327.
Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C. J., Woodward, P. M., & Stoltzfus, M. W. (2017). *Chemistry: The Central Science (14th Edition)*. Boston: Pearson Education, Inc.
Bucat, B., & Mocerino, M. (2009). Learning at the Sub-micro Level: Structural Representations. In J. K. Gilbert & D. F. Treagust (Eds.), *Multiple Representations in Chemical Education* (pp. 11-29). Netherlands: Springer Netherlands.
Burrows, N. L., & Mooring, S. R. (2015). Using concept mapping to uncover students' knowledge structures of chemical bonding concepts. *Chemistry Education Research and Practice, 16*(1), 53-66.
Cakmakci, G. (2010). Identifying alternative conceptions of chemical kinetics among secondary school and undergraduate students in Turkey. *Journal of Chemical Education, 87*(4), 449-455.
Cakmakci, G., & Aydogdu, C. (2011). Designing and evaluating an evidence-informed instruction in chemical kinetics. *Chemistry Education Research and Practice, 12*(1), 15-28.
Cakmakci, G., Leach, J., & Donnelly, J. (2006). Students' Ideas about Reaction Rate and its Relationship with Concentration or Pressure. *International Journal of Science Education, 28*(15), 1795-1815.
Caleon, I., & Subramaniam, R. (2010a). Development and application of a three-tier diagnostic test to assess secondary students' understanding of waves. *International Journal of Science Education, 32*(7), 939-961.
Caleon, I., & Subramaniam, R. (2010b). Do students know what they know and what they don't know? using a four-tier diagnostic test to assess the nature of students' alternative conceptions. *Research in Science Education, 40*(3), 313-337.
Calik, M., Kolomuc, A., & Karagolge, Z. (2010). The effect of conceptual change pedagogy on students' conceptions of rate of reaction. *Journal of Science Education and Technology, 19*(5), 422-433.
Campbell, L., & Campbell, B. (2009). *Mindful Learning: 101 Proven Strategies for Student and Teacher Success.* . USA: Corwin Press.
Carson, E. M., & Watson, J. R. (2002). University Chemistry Education.
Cartrette, D. P., & Mayo, P. M. (2011). Students' understanding of acids/bases in organic chemistry contexts. *Chemistry Education Research and Practice, 12*(1), 29-39.
Chairam, S., Somsook, E., & Coll, R. K. (2009). Enhancing Thai students' learning of chemical kinetics. *Research in Science & Technological Education, 27*(1), 95-115.
Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice, 8*(3), 293-307.
Chang, R. (2009). *Chemistry* (10 ed.): McGraw-Hill Professional Publishing.
Choi, M. M. F., & Wong, P. S. (2004). Using a datalogger to determine first-order kinetics and calcium carbonate in eggshells. *Journal of Chemical Education, 81*(6), 859.
Chow, C.-F., So, W.-M. W., & Cheung, T.-Y. (2016). Past examination questions in senior secondary chemistry: from written practice to hands-on experiments. *School Science Review, 97*(360), 77.
Chu, H. E., Treagust, D. F., & Chandrasegaran, A. L. (2009). A stratified study of students' understanding of basic optics concepts in different contexts using two-tier multiple-choice items. *Research in Science & Technological Education, 27*(3), 253-265.

Costu, B. (2010). Algorithmic, conceptual and graphical chemistry problems: a revisited study. *Asian Journal of Chemistry, 22*(8), 6013-6025.
Cracolice, M. S., Deming, J. C., & Ehlert, B. (2008). Concept learning versus problem solving: a cognitive difference. *Journal of Chemical Education, 85*(6), 873.
Cunningham, K. (2007). Applications of reaction rate. *Journal of Chemical Education, 84*(3), 548–554.
Department of Education, U. (2014). *Science Programmes of Study: Key Stage 4 National Curriculum in England*.
DiBattista, D., & Kurzawa, L. (2011). Examination of the quality of multiple-choice items on classroom tests. *Canadian Journal for the Scholarship of Teaching and Learning: CJSoTL, 2*(2).
Dindar, A. C., & Geban, O. (2011). Development of a three-tier test to assess high school students' understanding of acids and bases. In *3rd World Conference on Educational Sciences* (Vol. 15).
Feldt, L. S. (1993). The relationship between the distribution of item difficulties and test reliability. *Applied Measurement in Education, 6*(1), 37-48.
Gabel, D. (1999). Improving teaching and learning through chemistry education research: A look to the future. *Journal of Chemical Education, 76*(4), 548-554.
Garnett, P. J., Garnett, P. J., & Hackling, M. W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education, 25*(1), 69-96.
Gegios, T., Salta, K., & Koinis, S. (2017). Investigating high-school chemical kinetics: the Greek chemistry textbook and students' difficulties. *Chemistry Education Research and Practice, 18*(1), 151-168.
Ghasemi, A., & Zahediasl, S. (2012). Normality tests for statistical analysis: a guide for non-statisticians. *International Journal of Endocrinology and Metabolism, 10*(2), 486-489.
Gilbert, J. K., & Treagust, D. F. (2009). Macro, submicro and symbolic representations and the relationships between them: key models in chemical education. In J. K. Gilbert & D. F. Treagust (Eds.), *Multiple Representations in Chemical Education* (pp. 1-8). Netherlands: Springer Netherlands.
Glazer, N. (2011). Challenges with graph interpretation: a review of the literature. *Studies in Science Education, 47*(2), 183-210.
Gochyyev, P., & Sabers, D. (2010). Item Analysis. In N. J. Salkind (Ed.), *Encyclopedia of Research Design* (Vol. 2, pp. 641-645). Thousand Oaks, CA: SAGE Reference.
Griffard, P. B., & Wandersee, J. H. (2010). The two-tier instrument on photosynthesis: What does it diagnose? *International Journal of Science Education, 23*(10), 1039-1052.
Gronlund, N. E., & Linn, R. L. (1990). *Measurement and Evaluation in Teaching*. New York: Macmillan Publishing Company.
Gunstone, R. F. (2008). A comment on “the problem of terminology in the study of student conceptions in science”. *Science Education, 73*(6), 643–646.
Gurcaya, D., & Gulbasa, E. (2015). Development of three-tier heat, temperature and internal energy diagnostic test. *Research in Science & Technological Education, 32*(3), 229–250.
Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2017). Development and application of a four-tier test to assess pre-service physics teachers’ misconceptions about geometrical optics. *Research in Science & Technological Education, 35*(2), 238-260.
Guzel, B. Y., & Adadan, E. (2013). Use of multiple representations in developing preservice chemistry teachers' understanding of the structure of matter. *International Journal of Environmental & Science Education, 8*(1), 109-130.
Hahn, K. E., & Polik, W. F. (2004). Factors influencing success in physical chemistry. *Journal of Chemical Education, 81*(4), 567.

Hailikari, T. K., & Nevgi, A. (2010). How to diagnose at-risk students in chemistry: The case of prior knowledge assessment. *International Journal of Science Education, 32*(15), 2079-2095.
Haim, A. (1989). Catalysis: new reaction pathways not just a lowering of the activation energy. *Journal of Chemical Education, 66*(11), 935-937.
Haladyna, T. M. (2004). *Developing and Validating Multiple-Choice Test Items*. Mahwah,: Taylor and Francis.
Halakova, Z., Zuzana, H., & Miroslav, P. (2007). Two kinds of conceptual problems in chemistry teaching. *Journal of Chemical Education, 84*(1), 172.
Hasan, S., Bagayoko, D., & Kelley, E. L. (1999). Misconceptions and the Certainty of Response Index (CRI). *Physics Education, 34*(5), 294–299.
Herron, J. D., & Eubanks, I. D. (1996). *The Chemistry Classroom: Formulas For Successful Teaching*: American Chemical Society.
Hewson, S. (2011). Mathematical Issues for Chemists. Retrieved from https://nrich.maths.org/5904
Hoban, R. A., Finlayson, O. E., & Nolan, B. C. (2013). Transfer in chemistry: a study of students' abilities in transferring mathematical knowledge to chemistry. *International Journal of Mathematical Education in Science and Technology, 44*(1), 14-35.
Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-on activities and their influence on students' interest. *Research in Science Education, 40*(5), 743-757.
Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning, 7*(2), 75-83.
Justi, R. (2002). Teaching and learning chemical kinetics. In J. K. Gilbert, O. d. Jong, R. Justi, D. F. Treagust, & J. H. V. Driel (Eds.), *Chemical Education: Towards Research-based Practice* (pp. 293–315). Netherlands: Springer Netherlands.
Justi, R., & Gilbert, J. K. (1999a). A cause of ahistorical science teaching: Use of hybrid models. *Science Education, 83*(2), 163-177.
Justi, R., & Gilbert, J. K. (1999b). History and philosophy of science through models: The case of chemical kinetics. *Science & Education, 8*(3), 287-307.
Karelia, B. N., Pillai, A., & Vegada, B. N. (2013). The levels of difficulty and discrimination indices and relationship between them in four-response type multiple choice questions of pharmacology summative tests of Year II M.B.B.S students. *International e-Journal of Science, Medicine & Education, 7*(2), 6.
Kementrian Pendidikan dan Kebudayaan, R. I. (2013). Kompetensi inti dan komptensi dasar ilmu pengetahuan alam SMP/MTs. Retrieved from http://puskurbuk.kemdikbud.go.id/#
Kementrian Pendidikan dan Kebudayaan, R. I. (2016). *Silabus Mata Pelajaran Sekolah Menengah Atas/Madrasah Aliyah (SMA/MA)*.
Kimberlin, C. L., & Winterstein, A. G. (2008). Validity and reliability of measurement instruments used in research. *Am J Health Syst Pharm, 65*(23), 9.
Kinchin, I. M. (2000). Using concept maps to reveal understanding: a two-tier analysis. *School Science Review, 81*(296), 41-46.
Kıngır, S., & Geban, Ö. (2012). Effect of conceptual change approach on students' understanding of reaction rate concepts. *Hacettepe University Journal of Education*(43), 306-317.
Kirbulut, Z. D. (2014). Using three-tier diagnostic test to assess students' misconceptions of states of matter. *Eurasia Journal of Mathematics, Science & Technology Education, 10*(5), 509-521.
Kirik, O. T., & Boz, Y. (2012). Cooperative learning instruction for conceptual change in the concepts of chemical kinetics. *Chemistry Education Research and Practice, 13*(3), 221-236.

Kolomuc, A., & Calik, M. (2012). A comparison of chemistry teachers' and grade 11 students' alternative conceptions of 'rate of reaction'. *Journal of Baltic Science Education, 11*(4), 333-346.
Kolomuç, A., & Tekin, S. (2011). Chemistry teachers' misconceptions concerning concept of chemical reaction rate. *International Journal of Physics and Chemistry Education, 3*(2), 84-101.
Kotz, J. C., Treichel, P. M., & Townsend, J. R. (2012). *Chemistry and Chemical Reactivity, 8th edition*. Belmont: Brooks/Cole.
Kousathana, M., & Tsaparlis, G. (2002). Students' errors in solving numerical chemical-equilibrium problems. *Chemistry Education Research and Practice, 3*(1), 5-17.
Kozma, R. B. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction, 13*(2), 205-226.
Kozma, R. B., & Russell, J. (1997). Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching, 34*(9).
LaDue, N. D., Libarkin, J. C., & Thomas, S. R. (2015). Visual representations on high school biology, chemistry, earth science, and physics assessments. *Journal of Science Education and Technology, 24*(6), 818-834.
Loh, A. S. L., Subramaniam, R., & Tan, K. C. D. (2014). Exploring students' understanding of electrochemical cells using an enhanced two-tier diagnostic instrument. *Research in Science & Technological Education, 32*(3), 229-250.
Lundeberg, M. A., Lundeberg, M. A., Fox, P. W., Brown, A. C., & Elbedour, S. (2000). Cultural influences on confidence: Country and gender. *Journal of Educational Psychology, 92*(1), 152-159.
Mason, D. S., Shell, D. F., & Crawley, F. E. (1997). Differences in problem solving by nonscience majors in introductory chemistry on paired algorithmic-conceptual problems. *Journal of Research in Science Teaching, 34*(9), 905.
McMillan, J. H. (2001). *Classroom Assessment: Principles and Practice for Effective Instruction*: Allyn and Bacon.
McMurry, J. E., Fay, R. C., & Robinson, J. K. (2016). *Chemistry, 7th Edition*. United States of America: Pearson.
McNeely, C. L. (1995). Prescribing national education policies: the role of international organizations. *Comparative Education Review, 39*(4), 483-507.
Milenkovic, D., Dusica, D. M., Tamara, N. H., Mirjana, D. S., & Sasa, H. (2016). Development of a three-tier test as a valid diagnostic tool for identification of misconceptions related to carbohydrates. *Journal of Chemical Education, 93*(9), 1514.
Mitra, N. K., Haleagrahara, N., Ponnudurai, G., & Judson, J. (2009). The levels of difficulty and discrimination indices in type a multiple choice questions of pre-clinical semester 1 multidisciplinary summative tests. *International e-Journal of Science, Medicine & Education, 3*(1), 2-7.
Morais, C. (2015). Storytelling with chemistry and related hands-on activities: informal learning experiences to prevent "chemophobia" and promote young children's scientific literacy. *Journal of Chemical Education, 92*(1), 58-65.
Muntinga, J. H. J., & Schuil, H. A. (2007). Effects of automatic item eliminations based on item test analysis. *Advances in Physiology Education, 31*(3), 247-252.
Nakhleh, M. B. (1992). Why some students don't learn chemistry: Chemical misconceptions. *Journal of Chemical Education, 69*(3), 191.
Nakhleh, M. B. (1993). Are our students conceptual thinkers or algorithmic problem solvers - identifying conceptual students in general-chemistry. *Journal of Chemical Education, 70*(1), 52-55.

Nakhleh, M. B., & Mitchell, R. C. (1993). Concept learning versus problem solving: There is a difference. *Journal of Chemical Education, 70*(3), 190.
Niaz, M. (1995). Progressive transitions from algorithmic to conceptual understanding in student ability to solve chemistry problems: A lakatosian interpretation. *Science Education, 79*(1), 19-36.
Nicoll, G., & Francisco, J. S. (2001). An investigation of the factors influencing student performance in Physical Chemistry. *Journal of Chemical Education, 78*(1), 99.
Novak, J. D. (1990). Concept mapping - a useful tool for science-education. *Journal of Research in Science Teaching, 27*(10), 937-949.
Nunnally, J. C. (1952). *Psychometric Theory*. New York: McGraw-Hill.
Nurrenbern, S. C., & Pickering, M. (1987). Concept learning versus problem solving: Is there a difference? *Journal of Chemical Education, 64*(6), 508.
Nyachwaya, J. M., Warfa, A.-R. M., Roehrig, G. H., & Schneider, J. L. (2014). College chemistry students' use of memorized algorithms in chemical reactions. *Chemistry Education Research and Practice, 15*(1), 81-93.
OCR. (2013). *GCE Chemistry A*.
Odom, A. L., & Barrow, L. H. (1995). Development and application of a two-tier diagnostic test measuring college biology students' understanding of diffusion and osmosis after a course of instruction. *Journal of Research in Science Teaching, 32*(1), 45-61.
OECD. (2016). PISA 2015 Results in Focus. http://www.oecd.org/pisa/
Onwu, G. O. M., & Randall, E. (2006). Some aspects of students' understanding of a representational model of the particulate nature of matter in chemistry in three different countries. *Chemistry Education Research and Practice, 7*(4), 226-239.
Orgill, M., & Crippen, K. (2010). Teaching with external representations: The case of a common energy-level diagram in Chemistry. *Journal of College Science Teaching, 40*(1), 78-84.
Osborne, R. J., & Gilbert, J. K. (1980). A method for investigating concept understanding in science. *European Journal of Science Education, 2*(3).
Pesman, H., & Eryilmaz, A. (2010). Development of a three-tier test to assess misconceptions about simple electric circuits. *Journal of Educational Research, 103*(3), 208-222.
Peterson, R. F., Treagust, D. F., & Garnett, P. (1989). Development and application of a diagnostic instrument to evaluate grade-11 and -12 students' concepts of covalent bonding and structure following a course of instruction. *Journal of Research in Science Teaching, 26*(4), 301-314.
Pickering, M. (1990). Further studies on concept learning versus problem solving. *Journal of Chemical Education, 67*(3), 254.
Pinarbasi, T., & Canpolat, N. (2003). Students' understanding of solution chemistry concepts. *Journal of Chemical Education, 80*(11), 1328-1332.
Potgieter, M., Harding, A., & Engelbrecht, J. (2008). Transfer of algebraic and graphical thinking between mathematics and chemistry. *Journal of Research in Science Teaching, 45*(2), 197-218.
Prilliman, S. G. (2014). Integrating particulate representations into ap chemistry and introductory chemistry courses. *Journal of Chemical Education, 91*(9), 1291-1298.
Pushkin, D. B. (1998). Introductory students, conceptual understanding, and algorithmic success. *Journal of Chemical Education, 75*(7), 809.
QS World University Rankings of 2018. (2017). Retrieved from https://www.topuniversities.com/university-rankings/world-university-rankings/2018
Rahayu, S., & Kita, M. (2009). An analysis of Indonesian and Japanese students' understandings of macroscopic and submicroscopic levels of representing

matter and its changes. *International Journal of Science And Mathematics Education, 8*(4), 667-688.
Räisänen, M., Tuononen, T., Postareff, L., Hailikari, T., & Virtanen, V. (2016). Students' and teacher's experiences of the validity and reliability of assessment in a bioscience course. *Higher Education Studies, 6*(4), 9.
Salta, K., & Tzougraki, C. (2011). Conceptual versus algorithmic problem-solving: focusing on problems dealing with conservation of matter in chemistry. *Research in Science Education, 41*(4), 587-609.
Sanger, M. J. (2000). Using particulate drawings to determine and improve students' conceptions of pure substances and mixtures. *Journal of Chemical Education, 77*(6), 762-766.
Sanger, M. J., Vaughn, C. K., & Binkley, D. A. (2013). Concept learning versus problem solving: evaluating a threat to the validity of a particulate gas law question. *Journal of Chemical Education, 90*(6), 700-709.
Sawrey, B. A. (1990). Concept learning versus problem solving: Revisited. *Journal of Chemical Education, 67*(3), 253.
Schmidt, H.-J. (1997). Students' misconceptions—looking for a pattern. *Science Education, 81*(2), 123–135.
Seery, M. K. (2009). The role of prior knowledge and student aptitude in undergraduate performance in chemistry: a correlation-prediction study. *Chemistry Education Research and Practice, 10*(3), 227-232.
Smith, K. C., & Nakhleh, M. B. (2011). University students' conceptions of bonding in melting and dissolving phenomena. *Chemistry Education Research and Practice, 12*(4), 398-408.
Smith, K. C., & Villarreal, S. (2015). Using animations in identifying general chemistry students' misconceptions and evaluating their knowledge transfer relating to particle position in physical changes. *Chemistry Education Research and Practice, 16*(2), 273-282.
Smith, K. J., & Metz, P. A. (1996). Evaluating student understanding of solution chemistry through microscopic representations. *Journal of Chemical Education, 73*(3), 233.
Sozbilir, M., & Bennett, J. M. (2007). A study of Turkish chemistry undergraduates' understandings of entropy. *Journal of Chemical Education, 84*(7), 1204-1208.
Sözbilir, M., Pınarbaşı, T., & Canpolat, N. (2010). Prospective chemistry teachers' conceptions of chemical thermodynamics and kinetics. *Eurasia Journal of Mathematics, Science and Technology Education, 6*(2), 111-120.
Sreenivasulu, B., & Subramaniam, R. (2013). University students' understanding of chemical thermodynamics. *International Journal of Science Education, 35*(4), 601-635.
Sreenivasulu, B., & Subramaniam, R. (2014). Exploring undergraduates' understanding of Transition Metals Chemistry with the use of cognitive and confidence measures. *Research in Science Education, 44*(6), 801-828.
Stamovlasis, D., Tsaparlis, G., Kamilatos, C., Papaoikonomou, D., & Zarotiadou, E. (2005). Conceptual understanding versus algorithmic problem solving: further evidence from a national chemistry examination. *Chemistry Education Research and Practice, 6*(2), 104-118.
Stankov, L., & Crawford, J. D. (1997). Self-confidence and performance on tests of cognitive abilities. *Intelligence, 25*(2), 93-109.
Suruchi, & Rana, S. S. (2014). Test item analysis and relationship between difficulty level and discrimination index of test items in an achievement test in Biology. *Paripex-Indian Journal of Research, 3*(6), 56 - 58.
Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: understanding student interest in school science. *Journal of Research in Science Teaching, 49*(4), 515-537.

Taber, K. S. (1999). Ideas about ionisation energy: a diagnostic instrument. *School Science Review, 81*(295), 8.
Taber, K. S. (2000). Chemistry lessons for universities?: a review of constructivist ideas. *University Chemistry Education, 4*(2), 10.
Taber, K. S. (2009). Learning at the symbolic level. In J. K. Gilbert & D. F. Treagust (Eds.), *Multiple Representations in Chemical Education* (pp. 75-105). Netherlands: Springer Netherlands.
Talanquer, V. (2011). Macro, Submicro, and Symbolic: The many faces of the chemistry "triplet". *International Journal of Science Education, 33*(2), 179-195.
Tan, K. C. D., Goh, N. K., Chia, L. S., & Treagust, D. F. (2002). Development and application of a two-tier multiple choice diagnostic instrument to assess high school students' understanding of inorganic chemistry qualitative analysis. *Journal of Research in Science Teaching, 39*(4), 283-301.
Tan, K. C. D., Goh, N. K., Chia, L. S., & Treagust, D. F. (2009). Linking the macroscopic, sub-microscopic and symbolic levels: The case of inorganic qualitative analysis. In J. K. Gilbert & D. Treagust (Eds.), *Multiple Representations in Chemical Education* (pp. 137-150). Dordrecht: Springer Netherlands.
Tan, K. C. D., Taber, K. S., Liu, X., Coll, R. K., Lorenzo, M., Li, J., . . . Chia, L. S. (2008). Students' conceptions of ionisation energy: a cross-cultural study. *International Journal of Science Education, 30*(2), 263-283.
Taştan, K. Ö., & Boz, Y. (2012). Cooperative learning instruction for conceptual change in the concepts of chemical kinetics. *Chemistry Education Research and Practice, 13*(3), 221-236.
Taştan, K. Ö., Yalçınkaya, E., & Boz, Y. (2010). Pre-service chemistry teachers' ideas about reaction mechanism. *Journal of Turkish Science Education, 7*(1), 47-60.
Towns, M. H., & Robinson, W. R. (1993). Student use of test-wiseness strategies in solving multiple-choice chemistry examinations. *Journal of Research in Science Teaching, 30*(7), 709-722.
Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education, 10*(2), 159-169.
Treagust, D. F. (2002). Teaching and learning about chemical compounds. In J. K. Gilbert, O. D. Jong, R. Justi, D. F. Treagust, & J. H. V. Driel (Eds.), *Chemical Education: Towards Research-based Practice* (pp. 187–188). Netherlands: Springer Netherlands.
Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education, 25*(11), 1353-1368.
Treagust, D. F., & Tan, K. C. D. (1999). Evaluating students' understanding of chemical bonding. *School science review, 81*(294).
Tro, N. J. (2017). *Chemistry : A Molecular Approach, 4th Edition*. Boston: Pearson.
Turányi, T., & Tóth, Z. (2013). Hungarian university students' misunderstandings in thermodynamics and chemical kinetics. *Chemistry Education Research and Practice, 14*(1), 105-116.
Tuysuz, C. (2009). Development of two-tier diagnostic instrument and assess students' understanding in chemistry. *Scientific Research and Essays, 4*(6), 626-631.
Tyson, L., Treagust, D. F., & Bucat, R. B. (1999). The complexity of teaching and learning chemical equilibrium. *Journal of Chemical Education, 76*(4), 554-558.
UK-Indonesia relations. (2010). Retrieved from https://web.archive.org/web/20100726040600/http://ukinindonesia.fco.gov.uk/en/about-us/working-with-indonesia/uk-indo-relation

Understanding Item Analyses. (2017). Retrieved from http://www.washington.edu/assessment/scanning-scoring/scoring/reports/item-analysis/

Van Driel, J. H. (2002). Students' corpuscular conceptions in the context of chemical equilibrium and chemical kinetics. *Chemistry Education Research and Practice, 3*(2), 201-213.

Voska, K. W., & Heikkinen, H. W. (2000). Identification and analysis of student conceptions used to solve chemical equilibrium problems. *Journal of Research in Science Teaching, 37*(2), 160–176.

Wan, Y., Yanlan, W., & Hualin, B. (2015). Representation and analysis of chemistry core ideas in science education standards between China and the United States. *Journal of Chemical Education, 93*(1), 70.

Whitten, K. W., Davis, R. E., Peck, M. L., & Stanley, G. G. (2014). *Chemistry, Tenth edition*. Belmont: Brooks/Cole.

Woodward, D., Drager, N., Beaglehole, R., & Lipson, D. (2001). Globalization and health: a framework for analysis and action. *Bulletin of the World Health Organization, 79*(9), 875-881.

Wright, M. R. (2004). *An Introduction to Chemical Kinetics*. West Sussex: John Wiley & Sons, Ltd.

Wu, H. K. (2003). Linking the microscopic view of chemistry to real-life experiences: Intertextuality in a high-school science classroom. *Science Education, 87*(6), 868-891.

Yalçınkaya, E., Taştan, K. Ö., Boz, Y., & Yıldıran, D. (2012). Is case-based learning an effective teaching strategy to challenge students' alternative conceptions regarding chemical kinetics? *Research in Science & Technological Education, 30*(2), 151-172.

Yan, Y. K., & Subramaniam, R. (2016). Diagnostic appraisal of grade 12 students' understanding of reaction kinetics. *Chemistry Education Research and Practice, 17*(4), 1114-1126.

Zoller, U., Lubezky, A., Nakhleh, M. B., Tessier, B., & Dori, Y. J. (1995). Success on algorithmic and LOCS vs conceptual chemistry exam questions. *Journal of Chemical Education, 72*(11), 987.

Zurawski, R. M. Making the most of exams: procedures for item analysis. Retrieved from http://faculty.mansfield.edu/lfeil/201/item-analysis-explained.htm

APPENDICES

Appendix A. Consent form and instrument for food science students, the University of Reading

CONSENT FORM

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you will be studying this topic we would like you to attempt the following questions and choose reasons for your answers.

The results from the investigation will be used alongside data from other students to gain a better understanding of students' understanding of reaction rates and may be published in the educational literature. The outcomes will be completely anonymous and no participants will be identifiable.

If you are happy for your results to contribute to our investigation, please tick the box below:

◯ **I am happy to take part in this investigation and for my results to contribute to the investigation**

Signed: Date:

Name :

Chemical Kinetics Test

A. Multiple choice

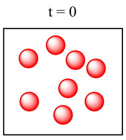
Instructions:

- *Write your name in the space provided on your answer sheet*
- *You may write in your question booklet, but you must mark your answer on the separate ANSWER SHEET*
- *Each Multiple-Choice question is followed by a series of possible answers or choices*
- *Read each question and decide which answer or choice is best.*
- *Circle the appropriate letter (A, B, C, or D) as a correct response on your ANSWER SHEET next to the NUMBER of the question you are answering.*
- *Write the reason for your answer for each question except No.10*

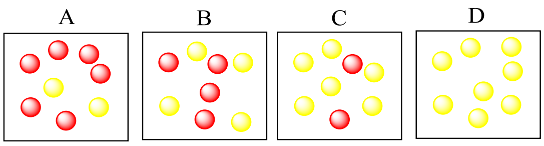
Useful equations:

$\ln[A]_t = \ln[A]_0 - kt$; $\frac{1}{[A]_t} = \frac{1}{[A]_0} + kt$; $t\frac{1}{2} = \frac{1}{[A]_0 k}$; $t\frac{1}{2} = \frac{0.693}{k}$;

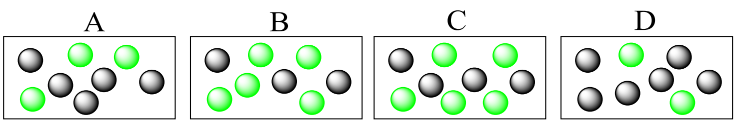
1. The diagram shows the concentration of reactant S in the first order reaction S → T at time $t = 0$ minutes.



Red spheres represent S molecules are converted to yellow spheres that represent T molecules. Which is the appropriate figure (from A, B, C and D) that represents reaction at the half-life of reaction($t½$)?



2. For the hypothetical reaction X + Y → Products, the black spheres represent molecules of X and the green spheres represent molecules of Y. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?

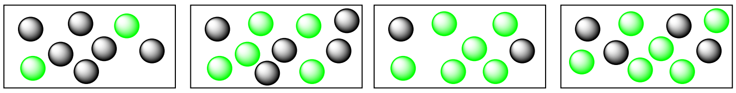


3. The reaction of $HCO_2H(aq)$ and $Br_2(aq)$ is a first order with respect to Br_2 and a zero order with respect to HCO_2H. If the concentration of both reactants increases by a factor of 3, the reaction rate will....
   A. Increase by a factor of 3
   B. Increase by a factor of 6
   C. Decrease by a factor of 9
   D. Remain constant

4. A 12.0 mg radioactive sample decays by first order reaction. How many grams of this sample remain after two half-lives?
   A. 10 mg B. 6 mg C. 3 mg D. 0 mg

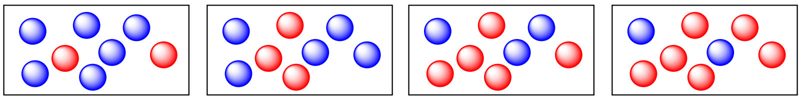
5. For a hypothetical reaction: $Q + Z \rightarrow$ Products, the black spheres represent molecules of Q and the green spheres represent molecules of Z. The rate of reaction is first order with respect to Q but zero order with respect to Z. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?

A B C D



6. For a hypothetical reaction: $X + Y \rightarrow$ Products, the blue spheres represent molecules of X and red spheres represent molecules of Y. The rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?

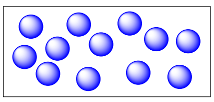
A B C D



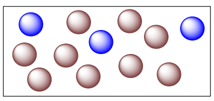
7. The rate law of the reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is $Rate = k[NO_2]^2$, where Rate is the rate of reaction at any time and k is the rate constant. If the concentration of CO increases by a factor of 3, the reaction rate will....
   A. Increase by a factor of 3
   B. Increase by a factor of 9
   C. Decrease by a factor of 3
   D. Remain constant

8. The decomposition of N_2O_5 in a solvent occurs according to the following equation
   $N_2O_5 \rightarrow 2NO_2 + \frac{1}{2} O_2$
   In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is not a correct expression of the reaction rate?
   A. Rate = 0.001 $M.minute^{-1}$ N_2O_5 consumed
   B. Rate = 0.002 $M.minute^{-1}$ NO_2 formed
   C. Rate = 0.002 $M.minute^{-1}$ O_2 formed
   D. Rate = 0.001 $M.minute^{-1}$

9. Consider the first order reaction $P \rightarrow Q$ in which P molecules drawn as blue spheres are converted to Q molecules drawn as brown spheres.



t = 0 min



t = 8 min

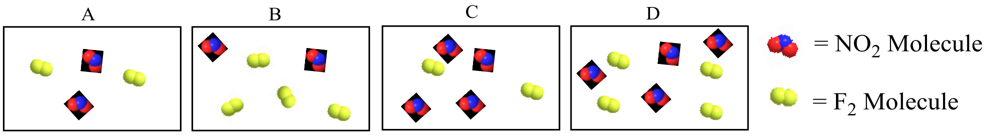
   What is the half-life of this reaction?
   A. 4 min B. 8 min C. 12 min D. 16 min

10. The decomposition of nitrogen dioxide to nitric oxide and oxygen at 300^0C is a second order reaction.
   $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$
   What is the concentration of NO_2 at t = 10 minutes, if its initial concentration is 8.00×10^{-3} M and the rate constant is 0.54 $M^{-1}.s^{-1}$?
   A. 0.54 M B. 7.94×10^{-3} M C. 2.23×10^{-3} M D. 3.61×10^{-5} M

B. Short answer questions

Instruction: read each question carefully and write your answer on the answer sheet

11. The gas-phase reaction of nitrogen dioxide and fluorine is written as
    $2NO_2(g) + F_2(g) \rightarrow 2NO_2F\,(g)$
    The relative rates of reaction for reaction mixtures depicted in the containers (A,B,C,D) are 1:2:2:4. The concentration of each reactant is represented by the spheres according to the key below.

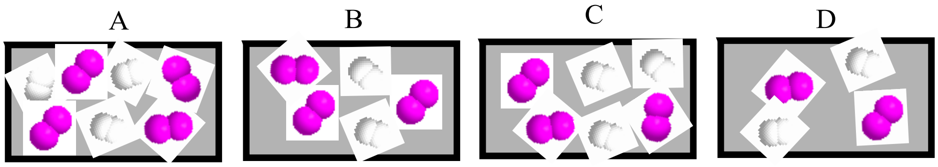


Determine,

a. The order of reaction with respect to NO_2 and F_2

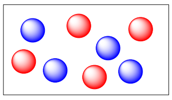
b. The overall order of the reaction

12. The experimentally determined rate law for the reaction $H_2(g) + I_2(g) \rightarrow 2HI(g)$ is rate = $k\,[H_2][I_2]$ where k is the rate constant for the reaction. Each of the boxes below represents a reaction mixture in which a H_2 molecule is shown as white sphere and an I_2 molecule is shown as a purple sphere. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D.

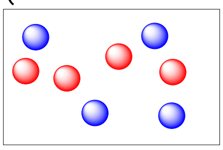


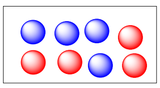
Arrange these mixtures from the lowest to the highest reaction rate!

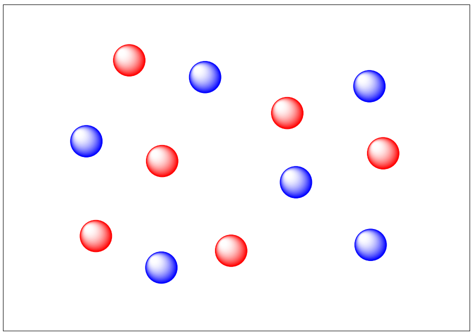
13. The hypothetical reaction of A + B → Products is the first order for both reactants. In the picture below blue spheres represent A molecules and red spheres represent B molecules.



The size of the box is proportional to the volume of the reaction container. State whether the three changes below represented by the pictures A, B and C will ......(*increase or decrease*).....the rate of reaction, and state your reason.

A.  .... because ....

B.  .... because ....

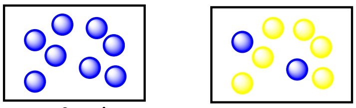
C.  ……………… because ………………

14. The reaction of nitric oxide with hydrogen is represented by the equation:
$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$
The following data were collected at a certain temperature,

Experiment	$[NO]_0$ (M)	$[H_2]_0$ (M)	r_0 (M/s)
1	0.015	0.015	0.048
2	0.030	0.015	0.192
3	0.015	0.030	0.096
4	0.030	0.030	0.384

Determine: (a) the rate law, (b) the rate constant

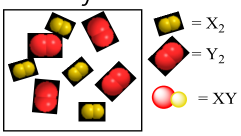
15. The first order reaction S → T is shown pictorially below, where S molecules represented as blue spheres are converted to T molecules represented as yellow spheres.



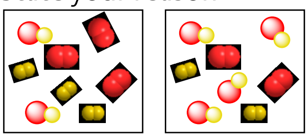
t = 0 min t = 10 min

Based on the figure above,
a. What is the rate constant of the reaction?
b. How many S (blue) molecule and T (yellow) molecule present at t = 15 minutes?

16. The figure below describes the initial mixture in a reaction represented by $X_2 + Y_2 \rightarrow 2XY$
The key shows that the yellow molecules are X_2 and the red molecules are Y_2.



If the reaction is carried out at two different temperatures over the same time period, which figure (A or B) represents the reaction at the higher temperature? State your reason



(A) (B)

Appendix B. Consent from and instrument for chemistry students, the University of Reading

CONSENT FORM

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you will be studying this topic we would like you to attempt the following questions and choose reasons for your answers.

The results from the investigation will be used alongside data from other students to gain a better understanding of students' understanding of reaction rates and may be published in the educational literature. The outcomes will be completely anonymous and no participants will be identifiable.

If you are happy for your results to contribute to our investigation, please tick the box below:

○ **I am happy to take part in this investigation and for my results to contribute to the investigation**

Signed: Date:

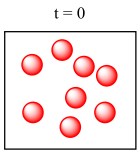
Name :

Chemical Kinetics Test

A. Short answer questions

Instruction: read each question carefully and write your answer on the answer sheet

1. The diagram shows the concentration of reactant S in the **second order** reaction $S \rightarrow T$ at time $t = 0$ minutes.



Red spheres represent S molecules are converted to yellow spheres that represent T molecules.

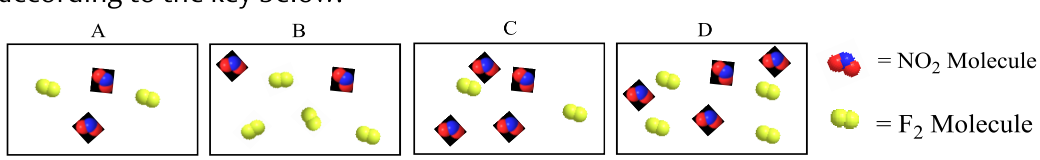
   a. Draw the appropriate diagram that represents this reaction at the half-life of reaction ($t\frac{1}{2}$).

   b. **If the reaction is first order**, draw the appropriate diagram after the first half-life and the second half-life of reaction.

2. A 12.0 mg radioactive sample decays by the first order reaction.
   a. How many milligrams of this sample remain after two half-lives?
   b. Assume that two half-lives is reached in 126 days, what is the rate constant of this reaction?

3. The combustion of ammonia is represented by the following equation
$4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O$
In the interval between 20 minutes and 40 minutes, the $[NH_3]$ decreases from 0.1 M to 0.080 M.
Write 4 different expressions for the rate of this reaction!

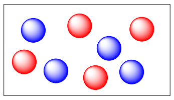
4. The gas-phase reaction of nitrogen dioxide and fluorine is written as
$2NO_2(g) + F_2(g) \rightarrow 2NO_2F\,(g)$
The relative rates of reaction for reaction mixtures depicted in the containers (A,B,C,D) are 1:2:2:4. The concentration of each reactant is represented by the spheres according to the key below.



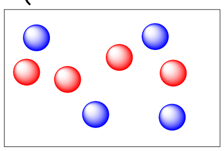
Determine,

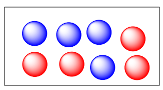
   a. The rate law of this reaction,
   b. The overall order of the reaction

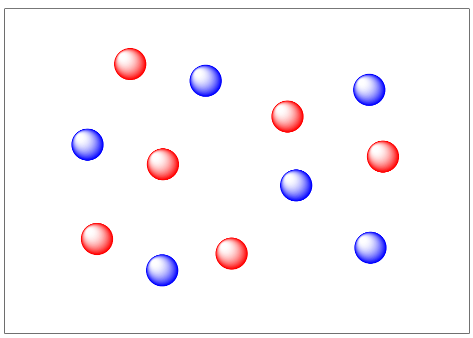
5. The hypothetical reaction of $A + B \rightarrow$ Products is the first order for both reactants. In the picture below blue spheres represent A molecules and red spheres represent B molecules.



The size of the box is proportional to the volume of the reaction container. State whether the three changes below represented by the pictures A, B and C will ……(*increase or decrease*)…..the rate of reaction, and state your reason.

a.  ……… because ………………

b.  …………… because ………………

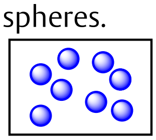
c.  ……………… because ………………

6. The initial rate data below are obtained from the reaction
$2X + 3Y \rightarrow 2S + Z$

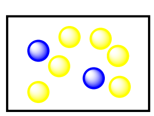
Experiment	$[X]_0$	$[Y]_0$	Initial rate of formation of Z
1	1.00×10^{-3} M	1.00×10^{-3} M	6.00×10^{-3} M/minute
2	3.00×10^{-3} M	2.00×10^{-3} M	1.44×10^{-1} M/minute
3	2.00×10^{-3} M	1.00×10^{-3} M	1.20×10^{-2} M/minute

Determine: (a) the rate law, (b) the rate constant of this reaction

7. The first order reaction $S \rightarrow T$ is shown pictorially below, where S molecules represented as blue spheres are converted to T molecules represented as yellow spheres.



t = 0 min



t = 10 min

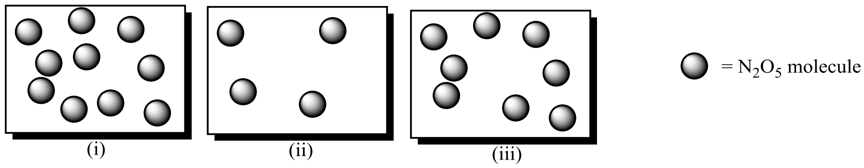
Based on the figure above,

a. What is the rate constant of the reaction?

b. How many S (blue) molecule and T (yellow) molecule present at t = 15 minutes?

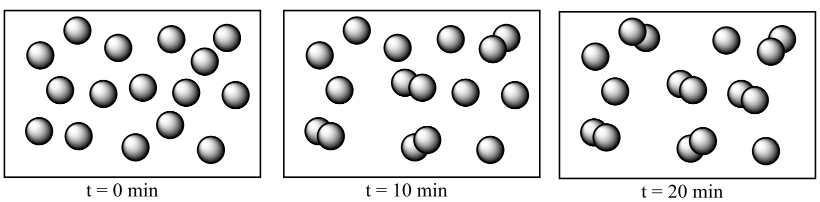
8. The activation energy for the reaction $NO_2(g) + NO_3(g) \rightarrow N_2O_5(g)$ $\Delta H^0 = 11$ kJ/mol is 165 kJ/mol.
   a. Sketch the energy profile for this reaction, and label Ea and ΔH
   b. What is Ea for the reverse reaction?

9. The decomposition of $N_2O_5(g) \rightarrow$ product follows the first order reaction.



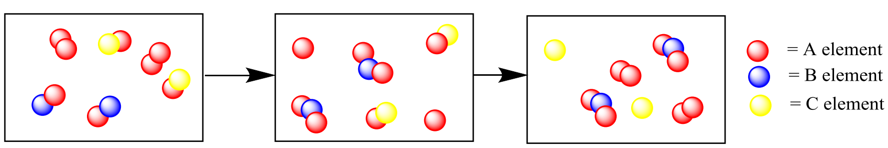
Initially different amounts of N_2O_5 molecules are placed in three equal-volume containers at the same temperature as shown pictorially (i, ii, and iii) above.
   a. What are the relative rates of the reaction in these three containers?
   b. How would the relative rates be affected if the volume of each container were doubled?
   c. How would the actual rates be affected if the volume of each container were doubled?
   d. What are the relative half-lives of the reactions in (i) to (iii)?

10. The following pictures depict the progress of the reaction $2X \rightarrow X_2$.



Based on the picture, determine:
   a. Whether the reaction is first order or second order?
   b. the rate constant?

11. The following diagram depicts an imaginary two step mechanism.



Based on the picture:
   a. Write the equation for the net reaction
   b. What is the intermediate? State your reason
   c. What is the catalyst? State your reason

12. The reaction formation of HI(g) may occur with the following mechanism:

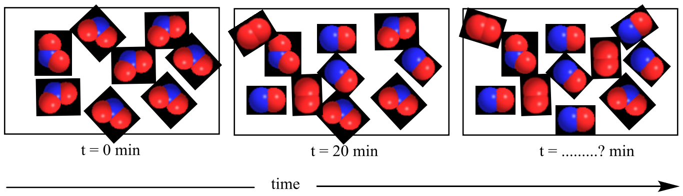
$$I_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2I \qquad \text{fast}$$

$$I + I + H_2 \xrightarrow{k_2} 2HI \qquad \text{slow}$$

Predict the rate law based on this mechanism!

13. The decomposition of nitrogen dioxide to nitric oxide and oxygen at a certain temperature is depicted pictorially below

$2NO_2(g) \rightarrow 2NO(g) + O_2(g)$



Determine the time for the final representation above if the reaction is

a. zero order b. first order c. second order

Appendix C. Consent form and instrument for Indonesian students, State University of Malang and Haluoleo University

CONSENT FORM

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you will be studying this topic we would like you to attempt the following questions and choose reasons for your answers.

The results from the investigation will be used alongside data from other students to gain a better understanding of students' understanding of reaction rates and may be published in the educational literature. The outcomes will be completely anonymous and no participants will be identifiable.

If you are happy for your results to contribute to our investigation, please tick the box below:

○ **I am happy to take part in this investigation and for my results to contribute to the investigation**

Signed : Date :

Name :

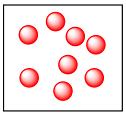
Chemical Kinetics Test

Instructions:

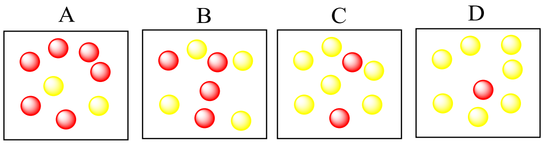
- *Write your name in the space provided on your answer sheet*
- *Each Multiple Choice question is followed by a series of possible answers or choices*
- *Read each question and decide which answer or choice is best.*
- *Circle the appropriate letter (A, B, C, or D) as a correct response*
- *Write the reason for your answer for each question in the space provided*
- *Circle the appropriate number (1, 2, 3, 4, 5 or 6) to show how sure you are on your answers*
- *For the question number 1 and 6, multiple choice questions are followed by a short answer question*

1. The diagram shows the concentration of reactant S in the first order reaction S → T at time $t = 0$ minutes.

t = 0



Red spheres representing S molecules are converted to yellow spheres that represent T molecules. Which is the appropriate figure (from A, B, C and D) that represents reaction progress at the half-life of reaction($t_{1/2}$)?



Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

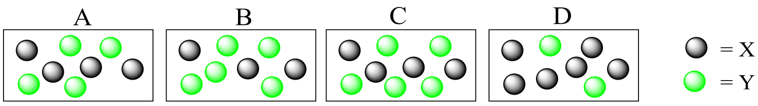
If the reaction is Second order, draw the appropriate diagram after the first half-life and the second half-life

Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

2. For the hypothetical reaction X + Y → Products. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?

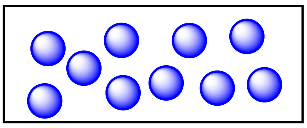
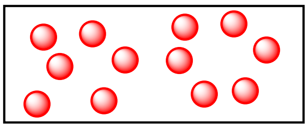
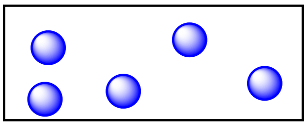
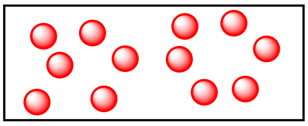
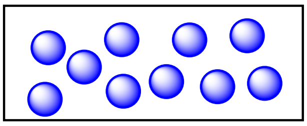
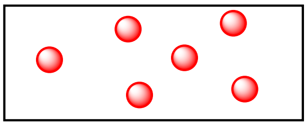


Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

3. Consider the reaction between t-butylbromide and a base at 55°C:
$(CH_3)_3CBr(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq) + Br_2(aq)$, the blue spheres represent molecules of $(CH_3)_3CBr$ and red spheres represent ion of OH^-
A series of experiments is carried out with the following results:

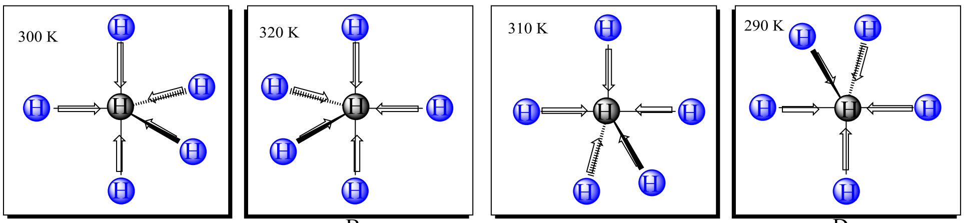
Experiment	$[(CH_3)_3CBr]$ (mol/L) x 10^{-1}	$[OH^-]$ (mol/L) x 10^{-1}	Rate (mol/L.s)
1.			0.01
2.			0.005
3.			0.01

Based on this information, which of the following options is *not* a correct statement?
A. The reaction is first order with respect to $(CH_3)_3CBr$
B. $k = 0.010\ s^{-1}$
C. at the higher temperature, the rate of 2nd experiment will be > 0.005 mol/L.s
D. Rate = $k\,[(CH_3)_3CBr]\,[OH^-]$

Show working:

State the confidence rating of your answer
1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

4. The reaction of $\cdot H + \cdot H \rightarrow H_2$ is represented pictorially below. Which figure (A, B, C or D) represents the highest rate of reaction? The arrows represent the direction of the collision.

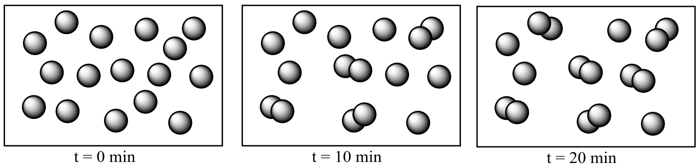


A B C D

Show working:

State the confidence rating of your answer
1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

5. The following pictures depict the progress of the reaction $2X \rightarrow X_2$.



Based on the picture, the order of the reaction is...

A. 0 B. 1 C. 2 D. 3

Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

6. A 12.0 mg radioactive sample decays by the first order reaction. How many grams of this sample remain after two half-lives?

A. 6 mg B. 4 mg C. 3 mg D. 2 mg

Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

Assume that two half-lives is reached in 126 days, what is the rate constant of this reaction?

Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

7. The decomposition of N_2O_5 in a solvent occurs according to the following equation

$N_2O_5 \rightarrow 2NO_2 + \frac{1}{2} O_2$

In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is *not* a correct expression of the average reaction rate?

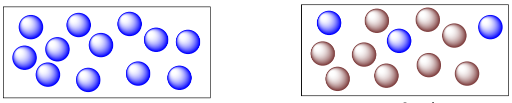
A. Rate = 0.001 $M.minute^{-1}$ N_2O_5 consumed
B. Rate = 0.002 $M.minute^{-1}$ NO_2 formed
C. Rate = 0.002 $M.minute^{-1}$ O_2 formed
D. Rate = 0.001 $M.minute^{-1}$

Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

8. Consider the first order reaction P $\rightarrow$ Q in which P molecules drawn as blue spheres are converted to Q molecules drawn as brown spheres.



t = 0 min   t = 8 min

What is the half-life of this reaction?

A. 2 min   B. 4 min   C. 6 min   D. 8 min

Show working:

State the confidence rating of your answer

1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

9. The rate law of the reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is $Rate = k[NO_2]^2$, where Rate is the rate of reaction at any time and k is the rate constant. If the concentration of CO increases by a factor of 3, the reaction rate will....

A. Increase by a factor of 3
B. Increase by a factor of 6
C. Increase by a factor of 9
D. Remain constant

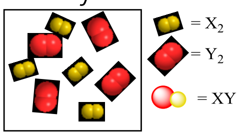
Show working:

State the confidence rating of your answer

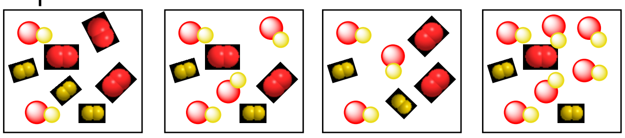
1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

10. The figure below describes the initial mixture in a reaction represented by $X_2 + Y_2 \rightarrow 2XY$

The key shows that the yellow molecules are X_2 and the red molecules are Y_2.



If the reaction is carried out at two different temperatures over the same time period, which figure (A, B, C or D) that represents the reaction at the highest temperature?



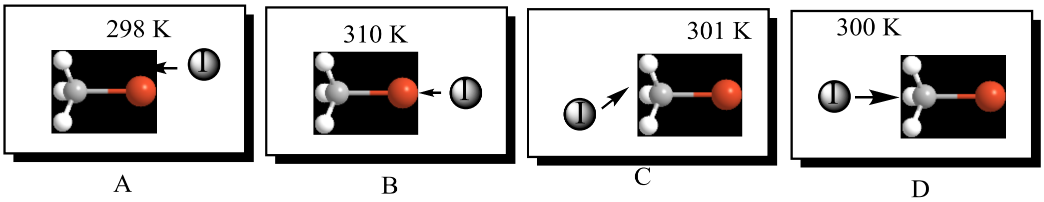
(A)   (B)   (C)   (D)

Show working:

State the confidence rating of your answer

1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

11. The reaction of $I^- + CH_3Br \rightarrow CH_3I + Br^-$ is represented pictorially below. Which figure (A, B, C or D) that represents the highest rate of reaction? The arrows represent the direction of the collision.

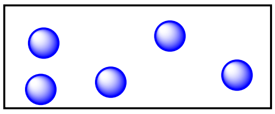
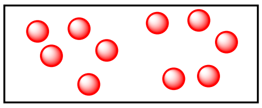
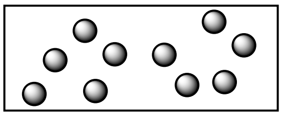
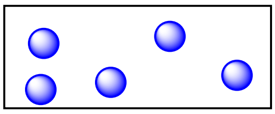
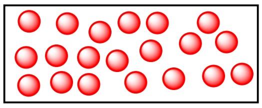
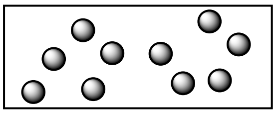
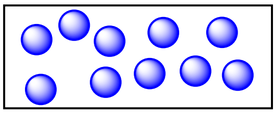
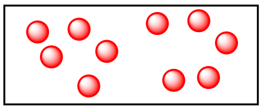
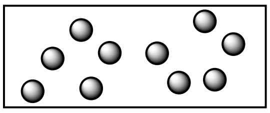
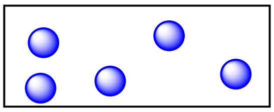
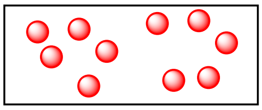
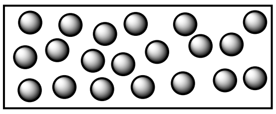


Show working:

State the confidence rating of your answer

1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

12. For a hypothetical reaction: X + Y + Z $\rightarrow$ Products, the blue spheres represent molecules of X, red spheres represent molecules of Y and black spheres represent molecules of Z. A series of experiments is carried out with the following results:

Exp	[X] (mol/L) x 10^{-2}	[Y] (mol/L) x 10^{-3}	[Z] (mol/L) x 10^{-4}	Rate (mol/L.s)
1.				0.2
2.				0.8
3.				0.4
4.				0.2

Based on this information, which of the following options is *not* a correct statement?

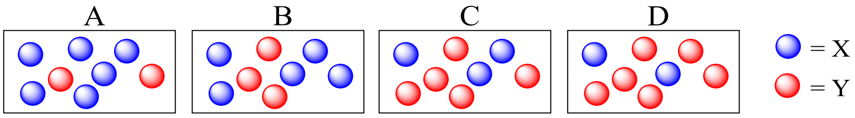
A. The reaction is first order with respect to X
B. $k = 4 \times 10^4\ mol^{-2}.L^2.s^{-1}$
C. The addition of [Z] at experiment 1 will increase the rate
D. The overall order is 3

Show working:

State the confidence rating of your answer

1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

13. For a hypothetical reaction: $X + Y \rightarrow$ Products. The rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



Show working:

State the confidence rating of your answer

1. no idea, just guessing
2. very unconfident
3. unconfident
4. confident
5. very confident
6. absolutely confident

Appendix D. Translation of consent form and instrument for Indonesian students, State University of Malang and Haluoleo University

LEMBAR PERSETUJUAN

Saat ini kami sedang melakukan penelitian tentang pemahaman mahasiswa terhadap konsep-konsep kinetika kimia. Mengingat anda sedang atau telah mempelajari topik tersebut, kami mengharapkan anda untuk menjawab pertanyaan-pertanyaan berikut dan menjelaskan alasan jawaban anda.

Lembar jawaban anda akan kami kumpulkan dan dikoreksi. Selanjutnya anda dimungkinkan untuk mengikuti wawancara sebagai tindak lanjut dari pelaksanaan tes ini. Untuk tujuan tersebut, anda akan kami hubungi lebih lanjut.

Hasil-hasil dari penelitian ini akan memberikan wawasan tentang bagaimana pemahaman mahasiswa dalam topik ini dan dimungkinkan untuk dipublikasikan dalam jurnal internasional. Namun demikian, kerahasiaan identitas anda akan terjaga dalam seluruh proses penelitian ini, mulai dari pengumpulan data hingga publikasi.

Jika anda bersedia untuk berpartisipasi dalam penelitian ini, silahkan centang bulatan berikut ini:

○ **saya bersedia untuk perpartisipasi/menjadi responden dalam penelitian ini**

○ **Saya bersedia untuk mengikuti wawancara sebagai tindak lanjut pelaksanaan tes yang telah saya ikuti**

○ **Saya menyadari bahwa hasil penelitian ini akan dipublikasikan secara anonim/ menjaga kerahasiaan identitas responden.**

Nama :

Tanda Tangan:

Email :

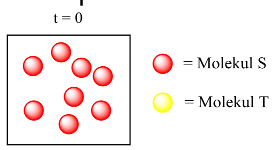
Tanggal:

<u>Tes Kinetika Kimia</u>

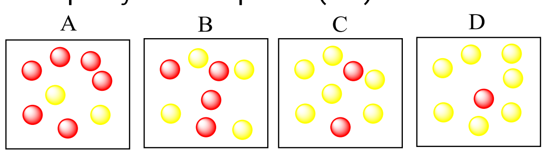
Petunjuk:

- *Tulislah nama anda pada kotak yang telah disediakan*
- *Setiap pertanyaan diikuti oleh empat (A, B, C, dan D) pilihan jawaban*
- *Bacalah pertanyaan dengan seksama, selanjutnya pilihlah jawaban yang paling benar diantara pilihan jawaban yang tersedia.*
- *Lingkarilah huruf (A, B, C, atau D) sebagai pilihan jawaban yang anda anggap benar*
- *Tuliskan alasan jawaban yang anda pilih pada kotak yang telah disediakan*
- *Lingkarilah angka (1, 2, 3, 4, 5 atau 6) untuk menunjukan seberapa besar keyakinan anda akan kebenaran jawaban anda*
- *Khusus untuk pertanyaan nomor 1 dan 6, pertanyaan pilihan ganda diikuti dengan pertanyaan esai. Jawablah semua pertanyaan tersebut*

1. Gambar dibawah ini menunjukan konsentrasi reaktan S dalam suatu reaksi orde pertama
   $S \rightarrow T$ pada saat $t = 0$ menit.



Manakah gambar berikut ini (A, B, C dan D) yang menunjukan reaksi pada saat tercapainya waktu paruh (t½)?



Jelaskan alasan anda:

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak	2. Sangat tidak yakin	3. Tidak yakin
4. yakin	5. Sangat yakin	6. Sangat yakin sekali

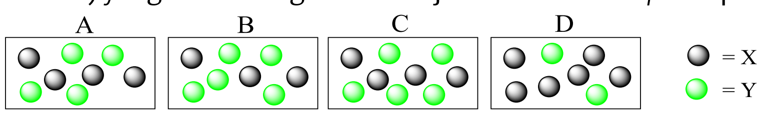
Sekiranya reksi ini adalah berlangsung menurut rekasi orde kedua, gambarkanlah kondisi yang cocok setelah tercapainya waktu paruh pertama dan waktu paruh kedua?

Jelaskan alasan anda:

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak	2. Sangat tidak yakin	3. Tidak yakin
4. yakin	5. Sangat yakin	6. Sangat yakin sekali

2. Suatu reaksi hipotetik $X + Y \rightarrow$ Produk, berlangsung menurut rekasi orde pertama masing-masing terhadap X dan Y. Mengacu pada variasi konsentrasi reaktan sebagaimana digambarkan secara mikroskopis berikut ini, kondisi manakah (A, B, C atau D) yang akan menghasilkan laju reaksi terbesar/tercepat?

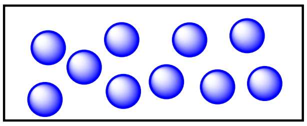
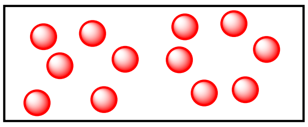
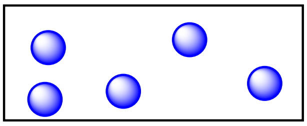
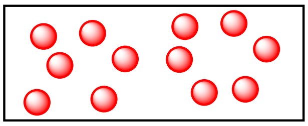
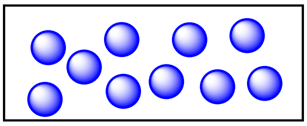
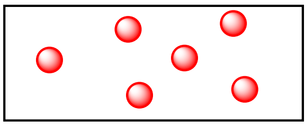


Jelaskan alasan anda:

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

3. Reaksi antara t-butylbromida dengan suatu basa pada temperatur 55°C berlangsung menurut persamaan reaksi berikut ini:
$(CH_3)_3CBr(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq) + Br_2(aq)$,
Bulatan biru mewakili molekul $(CH_3)_3CBr$ dan bulatan merah mewakili ion OH^-
Sejumlah eksperimen yang dilakukan menghasilkan data berikut ini:

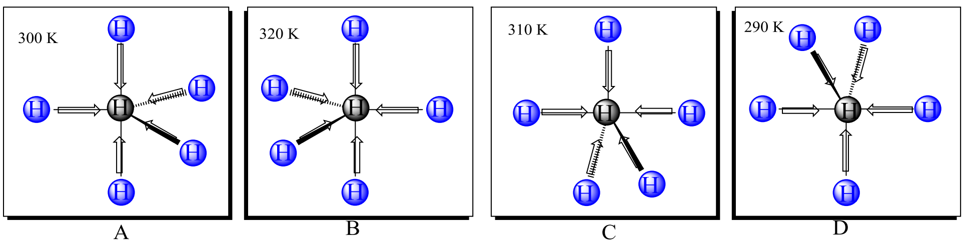
Experiment	$[(CH_3)_3CBr]$ (mol/L) x 10^{-1}	$[OH^-]$ (mol/L) x 10^{-1}	Rate (mol/L.s)
1.			0.01
2.			0.005
3.			0.01

Berdasarkan informasi di atas, manakah pernyataan berikut yang *tidak* benar?
A. Reaksi berlangsung menurut orde pertama terhadap $(CH_3)_3CBr$
B. $k = 0.010\ s^{-1}$
C. pada temperatur yang lebih tinggi, laju reaksi pada eksperimen ke-2 akan > 0.005 mol/L.s
D. laju reaksi (r) = $k[(CH_3)_3CBr][OH^-]$

Jelaskan alasan anda:

Seberapa yakinkah anda terhadap kebenaran jawaban anda
1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

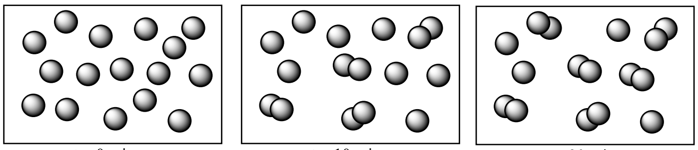
4. Orientasi tumbukan pada reaksi $\cdot H + \cdot H \rightarrow H_2$ digambarkan secara mikroskopik berikut ini. Gambar manakah (A, B, C atau D) yang menunjukan reaksi dengan laju tertinggi?



Jelaskan alasan anda:

Seberapa yakinkah anda terhadap kebenaran jawaban anda
1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

5. Gambar mikroskopik berikut menunjukan progress reaksi $2X \rightarrow X_2$.



Mengacu pada gambar di atas, reaksi ini adalah berlangsung menurut orde ...

A. 0 B. 1 C. 2 D. 3

Jelaskan alasan anda:

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

6. Sebanyak 12.0 mg sampel suatu zat radioaktif meluruh menurut reaksi orde pertama. Berapa mg sampel tersisa setelah waktu paruh kedua tercapai?

A. 6 mg B. 4 mg C. 3 mg D. 2 mg

Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

Anggaplah bahwa waktu paruh kedua dicapai dalam 126 hari, berapakah konstanta laju reaksinya?

Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

7. Dekomposisi N_2O_5 dalam suatu pelarut berlangsung menurut persamaan reaksi berikut ini

$N_2O_5 \rightarrow 2NO_2 + ½ O_2$

Pada selang waktu 20 menit, $[N_2O_5]$ berkurang dari 0.1 M menjadi 0.080 M. Manakah pilihan berikut yang menunjukan ungkapan laju rekasi yang *tidak* benar?

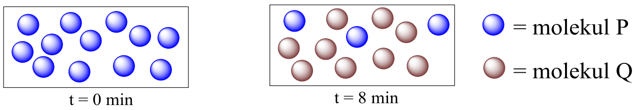
A. Laju reaksi = 0.001 M.menit^{-1} berkurangnya N_2O_5
B. Rate = 0.002 M.menit^{-1} terbentuknya NO_2
C. Rate = 0.002 M.menit^{-1} terbentuknya O_2
D. Rate = 0.001 M.menit^{-1}

Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

8. Suatu reaksi hipotetik P $\rightarrow$ Q.



Berapakah waktu paruh reaksi tersebut?

A. 2 menit B. 4 menit C. 6 menit D. 8 menit

Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

9. Hukum laju untuk reaksi $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ adalah $Rate = k[NO_2]^2$, dimana Rate adalah laju reaksi dan k adalah tetapan laju. Jika konsentrasi CO bertambah 3 kali semula, maka laju reaksi akan....

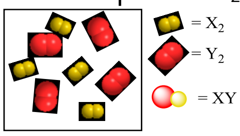
A. Bertambah sebesar 3 kali semula
B. Bertambah sebesar 6 kali semula
C. Bertambah sebesar 9 kali semula
D. tetap sama

Jelaskan alasan anda :

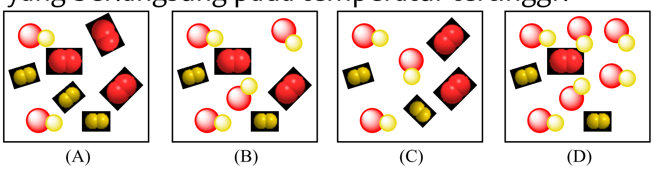
Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

10. Reaksi hipotetik $X_2 + Y_2 \rightarrow 2XY$ digambarkan secara mikroskopik berikut ini.



Jika reaksi berlangsung dalam beberapa temperatur yang berbeda dengan durasi waktu yang sama, gambar manakah yang (A, B, C atau D) yang menunjukan reaksi yang berlangsung pada temperatur tertinggi?

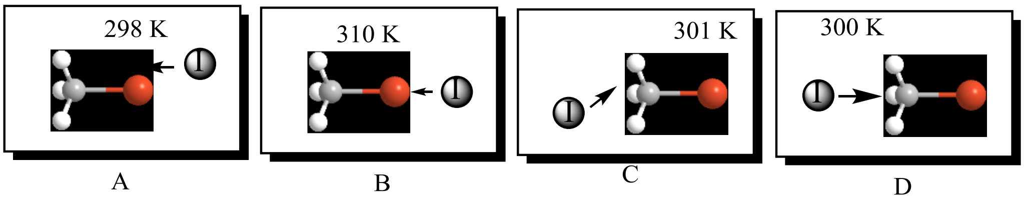


Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

11. Reaksi $I^- + CH_3Br \rightarrow CH_3I + Br^-$ digambarkan secara mikroskopik berikut ini. Gambar manakah (A, B, C atau D) yang menunjukan reaksi dengan laju reaksi terbesar? *Petunjuk*: tanda panah menunjukan arah tumbukan.

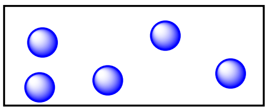
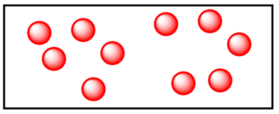
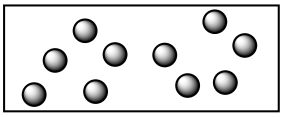
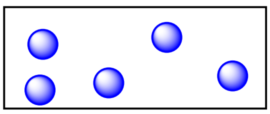
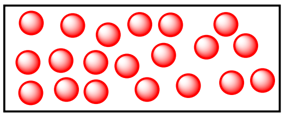
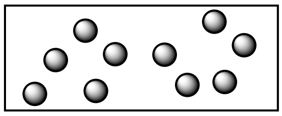
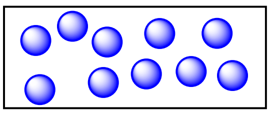
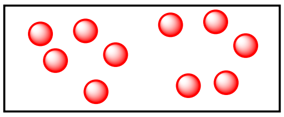
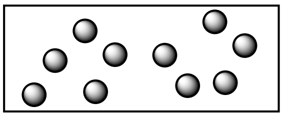
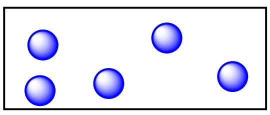
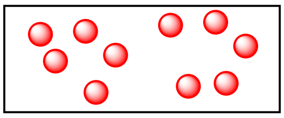
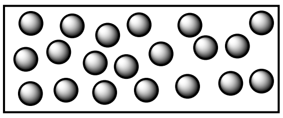


Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

12. Suatu reaksi hipotetik: $X + Y + Z \rightarrow$ Produk, bulatan bitu mewakili molekul X, bulatan merah mewakili molekul Y dan bulatan hitam mewakili molekul Z. sejumlah eksperimen dilakukan menghasilkan data berikut ini:

Exp	[X] (mol/L) x 10^{-2}	[Y] (mol/L) x 10^{-3}	[Z] (mol/L) x 10^{-4}	Rate (mol/L.s)
1.				0.2
2.				0.8
3.				0.4
4.				0.2

Berdasarkan informasi tersebut, manakah pernyataan berikut ini yang *tidak* benar?

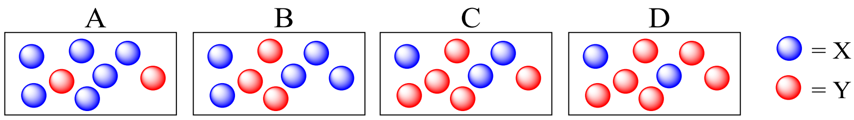
A. Reaksi berlangsung menurut orde pertama terhadap X
B. $k = 4 \times 10^4$ $mol^{-2}.L^2.s^{-1}$
C. penambahan [Z] pada eksperimen 1 akan meningkatkan laju reaksi
D. orde total reaksi adalah 3

Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak 2. Sangat tidak yakin 3. Tidak yakin
4. yakin 5. Sangat yakin 6. Sangat yakin sekali

13. Untuk reaksi hipotetik: X + Y → Produk, dimana reaksi berlangsung menurut orde kedua terhadap X dan orde pertama terhadap Y. Empat percobaan dilakukan dengan konsentrasi awal yang berbeda sebagaimana digambarkan secara mikroskopik dalam kotak A, B, C dan D. Gambar manakah (A, B, C atau D) yang akan menghasilkan laju reaksi terbesar?



Jelaskan alasan anda :

Seberapa yakinkah anda terhadap kebenaran jawaban anda

1. hanya menebak
2. Sangat tidak yakin
3. Tidak yakin
4. yakin
5. Sangat yakin
6. Sangat yakin sekali

Appendix E. Consent form and instrument for 2nd year students, the University of Reading

CONSENT FORM

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you will be studying this topic we would like you to attempt the following questions and choose reasons for your answers.

The results from the investigation will be used alongside data from other students to gain a better understanding of students' understanding of reaction rates and may be published in the educational literature. The outcomes will be completely anonymous and no participants will be identifiable.

If you are happy for your results to contribute to our investigation, please tick the box below:

○ **I am happy to take part in this investigation and for my results to contribute to the investigation**

Signed : Date :

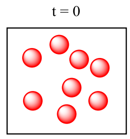
Name :

Chemical Kinetics Test

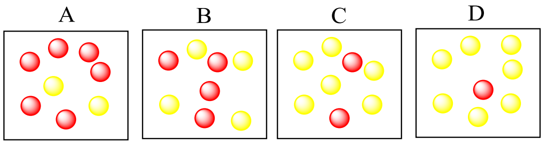
Instructions:

- *Write your name in the space provided on your answer sheet*
- *Each Multiple Choice question is followed by a series of possible answers or choices*
- *Read each question and decide which answer or choice is best.*
- *Circle the appropriate letter (A, B, C, or D) as a correct response*
- *Write the reason for your answer for each question in the space provided*
- *Circle the appropriate number (1, 2, 3, 4, 5 or 6) to show how sure you are on your answers*
- *For the question number 1 and 6, multiple choice questions are followed by a short answer question*

1. The diagram shows the concentration of reactant S in the first order reaction $S \rightarrow T$ at time $t = 0$ minutes.



Red spheres representing S molecules are converted to yellow spheres that represent T molecules. Which is the appropriate figure (from A, B, C and D) that represents reaction progress at the half-life of reaction(t½)?



Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

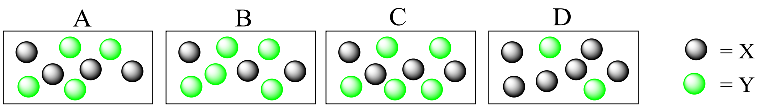
If the reaction is Second order, draw the appropriate diagram after the first half-life and the second half-life

Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

2. For the hypothetical reaction $X + Y \rightarrow$ Products. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



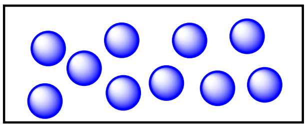
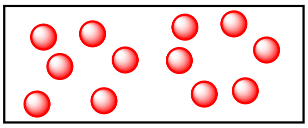
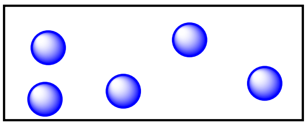
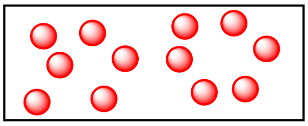
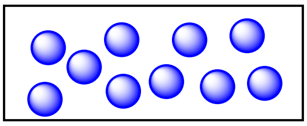
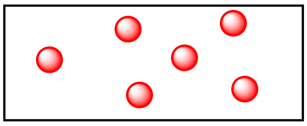
Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

3. Consider the reaction between t-butylbromide and a base at 55°C: $(CH_3)_3CBr(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq) + Br_2(aq)$, the blue spheres represent molecules of $(CH_3)_3CBr$ and red spheres represent ion of OH^-

A series of experiments is carried out with the following results:

Experiment	$[(CH_3)_3CBr]$ (mol/L) x 10^{-1}	$[OH^-]$ (mol/L) x 10^{-1}	Rate (mol/L.s)
1.			0.01
2.			0.005
3.			0.01

Based on this information, which of the following options is *not* a correct statement?

A. The reaction is first order with respect to $(CH_3)_3CBr$

B. $k = 0.010\ s^{-1}$

C. at the higher temperature, the rate of 2nd experiment will be > 0.005 mol/L.s

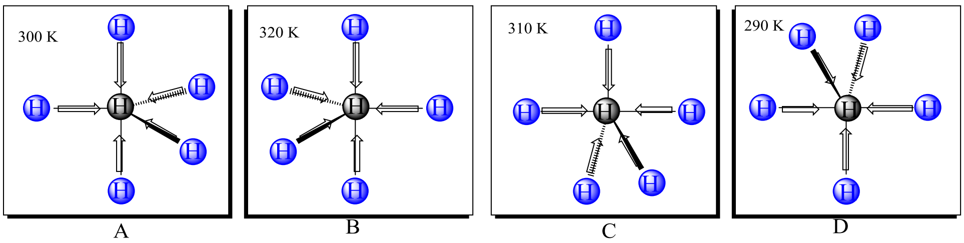
D. Rate = $k\,[(CH_3)_3CBr]\,[OH^-]$

Show working:

State the confidence rating of your answer

1. no idea, just guessing
2. very unconfident
3. unconfident
4. confident
5. very confident
6. absolutely confident

4. The reaction of $\cdot H + \cdot H \rightarrow H_2$ is represented pictorially below. Which figure (A, B, C or D) represents the highest rate of reaction? The arrows represent the direction of the collision.

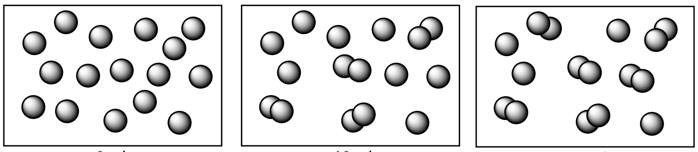


Show working:

State the confidence rating of your answer

1. no idea, just guessing
2. very unconfident
3. unconfident
4. confident
5. very confident
6. absolutely confident

5. The following pictures depict the progress of the reaction $2X \rightarrow X_2$.



t = 0 min　　t = 10 min　　t = 20 min

Based on the picture, the order of the reaction is…

A. 0　　B. 1　　C. 2　　D. 3

Show working:

State the confidence rating of your answer

1. no idea, just guessing　2. very unconfident　3. unconfident
4. confident　5. very confident　6. absolutely confident

6. A 12.0 mg radioactive sample decays by the first order reaction. How many grams of this sample remain after two half-lives?

A. 6 mg　　B. 4 mg　　C. 3 mg　　D. 2 mg

Show working:

State the confidence rating of your answer

1. no idea, just guessing　2. very unconfident　3. unconfident
4. confident　5. very confident　6. absolutely confident

Assume that two half-lives is reached in 126 days, what is the rate constant of this reaction?

Show working:

State the confidence rating of your answer

1. no idea, just guessing　2. very unconfident　3. unconfident
4. confident　5. very confident　6. absolutely confident

7. The decomposition of N_2O_5 in a solvent occurs according to the following equation

$N_2O_5 \rightarrow 2NO_2 + ½ O_2$

In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is *not* a correct expression of the average reaction rate?

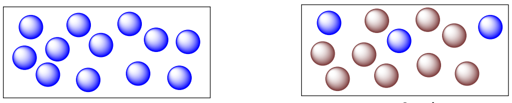
A. Rate = 0.001 $M.minute^{-1}$ N_2O_5 consumed
B. Rate = 0.002 $M.minute^{-1}$ NO_2 formed
C. Rate = 0.002 $M.minute^{-1}$ O_2 formed
D. Rate = 0.001 $M.minute^{-1}$

Show working:

State the confidence rating of your answer

1. no idea, just guessing　2. very unconfident　3. unconfident
4. confident　5. very confident　6. absolutely confident

8. Consider the first order reaction P $\rightarrow$ Q in which P molecules drawn as blue spheres are converted to Q molecules drawn as brown spheres.



t = 0 min   t = 8 min

What is the half-life of this reaction?

A. 2 min   B. 4 min   C. 6 min   D. 8 min

Show working:

State the confidence rating of your answer

1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

9. The rate law of the reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is $Rate = k[NO_2]^2$, where Rate is the rate of reaction at any time and k is the rate constant. If the concentration of CO increases by a factor of 3, the reaction rate will....

A. Increase by a factor of 3
B. Increase by a factor of 6
C. Increase by a factor of 9
D. Remain constant

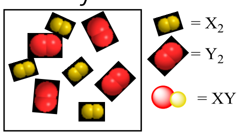
Show working:

State the confidence rating of your answer

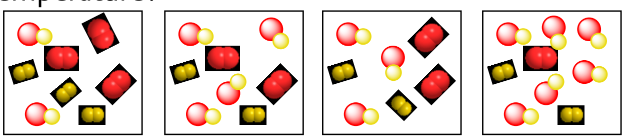
1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

10. The figure below describes the initial mixture in a reaction represented by $X_2 + Y_2 \rightarrow 2XY$

The key shows that the yellow molecules are X_2 and the red molecules are Y_2.



If the reaction is carried out at two different temperatures over the same time period, which figure (A, B, C or D) that represents the reaction at the highest temperature?



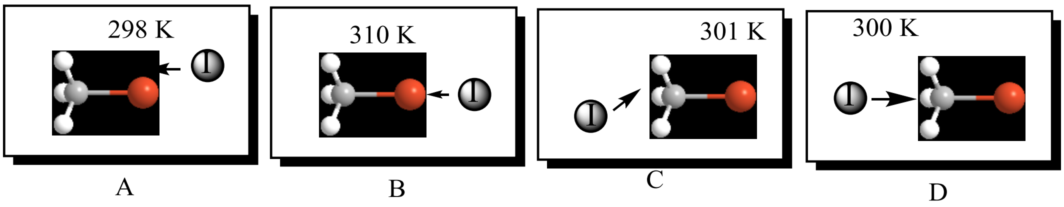
(A)   (B)   (C)   (D)

Show working:

State the confidence rating of your answer

1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

11. The reaction of $I^- + CH_3Br \rightarrow CH_3I + Br^-$ is represented pictorially below. Which figure (A, B, C or D) that represents the highest rate of reaction? The arrows represent the direction of the collision.

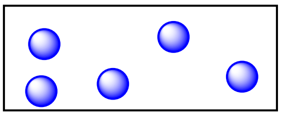
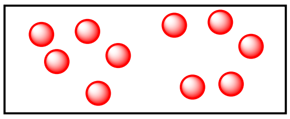
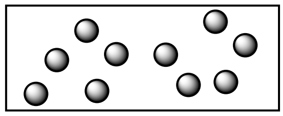
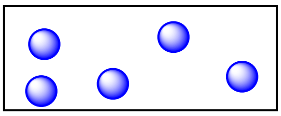
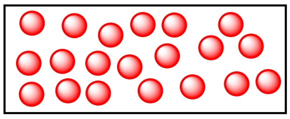
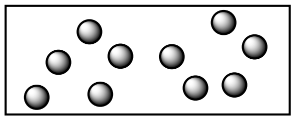
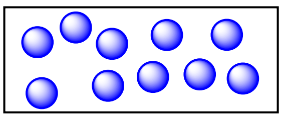
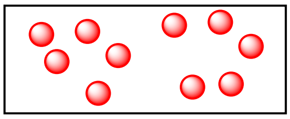
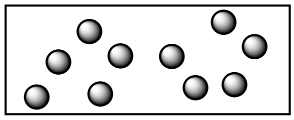
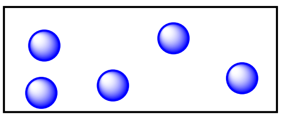
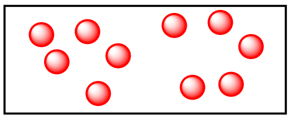
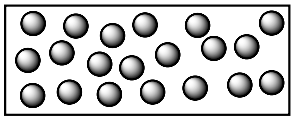


Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

12. For a hypothetical reaction: $X + Y + Z \rightarrow$ Products, the blue spheres represent molecules of X, red spheres represent molecules of Y and black spheres represent molecules of Z. A series of experiments is carried out with the following results:

Exp	[X] (mol/L) x 10^{-2}	[Y] (mol/L) x 10^{-3}	[Z] (mol/L) x 10^{-4}	Rate (mol/L.s)
1.				0.2
2.				0.8
3.				0.4
4.				0.2

Based on this information, which of the following options is *not* a correct statement?

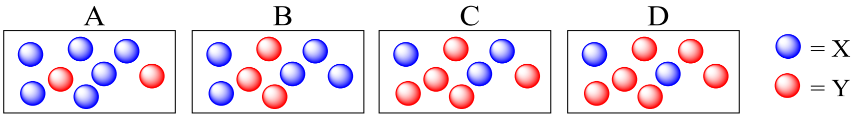
A. The reaction is first order with respect to X
B. $k = 4 \times 10^4$ $mol^{-2}.L^2.s^{-1}$
C. The addition of [Z] at experiment 1 will increase the rate
D. The overall order is 3

Show working:

State the confidence rating of your answer

1. no idea, just guessing 2. very unconfident 3. unconfident
4. confident 5. very confident 6. absolutely confident

13. For a hypothetical reaction: X + Y → Products. The rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



Show working:

State the confidence rating of your answer

1. no idea, just guessing   2. very unconfident   3. unconfident
4. confident   5. very confident   6. absolutely confident

Appendix F. Consent form and prototype FTDICK Instrument

CONSENT FORM

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you are currently studying this topic we would like you to attempt the following questions and, in some cases, explain the answers you have given.

We will collect the answer sheets in at the end and mark them, but we may like to follow up this initial investigation by asking you a few questions.

The results from the investigation will be used alongside data from other students to gain a better understanding of students' concepts of reaction rates and may be published in the educational literature. The outcomes would be completely anonymous and no participants will be identifiable.

If you are happy for your test results to contribute to our investigation, please tick the box below:

◯ **I am happy to take part in this investigation and for my test results to contribute to the investigation**

If you would be prepared to answer some further questions about your understanding of the topic please tick the box below:

◯ **I am happy to answer some further questions about my understanding and for the results to contribute to the investigation**

◯ **I understand the survey will be completely anonymous.**

Signed:

Email address:

Date:

GENERAL CONFIDENCE IN CHEMISTRY

Instruction**:**

Before you answer the questions, please rate your confidence level in chemistry and chemical kinetics by circling the appropriate response.

1. Please rate your overall confidence in your ability to be successful in a chemistry degree course.

   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

2. Please rate how confident you are in physical chemistry as compared to other areas of chemistry (for example organic/inorganic/practical)

   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

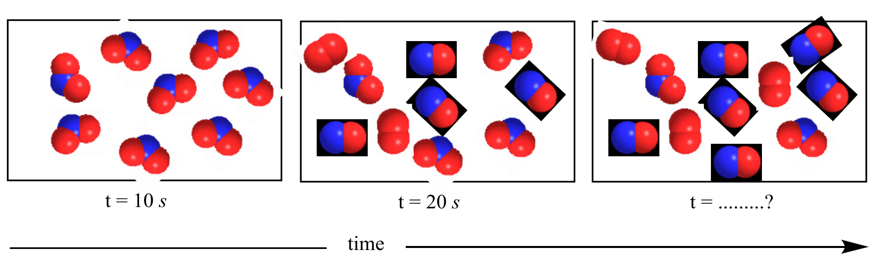
3. Please rate how confident you are in chemical kinetics as compared to other areas of chemistry (for example atomic structure, acid-bases, organic nomenclature, organic mechanism, moles and concentration, etc.)

   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

4. Please rate how confident you are in chemical kinetics as compared to other areas of physical chemistry (for example equilibria, energy changes, gases, etc.)

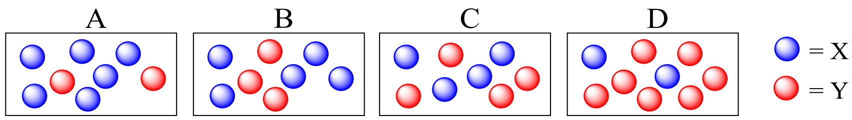
   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Instructions: answer the questions on the sheet about chemical kinetics. Circle the letter that represents the best answer in your view. Then circle the number that best represents how confident you are in your given answer. Don't worry if there are some questions you can't answer.

No	Question
1.	A 64 mg sample of radioactive material decays by first order reaction. After 10 minutes two half-lives are passed. What is the mass of sample that remains after 15 minutes? A. 24 mg B. 23 mg C. 16 mg D. 8 mg State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. After 10 minutes, half of the initial sample remained B. The rate of decay of this sample is a constant C. For each successive half-life, the mass of sample in a constant number D. The rate of decay of this sample increases as the mass of sample decreases E. For each successive half-life, the mass of sample decreases by a factor of 2 State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
2.	The decomposition of nitrogen dioxide to nitric oxide and oxygen at 300^{0}C is a second order reaction. $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$ What is the concentration of NO_2 at t = 10 minutes, if its initial concentration is 8.00 x 10^{-3} M and the rate constant is 0.54 $M^{-1}.s^{-1}$? A. 0.54 M B. 7.67 x 10^{-3} M C. 2.23 x 10^{-3} M D. 3.61 x 10^{-5} M State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. It obeys the equation $\ln[A]_t = \ln[A]_0 - kt$ B. It obeys the equation $\frac{1}{[A]_t} = \frac{1}{[A]_0} + kt$ C. It obeys the equation $[A]_t = [A]_0 - kt$ State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
3.	The decomposition of nitrogen dioxide to nitric oxide and oxygen at a certain temperature is shown pictorially below and is a second order reaction. $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$  The time at the final representation shown above is… A. 25 s B. 30 s C. 40 s D. 60 s

	State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. Each successive half-life is half the preceding one B. The value of t½ is constant C. The rate of disappearance of this sample increases with decrease in concentration D. The rate of disappearance of this sample decreases with decrease in concentration E. The value of each successive half-life is twice the preceding one. F. The value of of each successive half-life is 4 times the preceding one State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
4.	The second order reaction of $H_2O_2(aq) + 3I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_3^-(aq)$ is first order in H_2O_2, first order in I^- and zero order in H^+. The rate law expression for this reaction is…. A. $Rate = k\,[H_2O_2]\,[I^-]^3\,[H^+]^2$ B. $Rate = k\,[H_2O_2]\,[I^-]$ C. $Rate = k\frac{[H_2O]^2\,[I_3^-]}{[H_2O_2]\,[I^-]^3\,[H^+]^2}$ D. $Rate = k\,[H_2O_2]^x\,[I^-]^y\,[H^+]^z$ State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. The values of the exponents in the rate law are obtained from the coefficients in the balanced equation B. The rate law is expressed based on the law of mass action, that describes the relationship between the concentrations of the reactants and products. C. The values of the exponents in the rate law are based on the order of the reactants which are determined experimentally D. The information which is provided in the question is inadequate to determine the rate law. State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
5.	The reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is second order with respect to NO_2, but zero order with respect to CO. If the concentration of NO_2 increases by a factor of 2 and the concentration of CO increases by a factor of 3, the reaction rate will…. A. Increase by a factor of 36 B. Increase by a factor of 12 C. Increase by a factor of 4 D. Remain constant State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. Only an increase in concentration of NO_2 affects the rate B. The higher the concentration of both reactants, the higher the rate C. The overall order of reaction is 2, therefore an increase in the concentration of both reactants increases the rate by the power of 2 D. There is no effect on the reaction rate as the order with respect to one reactant is zero State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

6. For a hypothetical reaction: X + Y → Products, the rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

Which one of the following options is the reason for your answer to the question?

A. It has the highest concentration of the reactant which is 2nd order
B. The concentrations of both reactants are the same, therefore the ratio of collision is more favourable
C. The amount of X and Y and the average of each keep determine the rate
D. The concentration of Y is much higher than the concentration of X and this leads to the reaction being completed faster

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

7. The integrated rate law for a reaction can be expressed as $[A]_t = [A]_0 - kt$. If $[A]_0$ is the initial concentration, $[A]_t$ is the concentration at particular time, t is the time and k is the rate constant, then the expression of half-life for this reaction is....

A. $t_{½} = \frac{[A]_0}{2k}$ B. $t_{½} = -\frac{[A]_0}{k}$ C. $t_{½} = \frac{[A]_t}{2k}$ D. $t_{½} = -\frac{[A]_t - [A]_0}{k}$

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The concentration of A at its half-life is twice its initial concentration
B. The concentration of A at its half-life is a half of its initial concentration
C. The concentration of A at its half-life is same as its initial concentration

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

8. Hydrogen iodide dissociates at an elevated temperature according to the following equation:

$2HI(g) \rightarrow H_2(g) + I_2(g)$

The reaction is carried out with different concentration at 435°C and the data obtained are given below.

[HI], M	0.04	0.02	0.01
Rate, $M.s^{-1}$	4.8×10^{-2}	1.2×10^{-2}	3.0×10^{-3}

The rate constant of this reaction is....

A. $4.8 \times 10^{-2}\ M^{-1}\ s^{-1}$ B. $3.3 \times 10^{-2}\ M^{-1}\ s^{-1}$ C. $1.2\ M^{-1}\ s^{-1}$ D. $30\ M^{-1}\ s^{-1}$

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

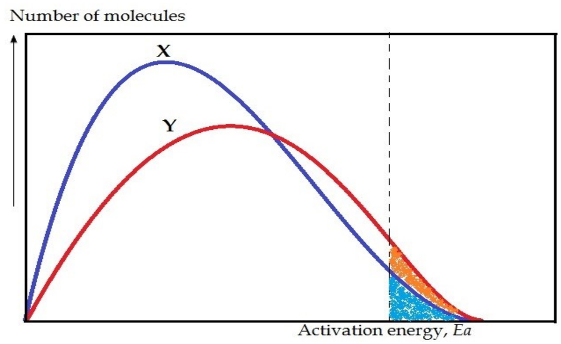
Which one of the following options is the reason for your answer to the question?

A. The data obey zero order reaction kinetics
B. The data obey first order reaction kinetics
C. The data obey second order reaction kinetics
D. The value of k will be equal to the concentration of reactant because it is a constant

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

9. The Boltzmann distribution curves below describe the distribution of the kinetic energies of molecules.



X and Y represent the same reaction carried out at a different temperature where X is lower than Y. Which the statement below is correct?

A. X has a higher rate of reaction than Y
B. Y has a higher rate of reaction than X
C. Both reactions have the same rate
D. There is insufficient information to determine the relative rates

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

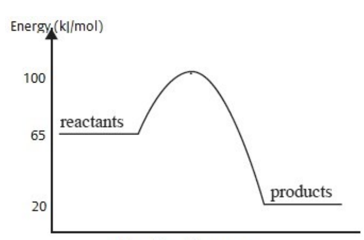
Which one of the following options is the reason for your answer to the question?

A. This reaction has the higher activation energy
B. The value of *k* and the number of molecules of both reactants are unknown
C. The higher the temperature, the higher the number of molecules with the *Ea*
D. The higher the temperature, the higher the activation energy (*Ea*)
E. This reaction has the lower activation energy
F. The value of activation energy is not determined the rate

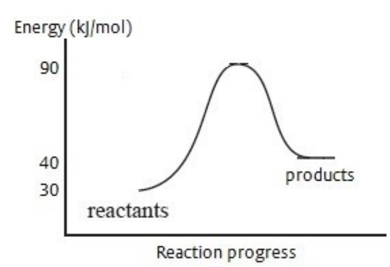
State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

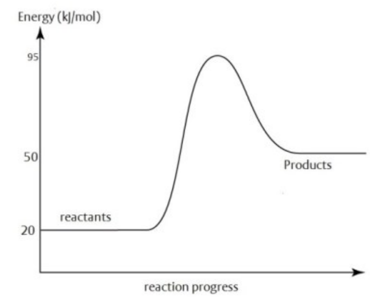
10. Consider four reactions as described in the energy profile of *Ea* and Δ*H* below. Assuming that all four reactions are carried out at the same temperature and the same Arrhenius factor A, which reaction is the slowest....



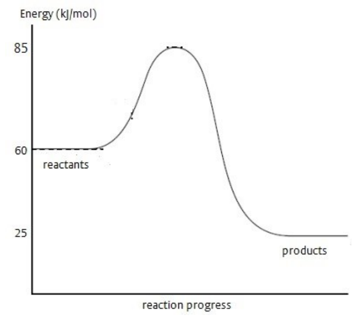
A.



B.



C.



D.

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The reaction has the highest energy in its transition state
B. The reaction has the highest activation energy
C. The reaction has the lowest energy in its transition state
D. The reaction has the lowest activation energy
E. The reaction releases higher energy
F. The reaction releases lower energy
G. The reaction absorbs higher energy
H. The reaction absorbs lower energy

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

11. Consider two reactions with the values of *Ea* and ΔH are given below.

Reaction 1. $Ea = 25$ kJ.mol^{-1}; ΔH below $= -65$ kJ.mol^{-1}

Reaction 2. $Ea = 25$ kJ.mol^{-1}; ΔH below $= +10$ kJ.mol^{-1}

Assuming both reactions are carried out at the same Arrhenius factor A, but the temperature of reaction 2 is higher.

Based on this information, which is the correct statement below?

A. Reaction 1 is exothermic and its rate is higher than the rate of reaction 2
B. Both reactions have the same rate
C. Reaction 2 is endothermic and its rate is lower than the rate of reaction 1
D. Reaction 2 is endothermic and its rate is higher than the rate of reaction 1

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. Increase in temperature increases the activation energy
B. Increases in temperature decreases the activation energy
C. Increases in temperature increases the rate an endothermic reaction, but decreases the rate an exothermic one
D. Increases in temperature increases the rate an exothermic reaction, but decreases the rate an endothermic one
E. Increase in temperature increases the rate constant
F. Increases in temperature decreases the rate constant
G. As two reactions have the same value of activation energy, they also have the same rate constant

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

12. The formation of HI(g) follows the reaction $H_2 + I_2 \rightarrow 2HI$. This reaction may occur with the following mechanism:

$$I_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2I \quad \text{fast}$$

$$I + I + H_2 \xrightarrow{k_2} 2HI \quad \text{slow}$$

The overall rate law of this reaction is....

A. Rate = $k_2[I]^2[H_2]$ B. Rate = $k\,\frac{[HI]^2}{[I]^2[H_2]}$ C. Rate = $k_2\,\frac{k_1}{k_{-1}}[I_2]\,[H_2]$ D. Rate = $k_1\,[I_2] - k_{-1}[I]^2$

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

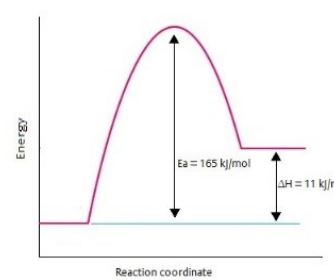
Which one of the following options is the reason for your answer to the question?

A. The rate law is obtained directly from the slow step in the mechanism
B. The rate law is obtained from the fast step in the mechanism
C. The rate law is obtained from the law of mass action
D. The rate law is obtained from the slow step by considering any intermediates in a preceding step

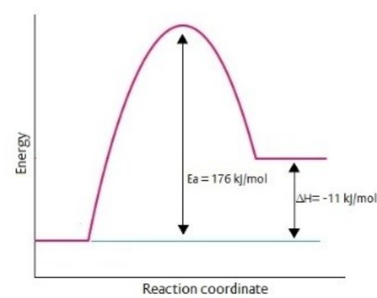
State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

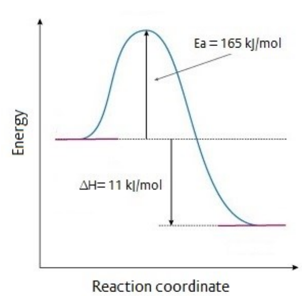
13. The reaction $NO_2(g) + NO_3(g) \rightarrow N_2O_5(g)$ with $\Delta H = 11$ kJ.mol^{-1} has the activation energy 165 kJ.mol^{-1}. The graph below that represents the energy profile for the **reverse reaction** is....



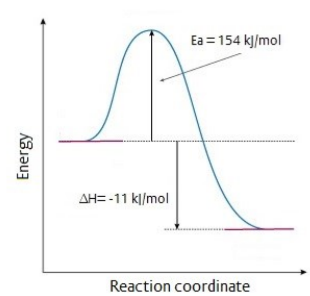
A.



B.



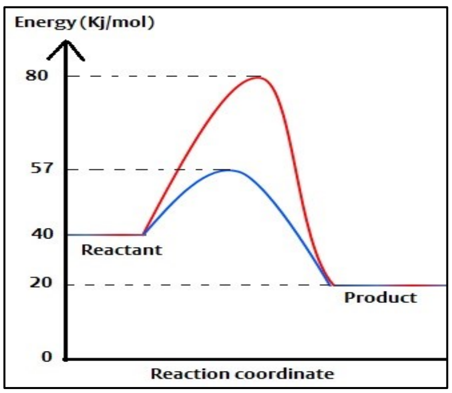
C.



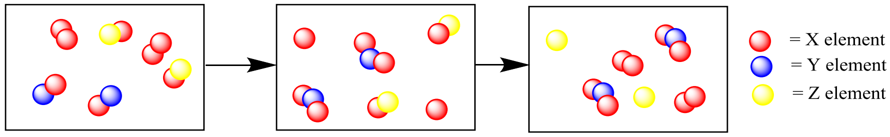
D.

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

	Which one of the following options is the reason for your answer to the question? A. The reverse reaction is endothermic and the activation energy for this reverse reaction incorporates the value of ΔH B. The reverse reaction is exothermic and the activation energy of this reverse reaction does not involve the value of ΔH. C. The reverse reaction is endothermic and the activation energy for the forward and the reverse reactions are same D. The reverse reaction is exothermic and the activation energy for this reverse reaction incorporates the value of ΔH State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
14.	The energy profile below describes a catalysed and an uncatalysed pathway for a given reaction.  The value of the activation energy of the catalysed one is.... A. 60 kJ/mol B. 40 kJ/mol C. 37 kJ/mol D. 17 kJ/mol State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. The activation energy of a catalysed and an uncatalysed pathway is the same, but the mechanisms are different B. The activation energy of a catalysed pathway is lower than an uncatalysed one and the mechanisms are the same C. The activation energy of a catalysed pathway is lower than an uncatalysed one and these mechanisms are different D. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are the same E. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are different F. Without an increase in temperature, the activation energies and mechanisms of a catalyst and an uncatalysed pathway are the same State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

15. The following diagram depicts an imaginary two step mechanism of a reaction.



Based on the representation above, the substance that acts as a catalyst is....

A. X   B. XZ   C. X_2 D. XY

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

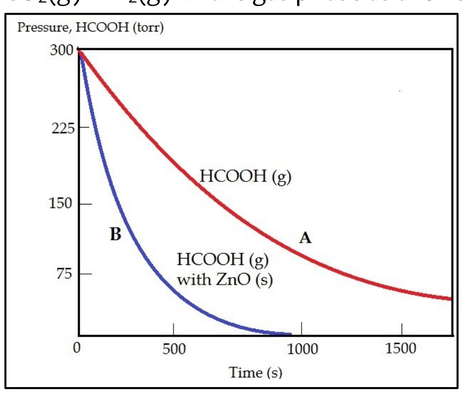
Which one of the following options is the reason for your answer to the question?

A. The substance does not undergo a permanent chemical change and is reformed in the last product
B. The substance is formed in one elementary reaction and consumed in the next
C. The substance increases the rate without involving chemically in the reaction
D. The substance is not present in the final product

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

16. The variation in partial pressure of HCOOH for the decomposition of formic acid $HCOOH(g) \rightarrow CO_2(g) + H_2(g)$ in the gas phase as a function of time at 838 K is described in the graph below.



A graph of the partial pressure of HCOOH versus time is shown as the red curve, A. Assuming that ZnO(s) is the catalyst, when a small amount of solid ZnO is added, the partial pressure of HCOOH versus time varies as shown by the blue curve, B.

Based on this information, which is the correct statement below?

A. This is an example of homogeneous catalysis and the rate of B is higher than the rate of A
B. This is an example of heterogeneous catalysis and the rate of B is higher than the rate of A
C. This is an example of homogeneous catalysis and the rate of A is higher than the rate of B
D. This is an example of heterogeneous catalysis and the rate of A is higher than the rate of B

State the confidence rating of your answer

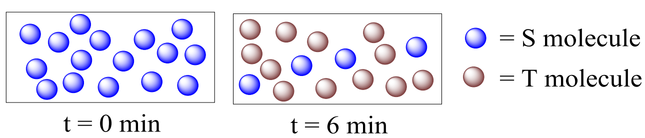
1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

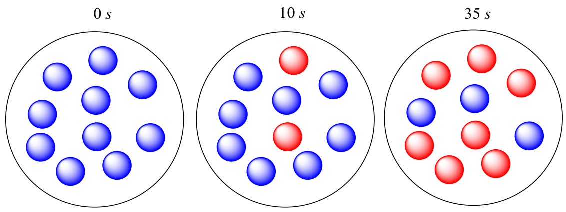
Which one of the following options is the reason for your answer to the question?

A. HCOOH, CO_2 and H_2 are in the same phase and the presence of ZnO increases the rate
B. HCOOH and ZnO are in different phases and the presence of ZnO decreases the rate
C. HCOOH, CO_2 and H_2 are present in the same phase and the presence of ZnO decreases the rate
D. HCOOH and ZnO are in different phases and the presence of ZnO increases the rate

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

17.	The reaction of nitrogen dioxide and carbon monoxide $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ may occur according to the following mechanism: Step 1: $NO_2(g) + NO_2(g) \xrightarrow{k_1} NO_3(g) + NO(g)$ slow Step 2: $NO_3(g) + CO(g)\ ) \xrightarrow{k_2} NO_2(g) + CO_2(g)$ fast If *k* is the overall rate constant, the rate law for this reaction is.... A. Rate = $k[NO_2][CO]$ B. Rate = $k\,[NO_2]^2$ C. Rate = $k\,[NO_3]\,[CO]$ D. Rate = $k\,\frac{[NO_2]^2\,[CO]}{[NO][CO]_2}$ State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. Step 1 is the rate determining step B. Step 2 is the rate determining step C. The rate law is obtained directly from the overall reaction equation D. The rate law is derived from the law of mass action State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
18.	Consider the first order reaction S → T in which S molecules are converted to T molecules.  How many S (blue) molecules and T (brown) molecules are present at the half-life? A. Blue = 4 and brown = 12 B. Blue = 10 and brown = 6 C. Blue = 2 and brown = 14 D. Blue = 8 and brown = 8 State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. The number of S molecules is a half of its initial number B. The number of S molecules is a half of its number at 6 minutes C. The number of S molecules that react is a half the number that react between 0 and 6 minutes D. The half life is related to the concentration of a reactant at any time during the reaction State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

19.	The hypothetical reaction G → H is depicted pictorially below. Each blue sphere represents 0.2 moles of G and each red sphere represents 0.2 moles of H, and the container has a volume of 1.00 L.  The number of moles of G and H respectively in the mixture after 32 *s* is.... A. 1.280 mol; 0.720 mol B. 0.544 mol; 1.456 mol C. 0.720 mol; 1.280 mol D. 1.456 mol; 0.544 mol State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. As time increases, the rate of conversion G molecules to H molecules also increases B. As time increases, the rate of conversion G molecules to H molecules decreases C. The rate of conversion of G molecules to H molecules persecond is a constant State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
20.	The decomposition of N_2O_5 in a solvent occurs according to the following equation $N_2O_5 \rightarrow 2NO_2 + ½ O_2$ In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is the correct expression of the average reaction rate? A. $\text{Rate} = \frac{d[N_2O_5]}{dt} = 0.001 \text{ M min}^{-1}$ B. $\text{Rate} = \frac{d[NO_2]}{dt} = 0.001 \text{ M min}^{-1}$ C. $\text{Rate} = \frac{d[O_2]}{dt} = 0.0005 \text{ Mmin}^{-1}$ D. $\text{Rate} = -\frac{d[NO_2]}{dt} = -0.002 \text{ Mmin}^{-1}$ State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. O_2 is produced twice as fast as N_2O_5 is consumed B. NO_2 is produced a half as fast as N_2O_5 is consumed C. The rate law can only be expressed by the rate of disappearing N_2O_5 D. N_2O_5 is consumed twice as fast as NO_2 is produced E. NO_2 is consumed twice as the rate of N_2O_5 is consumed F. O_2 is produced a half as fast as N_2O_5 is consumed State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Appendix G. Consent form and FTDICK Instrument

CONSENT FORM

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you will be studying this topic we would like you to attempt the following questions and choose reasons for your answers.

The results from the investigation will be used alongside data from other students to gain a better understanding of students' understanding of reaction rates and may be published in the educational literature. The outcomes will be completely anonymous and no participants will be identifiable.

If you are happy for your results to contribute to our investigation, please tick the box below:

◯ **I am happy to take part in this investigation and for my results to contribute to the investigation**

Signed: Date:

GENERAL CONFIDENCE IN CHEMISTRY

Instruction**:**

Before you answer the questions, please rate your confidence level in chemistry and chemical kinetics by circling the appropriate response.

1. Please rate your overall confidence in your ability to be successful in a chemistry degree course.

   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

2. Please rate how confident you are in physical chemistry as compared to other areas of chemistry (for example organic/inorganic/practical)

   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

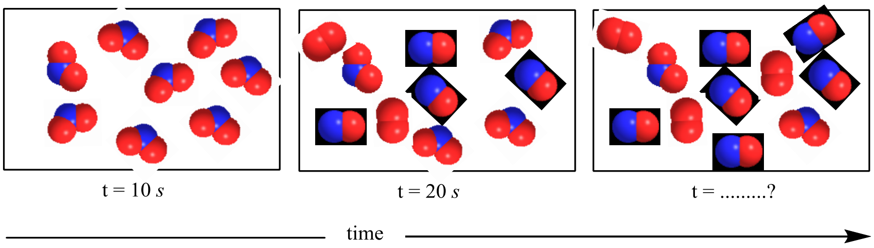
3. Please rate how confident you are in chemical kinetics as compared to other areas of chemistry (for example, atomic structure, acid-bases, organic nomenclature, organic mechanism, moles and concentration, etc.)

   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

4. Please rate how confident you are in chemical kinetics as compared to other areas of physical chemistry (for example equilibria, energy changes, gases, etc.)

   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Instructions: answer the questions on the sheet about chemical kinetics. Circle the letter that represents the best answer in your view. Then circle the number that best represents how confident you are in your given answer. Don't worry if there are some questions you can't answer.

No.	**Question**
1.	A 64 mg sample of radioactive material decays by first order reaction. After 10 minutes two half-lives have passed. What is the mass of the sample that remains after 15 minutes? A. 24 mg B. 23 mg C. 16 mg **D. 8 mg** State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. After 10 minutes, half of the initial sample remained B. The rate of decay of this sample is a constant C. For each successive half-life, the mass change of sample is a constant D. The rate of decay of this sample increases as the mass of sample decreases **E. For each successive half-life, the mass of sample decreases by a factor of 2** State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
2.	In a reaction represented by K → L + M the integrated rate expression is given by: $[A]_t = [A]_0 - kt$. At the start of the reaction the concentration of K is 0.8 mol dm^{-3}. If the value of the rate constant is 2 mol dm^{-3} s^{-1} determine the time taken for the concentration of K to drop to 0.4 mol dm^{-3}. A. 0.1 *s* **B. 0.2 *s*** C. 0.35 *s* D. 0.4 *s* State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident Which one of the following options is the reason for your answer to the question? A. The concentration of K at its half-life is twice its initial concentration **B. The concentration of K at its half-life is a half of its initial concentration** C. The concentration of K at its half-life is same as its initial concentration State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
3.	The decomposition of nitrogen dioxide to nitric oxide and oxygen at a certain temperature is shown pictorially below and is a second order reaction and the equation for the reaction is: $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$  The time at the final representation shown above is... A. 25 s B. 30 s **C. 40 s** D. 50 s State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The value of each successive half-life is half the preceding one
B. The value of t½ is constant
C. The rate of disappearance of this sample increases with decrease in concentration
D. The value of each successive half-life is twice the preceding one.

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

4. The second order reaction of $H_2O_2(aq) + 3I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_3^-(aq)$ is first order in H_2O_2, first order in I^- and zero order in H^+. The rate law expression for this reaction is....

A. $Rate = k\,[H_2O_2]\,[I^-]^3\,[H^+]^2$
B. $Rate = k\,[H_2O_2]\,[I^-]$
C. $Rate = k\frac{[H_2O]^2\,[I_3^-]}{[H_2O_2]\,[I^-]^3\,[H^+]^2}$
D. $Rate = k\,[H_2O_2]^x\,[I^-]^y\,[H^+]^z$ (x,y,z are $\neq 0$)

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The values of the exponents in the rate law are obtained from the coefficients in the balanced equation
B. The rate law is expressed based on the law of mass action that describes the relationship between the concentrations of the reactants and products.
C. The values of the exponents in the rate law are based on the order of the reactants which are determined experimentally
D. The information which is provided in the question is inadequate to determine the rate law.

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

5. The reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is second order with respect to NO_2, but zero order with respect to CO. If the concentration of NO_2 increases by a factor of 2 and the concentration of CO increases by a factor of 3, the reaction rate will....

A. Increase by a factor of 36
B. Increase by a factor of 12
C. Increase by a factor of 4
D. Remain constant

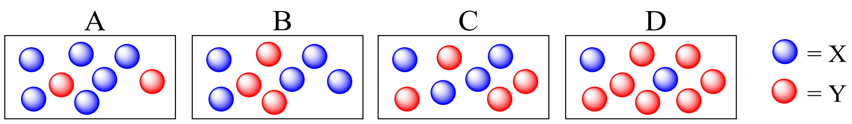
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. Only an increase in concentration of NO_2 affects the rate
B. The higher the concentration of both reactants, the higher the rate
C. The overall order of reaction is 2, therefore an increase in the concentration of both reactants increases the rate by the power of 2
D. There is no effect on the reaction rate as the order with respect to one reactant is zero

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

6. For a hypothetical reaction: $X + Y \rightarrow$ Products, the rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. It has the highest concentration of the reactant which is 2nd order

B. The concentrations of both reactants are the same, therefore the ratio of collisions is more favourable

C. Both 1st and 2nd order reactants determine the rate

D. The concentration of Y is much higher than the concentration of X and this leads to the reaction being completed faster

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

7. The integrated rate law for a reaction can be expressed as $[A]_t = [A]_0 - kt$. If $[A]_0$ is the initial concentration, $[A]_t$ is the concentration at particular time, t, and k is the rate constant, then the expression of half-life for this reaction is....

A. $t½ = \frac{[A]_t}{2k}$ **B. $t½ = \frac{[A]_0}{2k}$** C. $t½ = \frac{0.693}{k}$ D. $t½ = -\frac{[A]_0}{k}$

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The concentration of A at its half-life is twice its initial concentration

B. The concentration of A at its half-life is a half of its initial concentration

C. The concentration of A at its half-life is same as its initial concentration

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

8. Consider the first order reaction X → Y in which X molecules are converted to Y molecules. X is initially 2.4 mol dm^{-3} and after 10 minutes the concentration has dropped to 0.6 mol dm^{-3}. Calculate the concentration of X and Y after one half life.

A. X = 0.6 mol dm^{-3} & Y = 1.8 mol dm^{-3}

B. X = 0.9 mol dm^{-3} & Y = 1.5 mol dm^{-3}

C. X = 0.3 mol dm^{-3} & Y = 2.1 mol dm^{-3}

D. X = 1.2 mol dm^{-3} & Y = 1.2 mol dm^{-3}

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. **The concentration of X at its half-life is a half of its initial concentration**

B. The concentration of X is a half of its concentration at 10 minutes

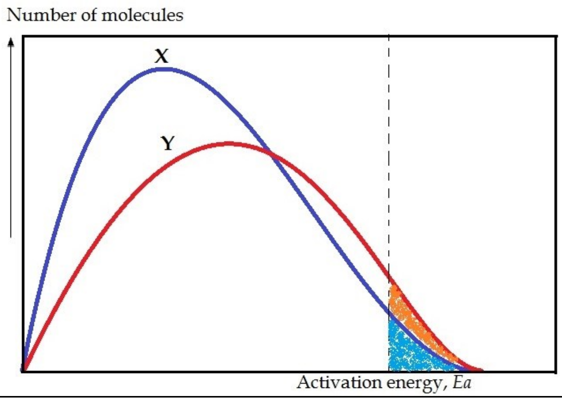
C. The concentration of X that react is a half the concentration that react between 0 and 10 minutes

D. The half-life is reached at 10 minutes

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

9. The Boltzmann distribution curves below describe the distribution of the kinetic energies of molecules.



X and Y represent the same reaction carried out at a different temperature where X is lower than Y. Which statement below is correct?

A. X has a higher rate of reaction than Y
B. **Y has a higher rate of reaction than X**
C. Both reactions have the same rate
D. There is insufficient information to determine the relative rates

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

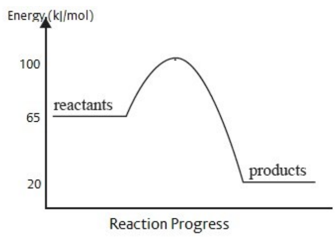
Which one of the following options is the reason for your answer to the question?

A. This reaction has the higher activation energy
B. The value of *k* and the number of molecules of both reactants are unknown
C. **The higher the temperature, the higher the number of molecules with the activation energy (*Ea*)**
D. The higher the temperature, the higher the activation energy (*Ea*)
E. This reaction has the lower activation energy
F. The value of activation energy does not determine the rate

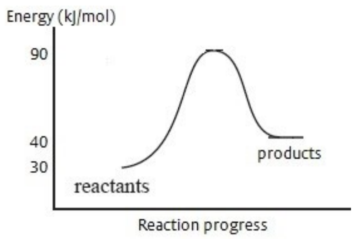
State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

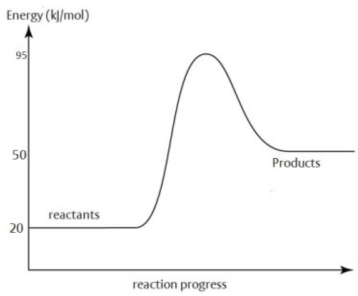
10. Consider four reactions as described in the energy profile of *Ea* and ΔH below. Assuming that all four reactions are carried out at the same temperature and have the same Arrhenius factor A, which reaction is the slowest....



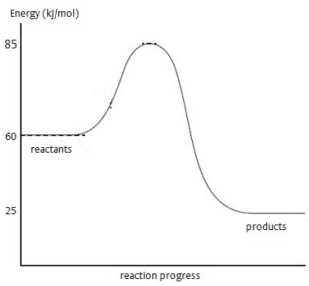
A.



B.



C.



D.

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The reaction has the highest energy in its transition state
B. The reaction has the highest activation energy
C. The reaction has the lowest energy in its transition state
D. The reaction has the lowest activation energy
E. The reaction is exothermic
F. The reaction is endothermic

State the confidence rating of your answer

1. Very unconfident   2. Not very confident   3. Average   4. Quite confident   5. Very confident

11. The decomposition of nitrogen dioxide to nitric oxide and oxygen takes place by second order kinetics:

$2NO_2(g) \rightarrow 2NO(g) + O_2(g)$

At time, t = 10 s the pressure of NO_2 is 80 torr and after 5 seconds the pressure has dropped to 40 torr. Determine the time at which the pressure of NO_2 is 20 torr.

A. 17.5 *s* B. 20 *s* **C. 25 *s*** D. 30 *s*

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?
A. The value of each successive half-life is half the preceding one
B. The value of t½ is constant
C. The rate of disappearance of this sample increases with decrease in concentration
D. The value of each successive half-life is twice the preceding one.

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

12. The formation of HI(g) follows the reaction $H_2 + I_2 \rightarrow 2HI$. This reaction may occur with the following mechanism:

$$I_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2I \qquad \text{fast}$$

$$I + I + H_2 \xrightarrow{k_2} 2HI \qquad \text{slow}$$

The overall rate law of this reaction is....

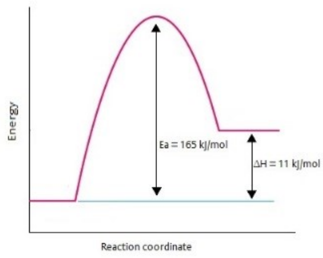
A. Rate = $k_2[I]^2[H_2]$ B. Rate = $k\frac{[HI]^2}{[I]^2[H_2]}$ **C. Rate = $k_2\frac{k_1}{k_{-1}}[I_2][H_2]$** D. Rate = $k_1[I_2] - k_{-1}[I]^2$

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

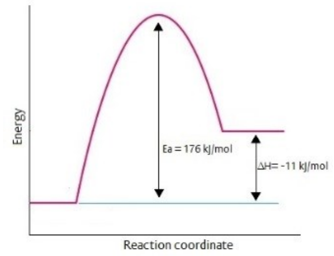
Which one of the following options is the reason for your answer to the question?
A. The rate law is obtained directly from the slow step in the mechanism
B. The rate law is obtained from the fast step in the mechanism
C. The rate law is obtained from the law of mass action
D. The rate law is obtained from the slow step by considering any intermediates in preceding steps

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

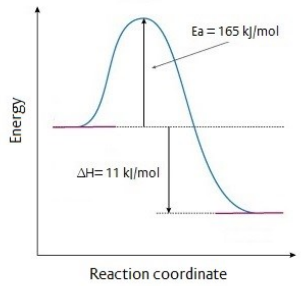
13. The reaction $NO_2(g) + NO_3(g) \rightarrow N_2O_5(g)$ with $\Delta H = 11$ kJ mol^{-1} has the activation energy 165 kJ mol^{-1}. The graph below that represents the energy profile for the **reverse reaction** is....



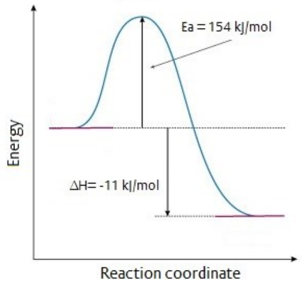
A.



B.



C.



D.

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

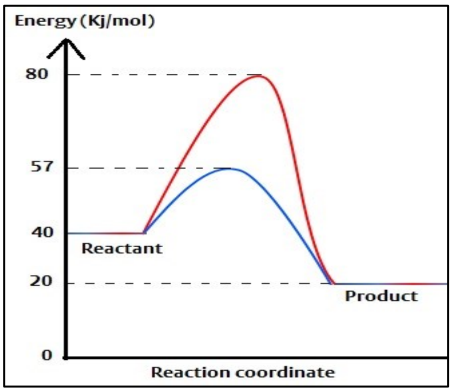
Which one of the following options is the reason for your answer to the question?

A. The reverse reaction is endothermic and its activation energy value is lower
B. **The reverse reaction is exothermic and its activation energy value is lower.**
C. The reverse reaction is endothermic and its activation energy value is higher
D. The reverse reaction is exothermic and its activation energy value is higher

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

14. The energy profile below describes a catalysed and an uncatalysed pathway for a given reaction.



The value of the activation energy of the catalysed reaction is....

A. 60 kJ mol^{-1} B. 40 kJ mol^{-1} C. 37 kJ mol^{-1} **D. 17 kJ mol^{-1}**

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

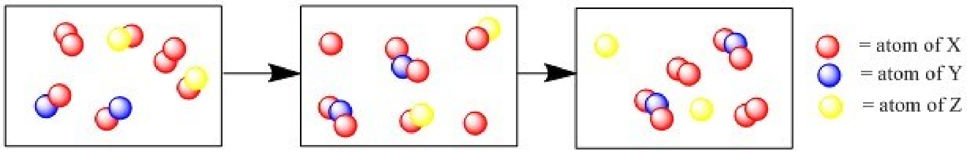
Which one of the following options is the reason for your answer to the question?

A. The activation energy of a catalysed and an uncatalysed pathway is the same, but the mechanisms are different
B. The activation energy of a catalysed pathway is lower than an uncatalysed one and the mechanisms are the same
C. **The activation energy of a catalysed pathway is lower than an uncatalysed one and the mechanisms are different**
D. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are the same
E. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are different
F. The mechanism of a reaction is only changed if the temperature increases

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

15. The following diagram depicts an imaginary two step mechanism of a reaction.



Based on the representation above, the substance that acts as a catalyst is....

A. X B. XZ **C. X_2** D. XY

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

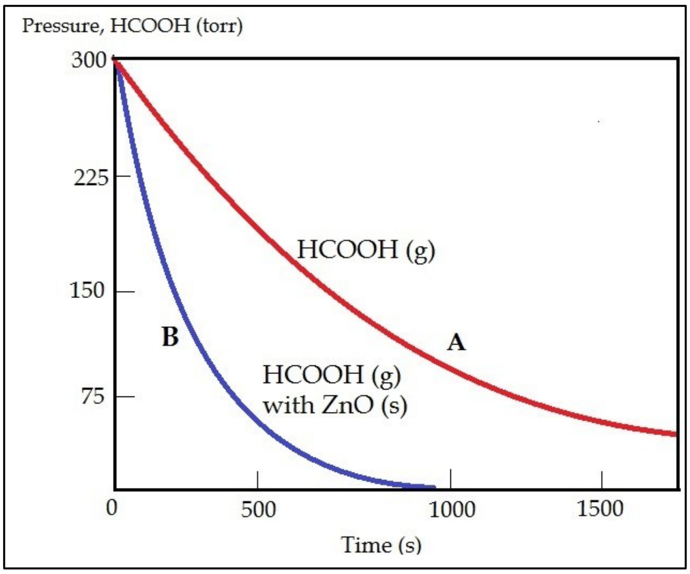
Which one of the following options is the reason for your answer to the question?

A. **The substance does not undergo a permanent chemical change and is reformed in the final product**
B. The substance is formed in one elementary reaction and consumed in the next
C. The substance increases the rate without being involved chemically in the reaction
D. The substance is not present in the final product

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

16. The variation in partial pressure of HCOOH for the decomposition of formic acid {$HCOOH(g) \rightarrow CO_2(g) + H_2(g)$} in the gas phase as a function of time at 838 K is described in the graph below.



A graph of the partial pressure of HCOOH versus time is shown as the red curve, A. Assuming that ZnO(s) is the catalyst, when a small amount of solid ZnO is added, the partial pressure of HCOOH versus time varies as shown by the blue curve, B.
Based on this information, which is the correct statement below?

A. This is an example of homogeneous catalysis and the rate of B is higher than the rate of A
B. This is an example of heterogeneous catalysis and the rate of B is higher than the rate of A
C. This is an example of homogeneous catalysis and the rate of A is higher than the rate of B
D. This is an example of heterogeneous catalysis and the rate of A is higher than the rate of B

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. HCOOH, CO_2 and H_2 are in the same phase and the presence of ZnO increases the rate
B. HCOOH and ZnO are in different phases and the presence of ZnO decreases the rate
C. HCOOH, CO_2 and H_2 are present in the same phase and the presence of ZnO decreases the rate
D. **HCOOH and ZnO are in different phases and the presence of ZnO increases the rate**

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

17. The reaction of nitrogen dioxide and carbon monoxide $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ may occur according to the following mechanism:

Step 1: $NO_2(g) + NO_2(g) \xrightarrow{k_1} NO_3(g) + NO(g)$ slow

Step 2: $NO_3(g) + CO(g) \xrightarrow{k_2} NO_2(g) + CO_2(g)$ fast

If k is the overall rate constant, the rate law for this reaction is....

A. Rate = $k[NO_2][CO]$ **B. Rate = $k\,[NO_2]^2$** C. Rate = $k\,[NO_3]\,[CO]$ D. Rate = $k\,\frac{[NO]\,[CO_2]}{[NO_2][CO]}$

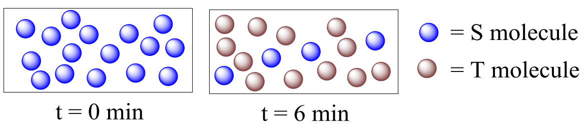
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. **Step 1 is the rate determining step**
B. Step 2 is the rate determining step
C. The rate law is obtained directly from the overall reaction equation
D. The rate law is derived from the law of mass action

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

18. Consider the first order reaction S → T in which S molecules are converted to T molecules.



How many S (blue) molecules and T (brown) molecules are present at the half-life?

A. Blue = 4 and brown = 12
B. Blue = 6 and brown = 10
C. Blue = 2 and brown = 14
D. Blue = 8 and brown = 8

State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. The number of S molecules is a half of its initial number

B. The number of S molecules is a half of its number at 6 minutes

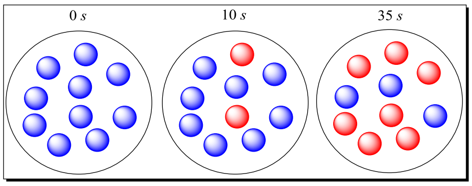
C. The number of S molecules that react is a half the number that react between 0 and 6 minutes

D. The half-life is reached at 6 minutes

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

19. The hypothetical reaction G → H is depicted pictorially below. Each blue sphere represents 0.2 moles of G and each red sphere represents 0.2 moles of H, and the container has a volume of 1.00 L.



The number of moles of G and H respectively in the mixture after 32 s is....

A. 1.280 mol; 0.720 mol B. 0.544 mol; 1.456 mol

C. 0.720 mol; 1.280 mol D. 1.456 mol; 0.544 mol

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. As time increases, the rate of conversion of G molecules to H molecules also increases

B. As time increases, the rate of conversion of G molecules to H molecules decreases

C. The rate of conversion of G molecules to H molecules per second is a constant

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

20. The decomposition of N_2O_5 in a solvent occurs according to the following equation

$N_2O_5 \rightarrow 2NO_2 + ½\, O_2$

In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is the correct expression of the average reaction rate?

A. $\text{Rate} = \frac{d[N_2O_5]}{dt} = 0.001\ \text{M min}^{-1}$ B. $\text{Rate} = \frac{d[NO_2]}{dt} = 0.001\ \text{M min}^{-1}$

C. $\text{Rate} = \frac{d[O_2]}{dt} = 0.0005\ \text{Mmin}^{-1}$ D. $\text{Rate} = -\frac{d[NO_2]}{dt} = -0.002\ \text{Mmin}^{-1}$

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

A. O_2 is produced twice as fast as N_2O_5 is consumed

B. NO_2 is produced a half as fast as N_2O_5 is consumed

C. The rate law can only be expressed by the rate of disappearance of N_2O_5

D. N_2O_5 is consumed twice as fast as NO_2 is produced

E. NO_2 is consumed twice as fast as N_2O_5 is consumed

F. O_2 is produced a half as fast as N_2O_5 is consumed

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Appendix H. Ethical approval

FW: 35/15 Development of a four-tier diagnostic instrument to identify first year chemistry students' understanding of chemical kinetics

Elizabeth M. Page <e.m.page@reading.ac.uk>

Thu 30/07/2015 12:09

To: Habiddin Habiddin <H.Habiddin@pgr.reading.ac.uk>;

Dear Habiddin

I hope you are well.

At last we have the ethics approval for the study. There is a form you need to sign when you return – please remind me to ask you.

Also please note the number of the study and the requirement to keep all data securely.

Elizabeth

From: Rainer Cramer [mailto:r.k.cramer@reading.ac.uk]
Sent: 30 July 2015 10:23
To: Elizabeth Page
Cc: Catherine Hale; a.v.powell@reading.ac.uk
Subject: 35/15 Development of a four-tier diagnostic instrument to identify first year chemistry students' understanding of chemical kinetics

Dear Elizabeth,

I am pleased to say that Prof Powell has approved your application for ethical approval via the in-School exceptions route. This email constitutes your permission to proceed with the studies as described in your application.

The following study number has been assigned to your study and you should quote this number in any correspondence you undertake about your studies.

35/15 Development of a four-tier diagnostic instrument to identify first year chemistry students' understanding of chemical kinetics

If you feel that you need to make changes to the way your studies are run, please let us know at the earliest opportunity and we can advise you of whether a formal amendment to your proposal is required or not.

I wish you the best of luck with the projects and finish by reminding you of the need for safe custody of project data at all times (a service that Cat Hale can provide if you require it).

Best regards,

Rainer

P.S. Please provide us with a fully signed application form once your student is back from his holiday.

Professor Rainer Cramer, FRSC

Professor of Mass Spectrometry and Bioanalytical Sciences

Department of Chemistry, University of Reading
Whiteknights
Reading RG6 6AD, UK
phone: +44 118 378 4550 | fax: +44 118 378 6331 | web: http://www.reading.ac.uk/chemistry/about/staff/r-k-cramer.aspx

Note: If using Satellite Navigation to find the University please enter RG6 6UR for the campus.

School of Chemistry, Food and Nutritional Sciences and Pharmacy
Research Ethics Committee

Application Form

SECTION 1: APPLICATION DETAILS

1.1

Project Title: Development of a four-tier diagnostic instrument to identify first year chemistry students' understanding of chemical kinetics

Date of Submission: June 2015 Proposed start date: October 2015 Proposed End Date: October 20-16

1.2

Principal Investigator: Dr. Elizabeth Page

Office room number: Chemistry, G27 Internal telephone: 8457

Email address: e.m.page@reading.ac.uk Alternative contact telephone:8454
(Please note that an undergraduate or postgraduate student cannot be a named principal investigator for research ethics purposes. The supervisor must be declared as Principal Investigator)

Other applicants

Name: Habiddin…………… …….. Student (delete) Institution/Department…University of Reading/ Chemistry…………Email:…h.habiddin@reading.ac.uk…………….

Name:…………… ……..Staff/Student (delete) Institution/Department……………Email:……………….

….

1.3

Project Submission Declaration

I confirm that to the best of my knowledge I have made known all information relevant to the Research Ethics Committee and I undertake to inform the Committee of any such information which subsequently becomes available whether before or after the research has begun.

I understand that it is a legal requirement that both staff and students undergo Criminal Records Checks when in a position of trust (i.e. when working with children or vulnerable adults).

I confirm that a list of the names and addresses of the subjects in this project will be compiled and that this, together with a copy of the Consent Form, will be retained within the School for a minimum of five years after the date that the project is completed.

Signed Prof. Elizabeth M. Page (Principal Investigator) Date26th June 2015………

Habiddin (Student) Date: 26th june 2015

…………………………… (Other named investigators) Date:…………

…………………………… (Other named investigators) Date:…………

1.4

University Research Ethics Committee Applications

Projects expected to require review by the University Research Ethics Committee must be reviewed by a member of the School research ethics committee and the Head of School before submission.

Signed…………………………… (Chair/Deputy Chair of School Committee) Date:……………………

Signed…………………………… (Head of Department) Date:……………………

Signed…………………………… (SCFP Ethics Administrator) Date:……………………

SECTION 2: PROJECT DETAILS

2.1

Lay summary

Please provide a summary of the project in non-specialist terms, which includes a description of the scientific background to the study (existing knowledge), the scientific questions the project will address and a justification of these. Please note that the description must be sufficient for the committee to take a reasonable view on the likely scientific rigor and value of the project.

Research into school students' understanding of chemical concepts has been conducted for decades, while similar research relating to university students is still limited. Several published studies relating to university students show that they have many difficulties in understanding chemical concepts, particularly in chemical kinetics.

A possible cause of the problem of chemistry students' understanding is a mismatch between the assumptions made by the teaching staff about the students' prior knowledge and understanding and the concepts actually held by the students. Students have their own preconceptions of some chemical phenomena and these are sometimes different from accepted scientific theory. These preconceptions obviously will influence their future understanding. It is helpful to be able to understand students' preconceptions in order to build upon their knowledge and there are many theories which attempt to explain misconceptions, dependent upon the topic under study.

Students' deep understanding in chemistry cannot easily be determined by a simple multiple choice test. This deep understanding can only be investigated by a multi-tier diagnostic instrument. This study aims to develop a four-tier diagnostic instrument to investigate students' understanding. The four tiers are explained below:

i. multiple choice test designed to analyse students' understanding and application of chemical concepts as applied to chemical kinetics

ii. an investigation of the confidence level of the answers from the multiple choice test

iii. explanation and justification of answers given in the multiple choice test

iv. an investigation of confidence in the scientific reasoning.

Few investigations have so far been made using a four tier test but this is thought to be valuable in assessing students' depth of understanding of particular concepts. Specifically, the main purposes of this research are to:

(1) develop and validate a reliable four-tier diagnostic instrument for chemical kinetics,

(2) identify students' understanding including misconceptions, partial understanding and lack of knowledge of chemical kinetics,

(3) contribute to the chemistry education literature by identifying misconceptions, partial understanding and lack of knowledge on chemical kinetics.

2.2

Procedure

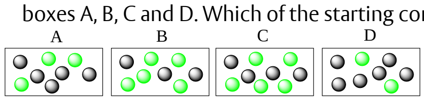
Please briefly describe what the study will involve for your participants and the procedures and methodology to be undertaken (*you may expand this box as required*).

The four-tier diagnostic test will be developed in three stages adopting procedures defined by Treagust (1995).

The first stage: testing and interviewing. The aim of this step is to collect data, including information on students' understanding that contradicts with that generally held acceptable by the scientific community. To obtain these data, first year fundamental chemistry students and first year chemistry students will be tested using a multiple choice test and short answer test. On the basis of the answers to these tests some students will be selected and interviewed individually. It is at this stage that the identities of individual students are necessary in order to contact appropriate students for interview. As a qualitative research, the sample size in this study will be adjusted to the research question as stated by Marshall (1996). In considering the essence of the qualitative research, naturalistic – studying real people in natural setting, the greater sample size is preferred. Therefore, there is no limitation on the sample size in this research. With the increasing of the sample size, the broader different students' understanding will be uncovered. In addition, all participants who are considered to follow interview session will be invited.

The second stage: paper-and-pencil test. A number of students' understandings of chemical kinetics will be obtained from the test and interview sessions in the first stage. These understandings will be used in constructing the four-tier diagnostic instrument of Chemical Kinetics (FTDOCK). As explained previously, FTDOCK consists of (i) first tier, multiple choice question, (ii) second tier, confidence level of students' answer to the multiple choice question at the first tier, (iii) third tier, scientific explanation of students' answers to the multiple choice question at the first tier, (iv) fourth tier, confidence level of students' reason to their scientific explanations at the third tier. Multiple choice questions and scientific explanation in the first and third tier respectively consist of one correct answer and several distracters. Distracters in these tiers will be attached from the real students' incorrect understandings uncovered from the stage one. The example of FTDOCK given below.

First tier : For the hypothetical reaction X + Y → Products, the black spheres represent molecules of X and the green spheres represent molecules of Y. The rate of reaction is first order in both X and Y. The reaction is carried out with different starting concentrations of X and Y represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction?



Second tier : How sure are you about your answer to the previous question

1. no idea, just guessing
2. very unconfident
3. unconfident
4. confident
5. very confident
6. absolutely confident

Third tier: which is the scientific reason for your answer in the previous question:

A. the concentration of both reactants is almost similar
B. …………..
C. ……………

Fourth tier : How sure are you about your answer to the previous question

1. no idea, just guessing
2. very unconfident
3. unconfident
4. confident
5. very confident
6. absolutely confident

This instrument will be tested to a group of sample to get the valid and reliable instrument for the next step. The instrument will be analysed in terms of validity, reliability, difficulty index, discrimination index, and distracter effectiveness. Some revisions to the FTDOCK will be applied based on the result of this analysis. Finally, the FTDOCK final product will be ready to be used in the third stage/ final stage.

The third stage: FTDOCK test
The FTDOCK will be used to investigate the first year chemistry students' understanding of chemical kinetics.

The groups of sample will be involved in this research are stated in the 2.3 point.

(Note: All questionnaires or interviews should be appended to this application)

2.3

Where will the project take place?

1. Chemistry Department, University of Reading : for all stages
2. Chemistry Department, State University of Malang, Malang, Indonesia : first and third stages
3. Chemistry Education Program, Faculty of Teaching Training and Education, Haluoleo University, Kendari, Indonesia : first and third stages

If the project is to take place in Hugh Sinclair Unit of Human Nutrition, please confirm that you have informed Ms Jan Luff (j.e.luff@reading.ac.uk) . …………………

2.4

Funding
Is the research supported by funding from a research council or other *external* sources (e.g. charities, business)? Yes

If Yes, please give details: this research is funded by Directorate General of Higher Education, Ministry of Education (now Ministry of Research, Technology and Higher Education), Republic of Indonesia.

Please note that *all* projects (except those considered as low risk, which would be the decision of the School's internal review committee and require Head of Department approval) require approval from the University Research Ethics Committee.

2.5

Ethical Issues
Could this research lead to any risk of harm or distress to the researcher, participant or immediate others? Please explain why this is necessary and how any risk will be managed.

I personally belief that this research will not lead to any risk of harm to the researcher and particularly not to the participants. In contrast, by taking part in this study, the students will gain additional knowledge in the understanding of microscopic and particulate level chemical concepts. This knowledge may help them to develop an overall better understanding of certain chemical concepts.

(*this box may be expanded as required*)

2.7

Payment

Will you be paying your participants for their involvement in the study? No

If yes, please specify and justify the amount paid

Participants will not be paid, but may receive rewards such as lunch/refreshments for taking part.

Note: excessive payment may be considered coercive and therefore unethical. Travel expenses need not to be declared.

2.8

Data protection and confidentiality

What steps will be taken to ensure participant confidentiality? How will the data be stored?

All participants will be asked for their permission before taking part in this research. Confidentiality and will be guaranteed when analysing data and publishing results. Publication and reporting of the results in any way will be completely anonymous. The participants will only provide their email address or telephone number to be contacted if they are willing to attend a follow-up interview session.

After the interview session the identities of the participants will no longer be required and their responses will be classified as from "interviewee A" etc if necessary. There is no need to identify individual participants in this study after the first stage when interviews have been carried out. Any data processing and publication after this point will be completely anonymous. Contact details for participants agreeing to be interviewed will be kept secure during the data collection period and deleted after completing the questioning phase. Contact details will be stored in a password protected spreadsheet on the University server and will not be transferred to any portable device.

On publication participants will be classified by the nature of their Year Group (e.g. "a year 1 student") and their module (e.g. "studying a fundamental chemistry module")

2.9

Consent

Please describe the process by which participants will be informed about the nature of the study and the process by which you will obtain consent

The students will be given an information letter about this research. If students wish to take part they will be asked to sign the consent form. Students who are also interested in being interviewed will inform the researcher by inserting their contact number or email address on the consent form. There is no requirement to do this. Students giving consent to participate can take part in the testing stage but not the interview stage should they not wish to do so. In this way they benefit from the experience of completing the test and will receive general feedback.

Please note that a copy of consent forms and information letters for all participants must be appended to this application.

2.10

Genotyping

Are you intending to genotype the participants? Which genotypes will be determined?

No, I do not

Please note that a copy of all information sheets on the implications of determining the specific genotype(s) to be undertaken must be appended to this application.

SECTION 3: PARTICIPANT DETAILS

3.1

Sample Size

How many participants do you plan to recruit? Please provide a suitable power calculation demonstrating how the sample size has been arrived at or a suitable justification explaining why this is not possible/appropriate for the study.

This study uses a qualitative approach with the aim to investigate students' understanding of chemical kinetics deeply. Generalizability is not the ultimate goal of this research. In the other words, this study concerns on an individual understanding of chemical kinetics concepts. Therefore, there is no limitation on the sample size in this research. With the increasing of the sample size, the broader different students' understanding will be uncovered. All students willing to participate will be accommodated.

3.2

Will the research involve children or vulnerable adults (e.g. adults with mental health problems or neurological conditions)? No

If yes, how will you ensure these participants fully understand the study and the nature of their involvement in it and freely consent to participate?

(Please append letters and, if relevant, consent forms, for parents, guardians or carers). Please note: information letters must be supplied for all participants wherever possible, including children. Written consent should be obtained from children wherever possible in addition to that required from parents.

3.3

Will your research involve children under the age of 18 years? No

Will your research involve children under the age of 5 years? No

3.4

	Will your research involve NHS patients, Clients of Social Services or will GP or NHS databases be used for recruitment purposes? No Please note that if your research involves NHS patients or Clients of Social Services your application will have to be reviewed by the University Research Ethics Committee and by an NHS research ethics committee.
3.5	**Recruitment** Please describe the recruitment process and append all advertising and letters of recruitment. Students attending the sessions will be given an information letter about this research. The students who are interested in taking part will sign a consent form. If they agree to being interviewed they will give their contact number or email address.

Important Notes

1. The Principal Investigator must complete the Checklist in Appendix A to ensure that all the relevant steps and have been taken and all the appropriate documentation has been appended.

2. If you expect that your application will need to be reviewed by the University Research Ethics Committee you must also complete the Form in Appendix B.

3. For template consent forms, please see Appendices C.

4. For examples of information letters, see Appendices D

Appendix A: Application checklist

This must be completed by an academic staff member (e.g. supervisor)

Please tick to confirm that the following information has been included and is correct.
Indicate (N/A) if not applicable:

Information Sheet

Is on headed notepaper	√☐
Includes Investigator's name and email / telephone number	√☐
Includes Supervisor's name and email / telephone number	√☐
Statement that participation is voluntary	√☐
Statement that participants are free to withdraw their co-operation	√☐
Reference to the ethical process	√☐
Reference to Disclosure	√☐ N/A ☐
Reference to confidentiality, storage and disposal of personal information collected	√☐

Consent form(s) √☐

Other relevant material

Questionnaires	√☐ N/A ☐
Advertisement/leaflets	√ ☐ N/A ☐
Letters	√☐ N/A ☐
Other (please specify)	☐ N/A ☐

Expected duration of the project (months) ☐

Name (print): Elizabeth Page

Signature

Department of Chemistry

Habiddin PhD research student

Dr Elizabeth M. Page BSc, Ph.D, Principal Investigator (PI)/Supervisor, University of Reading

Consent Form

Study Title: Development of a Four-Tier Diagnostic Instrument to Identify First year Chemistry Students' Understanding of Chemical Kinetics

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you are currently studying this topic we would like you to attempt the following questions and, in some cases, explain the answers you have given.
We will collect the answer sheets at the end of the session and mark them, but we may like to follow up this initial investigation by asking you a few questions.
The results from the investigation will be used alongside data from other students to gain a better understanding of students' concepts of reaction rates and may be published in the educational literature. No participants will be identifiable in the results of the study..
The proposed project has been subject to ethical review and has received approval.

If you are happy for your test results to contribute to our investigation, please tick the box below:

◯ **I am happy to take part in this investigation and for my test results to contribute to the investigation:**

If you would be prepared to answer some further questions about your understanding of the topic please tick the box below:

◯ **I am happy to answer some further questions about my understanding and for the results to contribute to the investigation:**

◯ **I understand that the results and outcomes from the survey will be completely anonymous.**

Signed:__________________________

Date: __________________________

Name of Participant (in block capitals):______________

Contact Details:____

______________________________	____________	_____________
Name of person taking consent	Date	Signature

APPENDIX D. INFORMATION LETTER

Department of Chemistry
University of Reading

Participant Information Leaflet

Study Title:

Development of a Four-Tier Diagnostic Instrument to Identify First year Chemistry Students' Understanding of Chemical Kinetics

Dear Students

You are being asked to take part in a research study investigating first year chemistry students' preconceptions of chemical kinetics. Before you decide whether to participate in this study it is important that you understand what the research it for and what you will be asked to do. Please take the time to read the information carefully and discuss it with others if you wish. Ask if there is anything that is not clear or if you think you would like more information. Please take time to decide whether you wish to take part or not. Thank you for reading this leaflet.

What Is The Purpose of This Study?
This study is designed to identify first year chemistry students' preconceptions of chemical kinetics in order to improve the way in which this subject is taught.

Why have I been chosen for this study?
You have been selected for this study because you are a first year undergraduate and have not yet learnt about chemical kinetics at university level.

Do I have to take part?
It is up to you to decide whether or not to take part in the study. Should you wish to have more information before making the decision please contact a member of the research team. You should not feel pressured to take part in the study, however, if you decide to take part you will be given this information sheet to keep and will be asked to sign a consent form. You can change your mind at any time and withdraw from the study without giving a reason. The teaching you experience will not depend upon whether or not you participate in this study.

What do I have to do?
If you agree to participate this will involve you in answering 15 multiple choice questions in a 90 minute test and giving your reasons for each of your answers. In addition, you could be chosen to follow this up with an interview if you agree. The interview will take approximately 30 minutes.

What are the possible disadvantages of taking part?
Apart from sacrificing a small amount of time for this study there should be no other potential disadvantages.

What are the possible benefits of taking part?
There are no intended benefits to be obtained by participating in this study. However, by taking part in this study, you will gain additional knowledge in the understanding of microscopic/particulate

level chemical concepts. This knowledge may help you to better understand certain concepts in chemistry, especially chemical kinetics.

What will happen to any data that I provide?
Confidentiality and anonymity will be guaranteed when analysing the final results and in any resulting publications. We request your contact details so that we can contact you if we would like to follow up the first part of the study (multiple choice test) with an interview. You do not need to give your name and contact details at all if you do not wish. In this case we will assume you do not want to be contacted further. Individual participants will not be identifiable in any of the publishable outcomes of the study. Contact details for participants agreeing to be interviewed will be kept secure during the data collection period and deleted after the initial interview phase has been completed. Contact details will be stored in a password protected spreadsheet on the University server and will not be transferred to any portable device.
In any resulting publications participants will be classified by the nature of the Year Group (e.g. "a year 1 student") and module or course(e.g. "studying a fundamental chemistry module")

Will my taking part in the research be kept private?
Your participation and all personal information collected will be kept strictly confidential.

Who is organizing and funding the research?
Habiddin (a PhD student in Chemical Education in the Department of Chemistry at the University of Reading) is conducting the study as an initial step of his PhD research. The research is funded by a scholarship from the Ministry of Education of the Indonesian Government.

We would like to thank you for your interest in the study. If you would like to discuss this study further or should you wish to participate, please contact the research team below.

Thank you again for your interest.

Contact Detail

Name : **Habiddin (PhD Research Student)**
Room G15, Chemistry Department
Phone: 07827092073

Supervisor/Principal Investigator : **Professor Elizabeth Page BSc, Ph.D, PGCE, CChem, FRSC, NTF, SFHEA**
Room G27, Chemistry Department

APPENDIX F: THE GUIDE OF INTERVIEW QUESTIONS

1. What is your highest qualification in chemistry?
2. What degree programme are you following?
3. In question No. 1 you were asked the concentration of reactant S at its half-life. The reactant is converted to a product in a first order reaction. If the reaction is second order, what is the appropriate figure that represents the concentration of S at the half life?$t = {}^{1}\!/_{2}$
4. In question No. 2, you explained that C is the correct answer because both reactants have the same concentration. Can you explain?
5. In question No. 5, you explained that because a reactant is zero order, increasing the concentration does not increase the reaction rate. Did you know that the other reactant is the first order? Can you explain your reason in more detail?
6. In question no. 6, the reaction is second order with respect to one reactant, but first order with respect to other reactant. As you said, increasing the concentration of the reactant which is second order results in the biggest increase in rate of reaction. What do you think if the increasing concentration of first order reactant is completely higher than that of second order reactant?
7. Can you tell me why you left question 8 blank?
8. In question No.12, you considered C and D experiments as having the highest reaction rate because both of the experiments are the same? Can you explain what is the similarity between both experiments?
9. In question No. 13, you stated that the bigger the volume, the higher the mobility of particles that led to the increased reaction rate. Can you explain this in more detail?

Note: *the interview questions are constructed based on the students' answers on the paper test. Therefore, the questions which will be given to one student will be different to those given to another.*

Appendix I. Students' answers to the FTDICK instrument

GC = general confidence
GC 1 = general confidence in chemistry
GC 2 = general confidence in physical chemistry
GC 3 = general confidence in chemical kinetics as compared to other areas of chemistry
GC 4 = general confidence in chemical kinetics as compared to other areas of physical chemistry

A = answer tier
R = reason tier

Student	GC				Question																			
					1				2				3				4				5			
	1	2	3	4	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)
					D		E		B		B		C		D		B		C		C		A	
1	4	3	3	4	A	4	B	3	B	4	B	2	B	4	A	3	B	5	C	5	C	4	A	5
2	4	3	3	5	A	2	A	1	B	2	B	2	C	3	B	3	C	4	B	4	C	2	C	1
3	4	3	4	3	C	5	A	3	B	4	B	1	C	2	B	1	B	2	A	1	C	4	A	3
4	4	4	3	3	A	5	C	2	B	5	B	5	A	3	B	1	D	3	A	3	B	1	C	1
5	4	3	3	4	A	4	E	3	B	5	B	4	A	3	C	3	B	5	D	4	C	5	A	5
6	4	3	3	3	D	3	B	2	B	5	B	4	B	3	B	3	B	5	C	4	C	5	A	4
7	5	4	5	3	C	4	A	3	B	5	B	5	B	5	B	4	B	5	C	5	C	5	A	4
8	4	3	5	4	A	1	C	1	B	1	B	1	C	4	D	3	D	4	A	4	C	4	A	4
9	5	4	4	4	C	1	D	1	B	4	B	4	B	4	B	3	A	4	B	3	A	1	C	1
10	5	3	4	4	C	4	D	4	B	3	A	4	B	3	B	4	D	4	C	3	D	2	C	2
11	4	3	4	4	B	3	D	2	B	5	B	4					B	5	C	3	C	5	A	3
12	5	4	5	4	A	3	E	3	D	2	B	3	B	4	C	3	C	4	A	4	C	4	C	3
13	3	2	3	4	A	4	E	4	B	5	B	3	B	4	B	4	B	4	C	2	C	5	A	5
14	4	2	4	3	A	2	D	3	D	4	B	4	B	2	B	2	C	4	A	2	C	3	A	3
15	2	3	3	3	A	3	E	3	B	5	A	2	B	1	B	1	B	5	B	3	C	4	A	3
16	4	4	3	4	A	5	C	4	B	4	C	4	B	5	B	4	D	5	C	5	D	4	D	5
17	4	4	4	4	C	4	D	4	B	3	A	3	B	3	D	3	C	3			C	4	A	4
18	4	2	4	3	C	3	C	2	D	3			C	4	B	3	D	5	C	3	B	3	C	2
19	4	3	4	4	C	2	C	2	B	3	C	2	A	1	B	2	D	3	C	3	C	1	B	1
20	3	2	4	4	A	1	C	1	B	2	B	2	B	4	B	4	B	2	D	2	C	4	A	4
21	3	3	3	4	C	3	D	2	C	3	C	3	B	4	A	4	B	5	C	2	C	5	C	4
22					A	2	A	2	B	1			B	1	B	1	A	5	C	2	D	4	D	4
23					A	2	A	2	B	1			B	1	B	1	A	5	C	2	D	4	D	4
24					A	2	A	2	B	1			B	1	B	1	A	5	C	2	D	4	D	3
25	4	2	3	3	B	4	A	3	B	5	B	5	B	4	A	4	D	4	C	5	C	5	A	4
26	4	3	3	3	C	2	A	3	C	4	B	2	B	3	B	3	B	4	C	3	C	4	C	4
27	4	4	3	5	D	5	D	5	B	5	B	5	C	4	C	4	B	5	C	5	C	4	A	4
28	4	4	3	3	B	5	A	4	B	5	B	5	A	3	A	3	B	5	C	5	C	5	A	5
29	3	4	3	3	B	3	A	3	B	5	B	4	B	3	B	3	B	5	C	5	C	5	A	5
30	3	3	3	4	B	3	A	3	B	4	B	3	B	2	B	2	B	4	C	3	C	4	A	4
31	4	2	3	3	C	5	E	5	B	5	B	3	B	4	A	3	B	4	C	3	C	4	C	4
32	5	3	3	3	B	5	A	5	B	5	B	5	C	4	D	3	B	5	C	3	C	4	A	4
33	4	3	4	4	D	5	D	5	B	5	C	4	B	5	B	4	B	5	C	1	C	4	A	4
34	4	5	4	4	D	5	D	5	B	5	B	4	C	4	C	4	B	5	C	4	C	5	A	5
35	4	3	3	3	D	4	B	5	B	5	B	4	B	4	D	3	B	5	D	5	C	5	A	5
36	2	4	4	4	C	5	A	5	B	5	B	5	B	5	B	5	B	5	C	5	C	5	A	5
37	5	2	3	4	A	4	E	4	B	3	A	3	B	4	B	3	B	3	C	2	C	2	A	2
38	2	3	4	4	C	3	E	2	A	2	B	2	B	1	B	1	B	4	C	3	C	3	A	3
39	4	3	4	2	A	4	A	1	D	1	B	1	C	5	B	5	B	5	C	4	C	5	A	5
40	4	3	3	4	C	5	E	4	B	4	B	4	C	3	C	3	B	5	C	4	C	5	A	5
41	4	3	2	4	A	4	E	4	B	5	B	5	A	5	A	5	C	5	C	5	C	5	A	5
42	4	3	4	4	C	4	A	4	B	4	B	4	B	4	B	4	B	4	C	4	C	4	A	4
43	4	3	3	2	D	5	C	3	B	5	B	4	B	5	B	5	B	5	C	3	C	5	A	5
44	5	2	4	3	B	5	C	3	B	5	B	2	C	5	D	5	B	5	C	5	C	5	A	5
45	3	3	3	3	A	3	E	3	B	4	B	3	B	4	A	3	B	4	C	3	C	3	A	3
46	5	3	3	3	C	3	E	3	B	5	B	4	B	4	A	3	B	5	C	4	C	5	A	5

47	3	3	2	4	A	2	B	2	B	3	B	3	B	2	B	2	B	4	C	4	C	3	A	4
48	5	3	3	2	A	5	E	2	D	2	C	1	B	4	A	4	A	4	A	2	C	5	A	5
49	3	3	3	3	C	4	E	3	B	5	B	2	B	5	B	4	B	4	C	4	C	4	A	3
50	4	3	4	4	D	3	D	3	A	3	B	2	A	3	A	2	B	5	C	5	C	5	A	5
51	2	3	4	5	A	4	C	3	B	5	B	4	A	4	A	2	B	5	C	5	C	5	A	4
52	5	4	2	3	B	5	E	3	A	5	C	4	C	4	B	3	B	5	D	3	C	5	A	4
53	3	2	3	3	B	3	E	3	B	3	B	3	A	3	D	3	D	3	C	3	C	3	A	3
54	4	3	3	3	D	5	B	3	B	5	B	5	B	3	B	3	B	2	C	3	C	4	A	5
55	4	2	3	3	C	5	E	5	B	1	B	4	B	4	C	5	B	1	A	5	C	2	A	3
56	4	4	3	4	B	3	C	3	B	3	C	3	B	5	A	4	C	5	B	5	D	4	D	3
57	5	4	4	4	A	4	D	2	B	5	B	4	C	5	C	5	C	3	D	1	D	4	A	2
58	2	3	3	2	C	3	A	3	C	2	B	2	C	2	A	3	B	4	D	2	D	2	D	3
59	3	2	3	3	C	3	E	2	B	4	B	3	B	4	B	2	B	4	C	3	C	3	A	3
60	4	2	3	4	C	1	E	1	A	5	B	5	B	4	D	3	A	4	C	2	C	5	A	5
61	3	3	2	2	A	4	B	3	B	3	A	3	C	2	D	3	A	3	D	3	D	4	D	4
62	5	2	4	5	A	4	E	3	D	2	B	3	B	4	A	3	B	5	C	5	C	4	C	4
63	4	4	4	4	B	2	D	2	B	2	B	1	B	3	C	2	C	3	B	3	A	2	C	2
64	4	4	5	4	C	2	B	4	C	3			C	3	C	5	D	2	C	5	B	3	D	2
65	3	2	3	4	D	4	E	2	B	5	B	5	B	4	A	1	B	4			C	5	A	4
66	4	4	4	4	B	5	C	5	B	5	A	5	B	5	B	5	A	5	A	5	A	5	C	4
67	4	3	4	4	B	5	C	4	B	5	C	4	B	5	B	4	D	4	C	3	D	4	D	4
68	4	3	3	4	D	2	B	2	B	3	C	2	B	4	B	4	A	5	B	4	D	3	D	4
69	4	4	4	3	B	5	C	1	B	5	A	3	B	5	B	4	A	4	A	3	A	4	C	4
70	5	5	5	4	A	4	A	4	B	5	B	5	B	5	A	5	A	4	A	4	A	4	C	4
71	4	3	4	2	D	5	E	5	B	3			C	2	C	2	C	5	A	5	A	5	C	4
72	5	5	4	4	A	4	A	4	B	3	A	3	A	5	A	4	D	5	D	4	D	2	D	2
73	4	4	4	3	C	5	A	5	B	5	B	5	C	4	C	4	B	5	C	5	C	4	C	5
74	4	3	4	3	C	4	C	3	B	1	C	1	B	4	B	2	C	4	B	4	D	2	C	2
75	4	3	5	5	B	4	D	3					B	4	C	4								
76	4	3	3	3													B	5	D	5	C	4	C	4
77	4	3	3	3	C	5	C	3	B	5	B	4	A	5	D	2	B	5	C	4	C	5	A	5
78	3	4	5	4	A	4	E	3	B	2	B	3	C	4	C	3	C	5	B	4	A	1	C	2
79	5	3	4	4	C	3	C	3	A	3	A	3	C	5	D	5	C	4	C	4	B	4	C	4
80					A	2	C	2	D	2	B	2	B	4	C	3	B	3	C	3	D	2	B	2
81	5	3	3	4	D	4	C	3	B	4	A	3	B	3	B	2	B	4	B	4	C	5	A	5
82	3	2	3	3	B	3	A	3	A	4	C	3	B	4	C	3	A	3			B	3	C	3
83	4	5	3	3	D	3	B	2	B	4	A	5	C	1	B	2	C	5	A	5	C	1	B	1
84	4	3	3	3	C	4	E	2	B	4	B	4	A	3	D	2	B	4	C	3	C	4	A	3
85	4	3	3	4	A	2	C	2	B	2	A	1	B	3	B	2	C	5	B	2	C	1	A	1
86	5	2	5	3	C	3	B	3	A	5	C	5	A	5	D	3	C	5	B	5	C			
87	5	4	4	4	C	3	E	4	B	3	A	2	A	3	D	2	B	5	D	5	C	3	A	5
88	4	3	3	3	D	3	E	3	B	4	C	4	B	3	A	4	B	4	C	4	C	5	A	5
89	5	2	2	2	C	1	D	1	B	4	B	3	C	4	D	2	B	5	D	3	C	3	A	5
90	5	5	4	4	A	4	C	4	B	5	B	5	B	5	A	4	A	4	A	3	A	2	C	2
91	4	4	3	3	C	4	C	2	A	2	B	2	B	3	D	2	C	3	A	3	C	3	D	2
92	3	3	3	3	C	3	C	3	B	3	A	3	C	3	D	3	C	3	B	3	A	3	B	3
93	3	3	3	3	C	3	D	3	B	3	B	3	C	3	C	3	A	3	A	3	A	3	A	3
94	3	3	3	3	B	1	E	1	C	1	B	1	B	2	C	1	A	3	A	3	D	1	A	1
95	3	3	3	3	D	3	C	3	B	5	C	3	B	1	B	1	B	5	C	5	B	2	C	1
96	5	5	4	4	D	5	E	1	B	5	B	1	C	5	D	1	C	1	B	1	A	1	B	1
97	3	2	3	3	B	2	D	2	D	3	C	2	B	2	B	3	D	2	C	2	C	2	C	1
98	3	3	2	3	B	4	B	5	B	3	C	3	A	3	B	2	B	5	C	5	D	5	D	5
99	3	4	3	3	A	2	A	2	B	1			B	1	B	1	B	3	C	2	D	4	D	4
100	5	5	4	4	A	5	A	4	B	5			B	5			B	5	C	4	D	5	D	4
101	3	2	3	3	A	3	A	2	B	2			A	3	A	3								
102	5	3	4	3	A	3	A	2	B	1			B	1			B	3	C	2	D	4	D	4
103	4				A	4	A	4	B	5			B	5			C	3	B	3	D	1		
104	4	2	2	2	A	4	A	3	D	3	B	3	B	2	C	1	C	1	B	2	D	4	C	2
105	4	3	3	3	A	3	E	2	C	2	B	2	A	4	B	4	C	3	A	2	D	3	C	3

106	4	2	4	4	C	3	A	3	C	3	A	3	B	4	B	4	C	5	A	3	C	3	D	3
107	4	3	3	4	C	3	D	2	B	3	B	3	C	5	D	5	C	4	D	2	C	3	B	3
108	4	3	3	5	C	2	B	3	B	5	A	4	C	4	D	5	C	4	C	5	C	3	C	2
109	5	3	4	3	A	3	A	2	B	1			B	1	B	1	B	3	C	2	D	4	D	4
110	3	3	3	3	A	2	A	2	B	1			B	1	B	1	A	3	C	2	D	4	D	4
111	3	3	4	3	A	2	A	2	B	3			B	3	B	2	A	5	C	3	D	2	C	2
112	5	3	4	3	A	2	A	2	B	1			B	3	B	1	A	5	C	2	D	4	D	4
113	3	3	3	3	A	2	A	2	B	1			B	3	B	1	A	5			D	4		
114	4	3	2	3	A	2	A	2	B	1			B	1	B	1	A	5	C	2	D	4	D	4
115	3	3	2	3	B	2	D	3	B	3	C	2	B	2	C	3	C	4	A	4	D	4	A	4
116	4	5	4	4					B	5	B	2	A	3	B	2	B	4	C	5	C	5	A	5
117	4	4	4	5	A	4	B	4	B	5	B	5	B	5	A	3	B	4	C	4	C	5	A	5
118	2	2	2	3	C	3	D	3	B	3	B	3	B	2	A	2	C	3	A	3	C	4	B	4
119	4	3	4	4	C	4	C	3	B	2	A	3	C	3	B	3	C	4	B	3	D	3	C	2
120	4	2	4	5	D	4			B	4	B	3	C	4	B	3	A	3	A	3	C	4	A	4
121	4	3	4	5	D	4			B	5			A	4			C	4			C	3	D	3
122	4	3	3	3	D	5	C	3	B	5	B	5	B	3	C	3	C	5	A	4	C	4	A	3
123	4	3	3	3	D	2	C	1	B	4	B	4	B	3	C	3	B	4	C	3	C	1	A	1
124	4	2	5	5	D	4	C	4	B	4	B	4	B	4	C	4	A	4	A	4	C	4	A	4
125	5	4	4	4	C	5	C	3	B	5	B	3	A	4	C	2	B	5	D	2	C	4	A	4
126	4	3	3	3	A	3	C	2	B	3	B	2	B	4	B	4	B	4	B	3	C	4	A	4
127	4	3	3	3	A	3	C	2	B	3	B	3	B	4	B	3	B	4	B	3	C	4	A	4
128	4	4	4	3	A	3	C	2	B	5	B	3	B	3	C	2	B	5	B	1	C	2	A	4
129	4	5	4	3	C	4	A	3	B	5	B	3	C	5	A	3	A	5	C	5	C	4	A	4
130	4	3	4	4	D	3	C	3	B	4	B	3	C	3	D	3	B	3	C	4	B	3	A	3
131	4	3	4	4	A	3	C	3	B	4	B	3	B	3	C	2	B	5	B	3	C	1	A	3
132	4	4	3	4	D	4	C	4	B	4	B	4	A	5	A	4	D	5	D	3	C	5	A	3
133	3	3	4	4	D	5	C	3	B	5	B	4	B	4	C	5	B	3	C	4	C	3	B	1
134	3	4	3	3	B	2	C	2	B	2	C	3	C	3	A	3	C	5	A	3	D	1		
135	4	3	4	3	D	5	C	3	B	5	B	4	B	5	C	5	C	4	D	3	C	3	A	4
136	3	3	3	3	D	5	C	3	B	5	B	4	A	1	C	5	C	4	D	4	C	4	A	3
137	4	3	3	3	C	3	A	3	B	2	B	2	B	3	C	2	B	4	D	4	D	3	D	3
138	4	3	4	3	C	4	B	3	B	5	B	4	B	4	B	3	C	4	B	4	C	3	C	4
139	5	5	5	5	C	5	B	3	B	5	B	5	B	5	B	5	B	5	C	5	C	5	A	5
140	5	3	3	4	C	5	B	4	B	5	B	5	B	5	B	5	B	4	C	3	C	4	A	4
141	4	3	4	4	C	4	B	3	B	5	B	3	B	4	B	3	B	5	C	3	C	4	C	3
142	4	4	3	3	D	5	C	2	B	5	B	5	B	3	C	3	C	4	A	3	C	2	A	3
143	4	3	3	3	C	5	C	3	B	5	B	4	A	5	C	5	C	4	D	3	C	4	A	3
144					C	5	C	4	B	5	B	4	A	4	C	4	C	5			C	3	A	3
145					C	5	C	3	B	5	B	4	A	5	C	5	C	4	D	1	C	4	A	3
146	4	4	5	4	A	3	C	2	B	5	B	3	B	2	C	2	B	5	C	3	C	3	A	3
147	4	4	3	4	C	4	C	4	A	4	C	4	B	4	B	4	B	4	D	4	B	3	C	3
148	4	2	5	5	C	5	C	1	A	5	C	5	B	3	C	1	D	5	C	4	C	1	C	3
149	5	4	4	4	A	5	C	4	B	5	B	5	B	5	C	4	C	5	B	4	C	4	A	3
150	5	4	4	4	A	5	C	4	B	5	B	4	A	4	A	4	C	5	B	4	C	2	A	4
151	5	3	5	5	C	5	C	5	A	5	C	5	B	5	B	5	B	5	C	5	C	5	A	5
152	4	2	3	3	D	4	C	3	B	4	C	4	D	3	C	3	C	4	D	3	B	3	C	3
153	5	4	4	5	D	5	E	5	B	5	C	5	A	5	A	4	B	5	C	5	C	5	A	5
154	4	2	2	3	C	4	C	3	A	2	A	2	C	4	B	2	C	3	B	2	C	5	A	5

155	4	3	4	3	C	4	E	2	C	3	B	3	A	4	A	2	C	3	C	3	B	3	C	3
156	3	3	2	2	A	3	A	3	B	4	C	3	C	3	B	2	C	2	C	3	A	3	B	3
157	5	4	5	5	A	5	A	5	C	5	B	1	B	2	A	2	C	5	A	5	B	2	B	2
158	4	3	3	2	B	4	D	1	A	1	B	1	C	4			A	5			D	1		
159	5	3	3	3	C	3	A	2	B	4	C	2	B	3	B	3	C	4	B	3	C	1	D	2
160	4	3	4	3	C	3	A	3	C	3	B	2	A	4	A	3	C	3	C	2	B	4	C	3
161	3	3	3	3	A	2	C	3	B	1	C	1	B	3	C	2	D	3	B	3	A	3	B	2
162	4	3	4	3	B	4	A	4	C	5	B	5	C	5	B	4	C	5	B	4	D	4	C	2
163	5	3	3	4	A	5	E	3	B	2	C	5	B	5	D	5	C	5	B	4	D	4	A	3
164	5	4	4	4	C	4	A	3	D	5	A	3	A	5	C	3	B	4	B	2	D	3	A	2
165	4	3	3	3	C	2	C	2	B	3	B	4	B	3	B	3	C	3	B	2	C	4	C	2
166	5	4	5	5	D	2	C	3	C	2			A	4	B	3	C	4	B	2	D	3	B	4
167	5	4	2	2	A	3	E	1	D	3	A	1	A	5	C	3	D	3	D	4	D	3	D	3
168					A	3	B	3	B	3	B	3	B	3	B	3	B	5			C	5	C	5
169	4	4	5	4	B	2	C	1	B	1							B	1	C	1	C	5	A	5
170	5	1	3	4	C	3	A	2	B	5	B	4	B	2	B	1	B	4	C	3	C	2	A	4
171	5	4	5	5	A	3	C	3	B	5	C	3	B	4	A	3	D	4	C	3	B	4	C	4
172	4	4	5	5	A	3	A	3	D	3	B	3	B	4	C	3	B	5	C	5	C	5	A	5
173	5	4	5	4	D	3	D	3	B	5	B	5	A	3	A	3	C	5	B	4	D	5	D	4
174	5	3	4	5	C	4	E	3	B	3	B	4	A	5	C	4	B	5	B	3	D	2	D	3
175					C	3	E	3	B	4	B	4	C	4	B	4	C	3	A	3	A	4	C	4
176	3	3	2	4	B	3	E	3	D	4	A	2	A	5	D	4	C	4	B	4	A	2	A	3
177	5	4	2	5	B	4	C	4	A	3	B	1	C	4	C	5	C	5	B	5	C	5	C	3
178	4	4	2	4	A	3	C	3	B	3	B	5	C	4	C	3	B	4	A	5	C	5	A	5
179	5	4	4	4	C	4	C	4	B	5	B	5	C	2	B	2	D	5	C	4	C	5	A	4
180	5	4	3	4	A	3	E	3	D	3	B	3	B	3	A	3	C	3	B	3	C	3	C	3
181	5	4	4	3	A	3	B	3	A	4	B	4	C	4	D	4	B	3	C	3	C	2	A	2
182	3	3	2	3	A	3	B	3	C	3	B	4	B	3	D	4	C	4	B	4	D	3	B	3
183	4	3	5	4	A	3	C	4	B	5	B	4	C	1	B	1	C	4			C	3	B	3
184	4	4	4	5	B	3	A	3	C	3	A	3	B	4	B	4	C	5	A	5	A	5	B	3
185	4	3	4	4	A	1	C	3	B	5	B	4	B	2	A	2	B	4	B	3	C	5	A	4
186	4	4	3	3	A	5	A	5	B	5	B	5	A	4	D	3	C	4	A	4	B	4	C	4
187	5	3	3	4	A	5	B	4	B	3	B	3	C	5	B	5					B	3	C	4
188	3	3			D	3	C	3	B	3			B	3			D	5						
189													A	5			D	5			A	4	A	4
190					A	2	D	1	B	1	B	2	A	1	A	1	C	1	B	1	B	1	C	2
191	4	5	4	4	B	3	C	3	C	1	B	3	B	5	A	5	C	1	C	1	A	3	C	3
192	4	5	4	4	A	4	B	4	B	5			B	5	B	3	C	1	C	1	A	3	C	3
193					B	3	B	3	A	3	B	3	A	3	B	3	C	3	B	3	D	1	C	1
194	4	4	3	4	A	1	B	1	D	3	C	3	B	3	A	3	C	3			D	3	B	1
195	4	2	3	3	B	3	A	3	D	3	C	3	B	3	A	3	C	3	B	3	D	3	B	3
196	4	4	3	3	A	2	E	2	B	1	A	1	B	3	D	3	C	3	C	3	D	3	B	1
197	4	2	3	3	C	3	B	3	D	3	C	3	B	4	A	3	C	4	B	3	D	3	B	3
198	4	2	3	3	C	3	C	5	B	4	B	4	B	5	B	5	B	4	B	4	A	3	C	4
199	2	2	3	3	A	2			D	2	B	1	D	3			D	5	C	5	A	3	C	1
200					C	4	C	4	A	1	C	3	A	4	B	4	C	5	B	5	C	2	B	2
201	4	4	4	4	D	4	B	2	D	5	C	3	B	2	B	3	D	5	B	5	D	3	C	3
202	3	2	3	3	C	2	B	1					A	4	B	3	C	5	B	4	D	3	A	2
203	3	2	4	3	C	2	B	3	B	2	B	2	A	4	B	3	C	5	B	5	D	3	A	2

204	5	3	3	3	C	3	B	3	A	3	C	3	B	3	B	4	C	5	B	5				
205	4	3	3	3	C	3	B	3	A	3	A	3	C	3			C	5	B	3				
206	3	3	3	3	C	2	D	2	A	3	B	3	B	3	D	2	C	4	B	3	B	4	C	2
207					C	4	A	1	A	1	C	5	D	5	C	5	A	1	B	5	B	5	B	4
208					A	4	B	4	B	5	B	4	B	5	B	4	C	5	B	4	A	5	B	4
209	2	4	4	4	B	4	D	3	B	2			C	2	C	2	A	3	B	2	B	2	C	1
210					A	3	A	3	C	3	C	3					D	5			D	3	A	3
211					A	4	D	2	A	3	B	3	B	3	A	1	C	4	B	2	D	2	D	2
212	3	2	4	2	D	3	B	3	B	1	C	1	B	3	B	5	C	5	B	3	D	3	D	4
213					C	4	B	3	B	5	C	4	A	4	C	3	B	5	C	4	C	5	A	5
214	5	4	4	4	C	4	A	2	B	4	B	4	C	4	A	3	D	3	D	3				
215	3	2	3	2	D	3	C	4	D	4	A	1	B	3	C	3	C	4	B	4	B	3	B	1
216	3	3	4	5	B	1	A	1	A	1	B	3	B	5	C	3	C	5	B	5	C	1	D	1
217	5	3	3	3	A	3	A	2	B	3	B	3	A	4	B	4								
218	4	4	4	4	D	3	A	2	B	3	A	3	A	3	B	4	C	4	B	3	C	2	A	1
219	2	3	2	2	B	1	A	1	B	2	B	2	B	3	A	2	C	5	B	5	C	1	C	1
220	5	4	3	3	C	3	B	4	B	4	A	1	D	3	D	3	C	5	B	3	B	3	C	2
221	3	3	4	4	B	3	D	4	D	3	C	4	B	4	B	4	C	5	A	5	C	3	D	4
222					A	3	A	2	D	3	C	2	B	3	C	3	C	5	B	3	C	4	C	5
223					C	3	E	2	D	2	A	1	C	3	B	1	C	5	B	3	C	3	C	3
224					C	3	B	1	B	5	B	3	C	3	C	5	A	5	C	3	D	4	D	3
225					C	4			D	4			B	4			B	4			C	3		
226					A	4	A	2	A	3	B	3	A	2	C	3	C	4	B	4	B	2	A	3
227					B	3	A	2	D	4	A	3	B	3	C	2	C	4	C	3	C	2	A	2
228					B	3	A	2	D	4	A	3	B	3	D	3	C	3	C	4	C	2	A	2
229	4	2	3	4	A	2	A	2	A	1	B	1	A	2	B	2	C	4	B	2	A	1	A	1
230	4	3	3	3	B	2	D	2	D	3	C	2	B	2	C	3	C	3	B	3	D	2	C	2
231	4	4	2	3	A	4	D	2	B	2	C	1	A	3	B	3	D	2	B	1	C	5	C	4
232	5	4	5	3	C	4	C	4	B	5	C	5	C	3	B	3	C	2	B	2	B	3	A	3
233	4	4	3	5	C	2	C	3	D	4	A	2	B	3	C	3	D	4	C	4	B	3	B	4
234	3	3	3	3	B	4	B	3	C	4	B	4	A	4	C	4	D	2	C	2	C	2	C	1
235					D	3	B	3	D	3	C	3	B	2	B	2	B	3	B	2	D	3	A	4
236					B	2	C	2	B	3	B	3	A	3	C	3	C	3	B	3	D	3	D	3
237	2	3	3	4	C	2	A	1					B	3			C	1	C	1	A	1	D	2
238	4	4	4	3	A	4	C	4	B	5	B	4	B	5	B	5	C	5	B	4	D	4	B	3
239	4	2	2	2									A	3			D	2						
240	2	3	3	2	A	1	A	2	B	5	B	3	B	4	B	4	C	5	B	5	B	3	C	4
241	2	3	4	2	B	2	C	1	B	1	C	1	C	3	B	2	B	4	A	1	B	1	A	1
242	4	3	3	4	B	4	D	1	B	4			B	4	B	1	C	4						
243	3	1	3	1									C	3	B	2	C	2	C	2	B	1	C	2
244	1	1	1	1	C	1	E	1	B	1	C	2	B	2	C	3	C	4	B	2	C	3	C	4
245	4	3	3	3					B	3	B	3	B	1	C	3	C	5	B	3				
246	4	3	5	4	C	3	C	5	B	5	B	5	B	5	B	4	C	4	B	4	A	3	C	1
247	5	4	2	3	C	3	A	1	D	4	B	3	B	5	C	3	C	5	B	2	C	5	C	5
248	2	2	3	4	D	1	C	1	C	2	A	1	B	5	B	5	C	3	B	1	D	2	C	1
249	5	3	2	1	C	3	D	2	B	2			A	4	C	4	C	4	C	4				
250					C	5	E	3	B	3	B	4	B	5	D	3	B	4	B	4	C	2	C	2
251					C	5	E	2	B	2	B	3	B	5	C	3	C	5	B	3	D	2	C	5
252	3	2	3	1	B	2	C	1	C	2	C	2	B	1	B	1	C	3	C	2	B	3	A	3

253	4	3	4	4	C	4	E	4	D	3	B	3	B	2	B	3	B	4	C	4	C	4	A	4
254	2	4	1	3	C	2	A	4	B	3	B	3	C	4	D	3	B	4	C	2	D	4	D	2
255	3	3	3	3	C	4	E	4	B	3	B	2	A	3	A	2	B	4	C	4	C	4	B	4
256	3	3	3	3	C	3	E	4	B	4			C	3	D	4	B	5	B	3	C	4	A	4
257	2	5	5	3	D	4	E	4	B	4	B	3	B	4	A	5	B	5	C	3	C	5	A	5
258	3	3	3	3	D	5	E	4	A	1	B	2	A	3	B	3	B	3	C	4	C	4	A	4
259	4	4	4	3	D	4	E	3	B	3	B	3	C	4	D	3	B	3	C	3	C	4	A	4
260	4	4	4	4	D	5	E	5	B	3	B	3					B	5	C	4	C	4	A	3
261	3	2	3	3	D	4	B	3	D	2	B	3	A	3	A	2	B	3	C	3	B	4	B	3
262	3	3	2	4	D	4	B	4	D	1	A	1	A	2	C	2	B	4	B	1	C	4	A	5
263	4	4	3	4	D	3	D	3	D	1	B	1					B	3	C	4	C	4	A	4
264	1	2	2	2	D	4	B	2	B	2	B	2	A	2	B	2	B	1	A	1	C	4	C	3
265	3	4	3	4	C	4	E	4	B	3	B	2	A	4	A	2	B	5	C	4	C	5	A	5
266	3	3	3	3	D	1	E	3	B	4	B	2	C	3	B	4	B	5	C	5	C	5	A	5
267	3	2	3	3	C	2	A	2					B	3	B	3	B	3	C	3	C	3	A	3
268	4	3	3	3	A	4	A	3	D	2	B	4	A	4	A	4	B	5	C	3	C	5	A	5
269	3	3	3	3	D	1	E	3	B	4	B	2	C	3	B	4	B	5	C	5	C	5	A	5
270	4	3	3	4	D	5	E	4	B	2	B	3	A	2	B	1	B	4	C	5	C	4	C	3
271	4	3	3	3	D	4	E	4	B	3	B	4	C	3	A	4	B	4	C	4	C	4	A	4
272	3	2	3	4	D	5	E	3	B	1	A	1	A	2	B	2	B	3	C	3	C	4	A	4
273	4	3	2	3	D	4	E	4			C	1	A	2	A	2	C	1	A	1	C	2	A	3
274	3	3	4	3	D	5	B	1	B	2	B	2	C	4	D	3	C	3	B	3	C	4	C	3
275	3	3	2	3	C	2	C	2	A	1	C	1	A	3	A	1	B	3	B	2	C	4	C	3
276	3	3	2	3	D	4	B	2					C	3	D	1	B	2	A	2	D	2	D	2
277	5	3	3	3	C	4	E	4	B	2	A	2	C	4	D	3	B	5	C	4	C	5	A	4
278	4	3	3	3	C	4	E	4	B	2	A	2	C	4	D	3	B	5	C	4	C	5	A	5
279	4	3	2	4	D	4	E	4	B	4	C	3	B	4	B	1	B	4	C	2	C	5	A	5
280	4	3	3	3	D	4	B	4	B	1	A	3	B	3	C	1	B	4	C	3	C	3	A	4
281	2	2	2	2	D	4	E	3	A	2	C	2	B	3	A	2	C	1	C	2	C	2	A	2
282	4	3	3	4	D	5	E	4	B	4	B	4	B	2	B	2	B	5	C	3	C	4	A	5
283	3	2	3	3	D	4	E	4					C	2			B	5	B	2	C	5	A	5
284	3	4	4	2	C	3	E	3	D	1	B	2	C	3	D	3	B	4	A	2	C	4	A	5
285	4	3	3	3	D	4	E	4	A	2	B	1	A	4	B	2	A	1	D	3	C	5	A	5
286	5	5	4	4	D	5	E	5	B	5	B	4	C	4	A	3	B	4	C	5	C	5	A	5
287	3	4	3	4	C	4	B	3	A	1	A	1	B	3	A	1	B	5	C	3	C	5	A	5
288	4	4	5	4	D	5	E	4	B	5	B	5	B	3	A	3								
289	3	2	2	2	D	3	B	3	B	2	B	2	B	2	C	2	B	2	C	2	C	2	A	2
290	3	2	3	4	D	4	B	4	B	4	B	3	A	2	B	4	B	4	C	4	C	3	A	3
291	3	3	3	3	B	2	E	3									C	5	C	3	C	4	C	3
292	3	2	2	3	D	4	E	3	D	1	B	2	C	2	D	3	B	3	C	3	C	4	A	4
293	4	2	4	4	D	5	E	4	B	4	C	1	C	3	D	3	B	5	C	4	C	4	A	4
294	4	2	2	3	D	4	E	3	D	3	B	2	C	2	D	2	B	4	C	4	C	3	A	3
295	3	2	3	4	C	3	E	4	C	2	B	2	A	2	C	2	B	4	A	5	C	4	A	5
296	3	3	3	3	D	4	E	3	B	2	B	3	C	4	B	2	B	4	C	3	C	3	A	4
297	3	3	4	4	D	4	E	3	B	3	B	4	A	2	A	2	B	4	C	3	C	3	C	3
298	3	2	4	4	C	2	E	4	B	2	B	2	C	2	D	2	B	4	C	4	C	3	A	4
299	1	1	1	1	C	4	C	2	B	4	B	3	B	3	C	2	B	4	B	3	B	3	A	3
300	3	3	4	4	C	5	E	4	B	3	B	3	C	4	C	3	B	4	C	3	C	3	A	3
301	4	4	3	3	D	5	E	5	B	3	B	2	C	1	B	3	B	2	A	1	C	4	A	4

302	3	4	3	3	D	2	E	1	B	1	B	1	C	1	A	1	B	3	C	3	C	4	A	4
303	3	3	2	4	C	3	B	3	B	4	B	1	A	3	A	3	C	3	A	4	C	4	A	4
304	3	2	2	3	D	4	E	4	B	3	B	3	C	4	D	4	B	4	C	3	C	4	A	3
305					D	3	E	4					B	2			B	5	C	4	C	3	A	3
306	4	4	3	4	D	3	B	2	B	3	B	2	C	3	D	3	A	5	A	4	C	5	A	5
307	4	4	3	3	D	3	E	3	B	1	B	1	C	2	A	1	B	4	C	4	C	4	A	4
308	3	2	2	2	D	2	E	2	B	1	B	1	C	1			B	2			C	2	A	2
309	4	2	3	3	D	3	E	3	B	4	B	1	A	2	A	2	B	4	C	3	C	3	A	3
310	4	3	3	3	D	4	B	3	B	4	B	3	C	3	D	2	B	4	C	3	C	3	A	3
311	4				D	5	E	4	B	5	B	3	C	4	D	4	B	5	C	5	C	3	A	4
312	4	3	3	3	D	4	C	3	B	2	B	3	C	2	D	3	B	5	B	3	C	5	A	3
313	2	3	3	3	D	3	B	2	B	3	C	2	A	2	A	1	B	4	C	4	C	3	A	3
314	3	4	3	4	D	4	B	4	B	4	B	4	A	2	B	2	B	4	C	3	C	4	A	4
315	3	3	3	3	D	3	E	3					B	3			B	3	C	5	C	3	A	5
316	2	2	3	3	D	4	E	3	A	2	B	1	A	1	A	3	B	4	C	4	C	4	A	5
317	2	3	3	3	D	3	B	3	B	2	B	2	C	2	D	2	B	3	C	2	C	4	A	4
318	4	3	3	3	D	3	E	2	D	2	C	2	C	3	D	2	B	3	C	3	C	3	A	3
319	3	2	2	2	D	4	E	3	D	1	C	1	C	3	D	1	B	5	C	3	C	2	C	2
320	3	3	3	4	D	4	E	2	D	3	C	2	A	2	A	2	B	5	C	3	C	4	C	2
321	3	4	3	3	D	3	E	3	B	4	C	3	C	2	B	2	B	4	C	4	C	4	A	4
322	3	4	4	4	D	4	E	5	B	5	B	4	C	1	B	3	B	3	C	3	C	4	A	4
323	2	3	3	3	D	4	B	3	B	2	B	2	A	2	A	2	B	4	C	3	C	3	A	4
324	2	3	3	3	D	4	C	1	D	2	B	1	A	2	B	1	B	3	C	3	C	4	A	4
325	3	4	3	4	D	4	E	4	B	4	B	4	C	3	D	2	B	4	C	4	C	4	A	4
326	4	3	3	3			E	4	C	2			A	2	B	1	B	5	C	5	C	5	A	1
327	3	3	3	3	D	3	B	3	B	3	B	3	A	3	A	3	B	4	C	4	C	3	A	1
328	4	3	2	3	C	4	E	3	D	2	B	2	B	1	B	2	B	4	B	3	C	3	A	5
329	3	4	3	2	A	2	C	3	B	3	A	2	C	1	D	2	B	5	C	4	C	5	A	5
330	3	2	3	3	C	3	E	3	B	1	B	2	B	3	A	3	B	3	B	2	C	4	A	4
331	3	2	3	4	C	4	E	3	B	3			B	1			A	3	B	2	C	3	B	1
332	2	2	2	2	D	3	E	3	D	1	B	1	A	2	A	1	B	3	C	3	C	4	A	3
333	2	1	3	2	D	5	E	3	A	1	B	1	C	1	D	1	B	2	C	1	C	2	A	3
334	3	3	4	4	D	4	E	4	D	1	C	2	C	3	D	3	B	4	C	4	C	4	C	4
335	4	3	4	3	D	4	E	2	B	2	B	2	B	3	A	3	B	4	B	2	B	2	A	4

Student	GC				Question																			
	1	2	3	4	6				7				8				9				10			
					A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)
					B		C		B		B		D		A		B		C		C		B	
1	4	3	3	4	B	5	C	4	B	5	B	4	D	3	A	3	B	4	C	2	B	2	D	2
2	4	3	3	5	D	1	D	1	B	5	B	5	C	1	B	1	A	5	A	4	D	2	F	2
3	4	3	4	3	C	4	B	2	B	2	A	2	A	4	C	3	A	3	A	1	A	3	B	4
4	4	4	3	3	B	1	C	2	B	5	B	5	A	2	B	2	A	5	E	5	C	4	B	5
5	4	3	3	4	B	5	A	4	B	5	B	4	D	4	A	3	B	5	A	3	A	4	B	3
6	4	3	3	3	B	5	C	3	B	5	B	5	A	1	B	1	D	3	F	3	A	4	B	4
7	5	4	5	3	B	5	C	3	B	5	B	5	C	3	B	2	B	4	E	4	C	2	B	3
8	4	3	5	4	B	5	A	2	C	5	B	5	B	5	C	4	A	5	E	5	A	5	B	4
9	5	4	4	4	A	1	A	1	B	5	B	1	A	1	B	4	B	4	E	4	A	3	F	3
10	5	3	4	4	D	5	A	2	B	5	B	5	D	4	A	3	A	4	C	3	C	2	A	3
11	4	3	4	4	A	4	A	4	B	5	B	5	C	4	D	2	B	4	E	4	A	2	F	3
12	5	4	5	4	D	2	D	2	B	4	B	4	D	3	A	3	A	2	A	2	B	3	B	3
13	3	2	3	4	A	3	C	3	A	4	A	4	A	3	B	3	A	3	D	4	D	3	C	3
14	4	2	4	3	B	4	C	3	B	4	B	4	A	2	C	2	B	2	C	2	C	2	C	2
15	2	3	3	3	B	4	C	2	B	5	A	1	D	1	C	1	A	1	D	1	B	2	A	1
16	4	4	3	4	C	3	D	5	B	3	C	4	B	4	C	3	D	4	C	5	A	5	D	4
17	4	4	4	4	A	4	C	4	D	3	C	3	D	4	A	4	C	4	C	4	A	4	D	4
18	4	2	4	3	A	2	B	1	A	2	A	1	A	1	B	1	B	4	E	3	C	3	F	3
19	4	3	4	4	C	2	B	1	C	1	A	1	C	3	C	1	D	1	B	1	D	1	A	1
20	3	2	4	4	A	3	A	3	B	2	B	3	C	4	C	2	D	3	B	2	C	2	E	3
21	3	3	3	4	D	2	B	2	C	3	B	3	D	1	C	2	A	3	F	4	D	3	E	2
22					D	3	D	3	B	2	A	1	A	3	B	3	A	3	F	3	D	3	E	4
23					D	3	D	3	B	2	A	1	A	3	B	3	A	3	F	3	D	3	E	4
24					D	3	D	2	B	1	A	3	A	3	B	3	A	3	F	3	D	4	E	2
25	4	2	3	3	B	5	C	4	B	5	C	4	A	3	A	3	B	3	D	2	C	3	C	2
26	4	3	3	3	C	2	B	3	C	5	B	3	A	2	A	2	D	3	B	2	D	3	C	2
27	4	4	3	5	B	4	A	4	B	5	B	5	A	5	C	4	A	3			C	4	B	4
28	4	4	3	3	A	5	A	5	B	5	B	5	D	5	A	5	B	5	C	3	C	4	B	4
29	3	4	3	3	B	5	C	5	B	5	B	5	A	5	C	5	A	2	E	1	C	4	B	4
30	3	3	3	4	B	3	C	3	B	4	B	3	A	4	C	3	A	2	E	3	C	1	B	1
31	4	2	3	3	C	3	B	2	B	4	B	2	D	4	A	3	A	3	E	2	B	4	B	4
32	5	3	3	3	B	4	C	3	B	4	B	1	D	3	A	3	B	3	C	3	A	2	B	4
33	4	3	4	4	B	4	A	4	B	5	B	4	A	4	C	4	A	5	D	5	C	5	C	4
34	4	5	4	4	B	5	A	4	B	5	B	5	A	4	C	4	A	3	F	4	C	4	B	4
35	4	3	3	3	A	4	A	4	B	4	C	3	D	5	A	5	B	5	C	3	C	4	B	4
36	2	4	4	4	A	5	A	5	B	5	B	5	D	5	A	5	B	5	E	5	C	5	B	5
37	5	2	3	4	B	4	A	3	D	3	B	3	C	3	D	1	A	1	A	1	D	2	B	2
38	2	3	4	4	B	4	C	3	B	5	B	3	D	2	A	2	A	4	D	3	C	2	D	3
39	4	3	4	2	A	5	A	5	B	5	B	1	B	3	B	1	A	4	E	1	C	3	C	1
40	4	3	3	4	B	5	C	5	B	4	B	5	D	3	A	3	B	3	C	3	C	3	B	3
41	4	3	2	4	B	5	C	5	B	5	B	4	D	5	A	4	A	3	D	3	B	3	B	5
42	4	3	4	4	B	4	C	4	C	4	B	4	D	4	A	4	C	4	D	4	C	4	B	4
43	4	3	3	2	A	5	D	4	B	5	B	5	D	5	A	3	B	5	C	4	C	4	B	4
44	5	2	4	3	A	5	A	5	B	4	C	2	D	5	A	5	B	4	E	5	B	5	A	4
45	3	3	3	3	A	3	B	3	C	3	C	3	A	3	A	1	A	3	C	1	A	3	E	3
46	5	3	3	3	B	5	A	3	B	5	B	5	D	4	A	3	B	3	E	2	C	2	F	2
47	3	3	2	4	D	3			D	3	B	2					B	4	C	2	C	2	B	2
48	5	3	3	2	C	4	A	4	B	4	C	3	B	3	A	2	A	3	B	2	D	2	F	3
49	3	3	3	3	A	4	A	4	C	3	B	3	D	3	A	3	A	3	E	3	C	3	B	2
50	4	3	4	4	C	3	C	3	B	5	C	4	D	2	A	2	A	3	E	3	C	3	C	3
51	2	3	4	5	B	5	C	3	B	5	B	4	C	4	B	3	A	4	E	4	D	3	A	3
52	5	4	2	3	A	2	A	1	D	5	C	5	A	4	D	4	A	1	D	1	B	2	A	2
53	3	2	3	3	B	3	C	3	C	3	C	3	D	3	A	3	A	3	D	3	C	3	D	3

54	4	3	3	3	A	5	C	5	B	4	B	4	D	3	A	3	A	4	E	5	C	4	A	4
55	4	2	3	3	A	3	C	4	B	2	B	4	A	3	A	5	B	2	E	2	C	3	B	3
56	4	4	3	4	C	5	B	3	B	5	B	4	B	5	C	4	A	5	E	5	A	4	D	3
57	5	4	4	4	C	2	B	1	B	3	C	3	D	3	A	4	B	2	D	2	C	5	F	2
58	2	3	3	2	A	3	A	3	B	2	B	3	A	2	B	3	A	3	E	4	C	3	B	3
59	3	2	3	3	C	1	B	1	B	3	B	3	C	2	B	2	B	1	D	1	C	2	A	1
60	4	2	3	4	B	5	A	5	B	5	B	1	A	1	A	1	B	5	E	3	C	2	D	1
61	3	3	2	2	C	4	B	3	C	3	B	3	C	4	B	3	B	3	A	3	C	2	B	1
62	5	2	4	5	B	5	A	5	B	5	B	5	C	2	C	2	A	4	E	4	C	3	B	3
63	4	4	4	4	C	2	D	2	A	2	B	2	A	2	C	2	A	3	B	2	A	3	A	3
64	4	4	5	4	C	3	C	2	B	3	C	2	D	4	A	2	D	3	D	3	C	4	D	2
65	3	2	3	4	C	3	A	1	B	5	B	5	D	5	A	3	A	2	A	1	C	4	B	3
66	4	4	4	4	C	4	B	4	B	5	B	5	D	5	C	5	B	5	D	5	A	4	A	4
67	4	3	4	4	C	4	C	4	B	5	C	4	A	5	B	4	D	4	E	4	A	5	E	5
68	4	3	3	4	C	3	B	3	B	5	A	5	A	3	C	3	B	4	C	4	D	4	E	4
69	4	4	4	3	C	4	B	3	B	4	B	3	D	4	D	3	A	5	C	4	D	5	E	5
70	5	5	5	4	A	4	A	4	B	5	B	5	A	2	C	4	B	4	D	4	C	4	D	3
71	4	3	4	2	C	1	B	4	C	1	C	5	A	4			B	5	E	5	A	5	B	5
72	5	5	4	4	C	3	D	2	C	5	A	4	A	3	B	3	A	4	C	3	A	4	E	4
73	4	4	4	3	D	5	C	5	C	4	B	5	A	3	C	3	B	5	C	4	A	4	B	4
74	4	3	4	3	D	2	D	2	B	1	C	1	C	1	B	1	B	3	E	3	D	2	B	2
75	4	3	5	5					C	5	B	2					B	4	C	4	D	5	B	3
76	4	3	3	3	A	5	A	4	B	4	B	5	A	5	D	3	B	3	E	3				
77	4	3	3	3	A	5	C	4	D	3	B	3	D	2	C	3	B	4	E	3	C	5	B	5
78	3	4	5	4	C	5	B	4	D	5	C	4	A	2	D	3	A	3	E	2	A	4	A	4
79	5	3	4	4	C	5	B	5	A	5	B	4	A	4	C	4	C	4	D	4	A	4	F	4
80					C	2	D	2	B	2			C	2	A	2	B	2	D	2	D	3	F	4
81	5	3	3	4	A	4	A	3	C	4	C	3	D	2	B	2	C	3	C	3	B	3	D	3
82	3	2	3	3	B	3	A	3	C	5	B	3	A	3	C	3	A	3	D	1	D	3	F	3
83	4	5	3	3	A	4	A	4	C	1	A	3	B	2	C	2	A	2	C	2	C	3	A	2
84	4	3	3	3	A	4	A	3	C	3	C	3	A	3	A	2	B	4	D	3	C	3	F	2
85	4	3	3	4	A	4	A	3	C	3	C	2	B	3	B	3	A	4	A	4	C	4	B	4
86	5	2	5	3	C	5	B	5	D	5	B	3	B	2	C	2	D	3	C	3	B	3	B	3
87	5	4	4	4	B	5	A	3	D	2	C	1	A	2	D	4	A	3	C	3	A	3	A	4
88	4	3	3	3	B	5	C	5	D	2	C	2	B	2	C	2	B	5	C	4	C	4	B	5
89	5	2	2	2	A	4	A	4	B	2	C	1					C	3	A	3	A	3	C	4
90	5	5	4	4	A	3	A	4	B	5	B	5	A	1	C	1	B	3	D	3	C	3	D	2
91	4	4	3	3	C	4	D	2	B	3	A	2	C	2	A	2	A	3	C	3	B	2	F	2
92	3	3	3	3	C	3	D	3	B	3	A	3	A	3	B	3	A	3	D	3	C	3	B	3
93	3	3	3	3	C	3	C	3	B	3	B	3	A	3	C	3	A	3	A	3	D	3	E	3
94	3	3	3	3	A	2	C	1	C	3	B	2	C	1	B	1	B	3	E	3	A	3	E	3
95	3	3	3	3	A	1	A	1	B	5	B	3	D	3	A	2	B	2	A	1	A	3	D	2
96	5	5	4	4	D	5	D	5	C	5			A	1	B	1	D	5			C	5	B	5
97	3	2	3	3	D	2	B	1	B	3	B	2	C	2	B	2	B	3	C	2	A	3	E	3
98	3	3	2	3	D	2	D	2	B	5	B	2	A	1	B	2	A	3	F	3				
99	3	4	3	3	D	3	D	3	B	1	A	1	A	3	B	3	A	4	F	3	D	3	E	4
100	5	5	4	4	D	5	D	5	C	5	C	5	A	4	B	4	A	4	F	4	D	5	B	4
101	3	2	3	3					B	5	B	3	A	3	B	2	A	3	F	2	D	2	E	3
102	5	3	4	3	D	3	D	3	C	2	C	2	A	3	B	3	A	3	F	3	D	5	B	4
103	4				D	5			C	5			A	1			D	4			C	3		
104	4	2	2	2	A	3	D	1	D	2	B	3	A	3	C	1	B	2	A	5	A	2	A	4
105	4	3	3	3	B	3	D	2	C	4	A	3	C	3	A	2	B	4	C	2	A	3	F	3
106	4	2	4	4	C	5	B	4	C	3	A	3	C	4	A	4	B	3	D	3	B	4	F	3
107	4	3	3	4	C	3	A	3	C	4	A	2	C	3	A	4	B	3	C	3	A	3	C	2
108	4	3	3	5	C	3	A	4	C	4	B	5	A	5	A	2	D	4	B	3	C	3	F	4
109	5	3	4	3	D	3	D	3	C	2	C	2	A	3	B	3	A	4	F	3	D	5	B	4
110	3	3	3	3	D	3	D	3	B	2	A	1	A	3	B	3	A	4	F	3	D	3	E	4

111	3	3	4	3	D	3	D	2	B	3	C	2	A	3	B	3	A	3	F	3	D	2	E	4
112	5	3	4	3	D	3	D	3	B	2	A	1	A	3	B	3	A	4	F	3	D	3	E	4
113	3	3	3	3	D	3			B	2			A	3	B	3	A	4	F	3	D	3		
114	4	3	2	3	D	3	D	3	B	2	A	1	A	3	B	3	A	3	F	3	D	3	E	4
115	3	3	2	3	B	5	C	5	C	5	B	5	D	3	C	3	B	5	E	4	C	4	B	4
116	4	5	4	4	A	5	A	5	B	2	B	2					B	4	E	3	C	5	B	4
117	4	4	4	5	A	5	A	4	C	2	B	3	D	5	A	3	D	3	B	3	B	1	B	1
118	2	2	2	3	D	4	D	4	A	4			B	2	B	2	B	2	C	2	B	2	C	2
119	4	3	4	4	C	3	D	2	D	3	B	3	A	3	C	2	A	3	C	3	A	3	C	2
120	4	2	4	5	A	3	A	4	B	3	B	3	C	1	B	1	B	4	E	4	C	4	D	4
121	4	3	4	5	A	4	C	4	C	3	B	3	D	4	D	2	B	3	C	3	D	3	F	3
122	4	3	3	3	D	3	D	3	C	5	B	3	D	4	D	4	D	3	C	3	C	4	B	3
123	4	3	3	3	D	3	D	3	C	5	B	3	C	1	B	1	D	3	C	1	C	2	B	4
124	4	2	5	5	A	4	A	4	C	4	B	4	D	4	D	4	B	4	E	4	C	4	B	4
125	5	4	4	4	A	3	A	3	B	3	B	3	D	3	C	3	A	4	A	4	D	5	E	3
126	4	3	3	3	A	3	A	3	C	4	B	4	D	5	B	3	B	3	C	3	C	3	B	4
127	4	3	3	3	A	3	A	3	C	4	B	4	D	5	B	3	B	2	C	2	C	4	B	3
128	4	4	4	3	A	3	A	3	C	5	B	3	D	4	C	3	B	2	D	2	C	3	B	4
129	4	5	4	3	A	4	D	3	B	5	C	3	D	4	C	2	A	4	A	3	D	5	E	5
130	4	3	4	4	A	4	A	4	C	4	B	3	D	2	A	3	A	2	C	3	A	4	B	3
131	4	3	4	4	A	4	A	4	C	5	B	3	D	5	C	3	B	2	D	3	C	3	B	3
132	4	4	3	4	A	4	A	3	C	3	B	4	D	2	B	4	B	4	A	4	C	3	B	3
133	3	3	4	4	A	3	A	3	C	4	B	2	D	3	D	2	B	4	A	4	C	4	D	1
134	3	4	3	3	B	3	C	2	D	3	B	2	D	4	C	3			E	3	C	5	B	4
135	4	3	4	3	A	3	A	3	C	4	B	3	D	2	B	4	B	3	C	3	C	3	B	3
136	3	3	3	3	A	3	A	3	C	4	B	3	D	4	B	3	B	3	C	4	C	3	B	3
137	4	3	3	3	A	4	A	4	A	3	C	3	A	4	C	3	B	4	E	3	A	3	C	3
138	4	3	4	3	A	4	A	3	B	4	C	3	D	5	C	3	B	5	A	4	C	3	B	2
139	5	5	5	5	A	5	C	5	C	5	C	5	D	5	A	5	B	4	D	5	C	3	F	4
140	5	3	3	4	A	3	A	3	C	5	B	4	D	2	A	4	B	3	D	3	C	5	B	4
141	4	3	4	4	A	4	A	3	C	4	B	4	D	4	C	3	B	5	E	3	C	5	B	4
142	4	4	3	3	B	3	C	3	C	1			D	3	D	2	A	3	A	3	C	4	B	3
143	4	3	3	3	A	4	A	4	C	4	B	3	D	4	B	4	B	4	C	3	C	5	B	4
144					B	1	A	1	C	4	B	4	D	4			B	4	B	3	C	4	B	4
145					A	5	A	3	C	3	B	4	D	4	B	1	B	4	B	3	C	5	B	5
146	4	4	5	4	A	4	A	3	C	4	B	4	D	3	C	3	B	3	E	3	C	4	B	4
147	4	4	3	4	B	4	C	4	C	3	B	3	D	4	A	3	B	4	C	4	C	3	A	3
148	4	2	5	5	C	5	D	3	A	2	B	2	D	4	D	4	A	5	E	1	A	5	C	4
149	5	4	4	4	A	5	D	5	B	5	A	4	D	4	C	4	B	4	D	3	C	4	B	4
150	5	4	4	4	A	3	A	3	C	4	B	3	D	4	C	3	B	2	D	3	C	4	B	4
151	5	3	5	5	B	5	A	5	C	5	C	5	D	5	A	4	B	5	E	5	C	5	B	5
152	4	2	3	3	C	3	D	4	C	4	C	3	B	4	C	4	C	3	D	3	C	4	E	4
153	5	4	4	5	B	4	C	5	B	5	B	5	D	5	A	5	B	5	E	5	B	5	B	5
154	4	2	2	3	A	2	A	4	D	4	A	2	D	3	A	2	B	4	C	2	C	3	A	3
155	4	3	4	3	A	2	A	3	A	2			B	3	D	2	B	3	E	3	A	3	B	3
156	3	3	2	2	A	2	A	2	C	4	B	4					B	4	C	4	B	3	B	3
157	5	4	5	5	D	3	D	3	C	5	B	2	A	2	C	2	A	4	D	4	C	2	C	2
158	4	3	3	2	B	5			B	2			D	1	C	1	A	3			A	3		
159	5	3	3	3	A	2	D	1	C	4	B	4	D	1	B	1	A	1	C	1	A	4	F	2

160	4	3	4	3	A	4	A	4	D	3	B	2	D	4	D	3	B	4	E	2	A	4	E	3
161	3	3	3	3	C	2	B	3	A	2	B	3	A	1	D	1	A	2	B	1	B	1	D	1
162	4	3	4	3	D	3	C	2	C	5	B	4	A	4	B	3	D	3	C	3	C	4	F	4
163	5	3	3	4	B	3	C	4	C	5	B	4	A	5	B	4	B	5	D	4	C	5	B	3
164	5	4	4	4	D	5	A	4	C	5	A	5	B	3	B	3	B	5	D	5	C	3	C	3
165	4	3	3	3	B	4	B	3	B	3	B	3	B	3	A	4	B	3	B	4	C	4	D	4
166	5	4	5	5	C	5	A	4	B	5	A	4	C	3	D	3	B	3	C	2	C	2	B	3
167	5	4	2	2	C	4	C	4	C	5	B	5	D	5	A	5	A	5	E	3	C	4	A	3
168					A	4	C	4	C	5	B	5	D	3	B	3	B	4	B	4	C	4	C	4
169	4	4	5	4	B	4	A	5	C	5	B	4					A	4	E	4	B	2	F	3
170	5	1	3	4	B	5	C	4	C	5	B	4	D	2	A	3	B	5	E	1	A	2	B	4
171	5	4	5	5	A	3	A	3	D	4	C	3	A	3	C	3	B	5	E	5	C	4	B	5
172	4	4	5	5	A	5	A	5	B	2	B	2	A	2	A	2	B	5	E	5	C	4	A	4
173	5	4	5	4	C	4	A	3	C	5	C	5	D	4	B	4	D	4	D	5	B	5	C	3
174	5	3	4	5	C	4	C	4	C	5	A	4	A	4	B	4	A	5	D	3	C	5	B	5
175					A	3	D	3	C	4	B	3	A	3	D	3	B	4	D	4	C	3	C	3
176	3	3	2	4	C	2	D	5	D	3	B	3	C	3	D	3	A	3	B	3	B	4	C	4
177	5	4	2	5	B	4	B	3	C	5	B	3	D	4	B	2	C	4	A	2	B	1	A	1
178	4	4	2	4	A	5	A	5	C	4	B	3	C	3	C	3	A	4	D	4	D	3	D	2
179	5	4	4	4	B	5	C	5	B	5	B	4					B	4	E	3	C	4	B	3
180	5	4	3	4	A	4	A	3	C	3	B	4	C	3	C	3	B	3	A	3	A	2	B	2
181	5	4	4	3	C	5	D	3	D	5	A	5	B	2	C	2	A	3	B	3	C	4	E	4
182	3	3	2	3	C	2	C	3	A	4	B	3	A	2	C	3	B	3	C	3	C	4	E	3
183	4	3	5	4	C	4			C	1			D	1			B	1			A	4	C	3
184	4	4	4	5	D	5	C	4	B	4	B	4	A	2	A	2	B	5	F	4	C	4	D	4
185	4	3	4	4	A	5	A	5	B	4	B	4	D	3	A	3	D	1	B	2	B	3	D	3
186	4	4	3	3	A	5	A	4	C	3	A	4	B	4	B	3	A	4	A	3	A	4	C	4
187	5	3	3	4	D	5	A	5	B	4	B	4	C	4	C	3	B	5	D	4	A	4	D	3
188	3	3			A	5	A	5	B	5	A	5	B	3			B	4			C	3		
189					A	5	B	5	B	5			A	5			B	3			B	4		
190					C	1	D	1	C	2	A	1	A	2	C	1	A	1	C	1	C	1	B	1
191	4	5	4	4			D	4	B	4	B	4	C	2	D	2	B	2	D	2	A	1	A	2
192	4	5	4	4					B	4	B	4	C	1	D	2	B	2	D	2	A	1	A	2
193					C	1	B	1	B	3	A	3	D	3	B	3	A	3	C	3	B	1	B	1
194	4	4	3	4	C	4	B	3	B	4	B	1	D	3	B	1	B	1	A	1	B	1	C	1
195	4	2	3	3	C	1	B	3	B	1	B	1	D	3	B	3	A	3	A	3	B	3	E	3
196	4	4	3	3	B	1	A	1	B	3	A	3	B	1	B	1	A	3	C	1	B	1	C	1
197	4	2	3	3	C	4	D	3	B	5	A	3	D	3	B	3	A	3	A	3	B	3	E	3
198	4	2	3	3	C	3	D	3	A	3	B	3	A	5	A	4	A	2	C	5	A	4	B	3
199	2	2	3	3	A	2	A	1	B	5	A	4	A	1	D	5	D	4	C	1			B	1
200					A	5	A	5	B	3	A	3	D	1	C	4	A	4	D	4	D	3	B	4
201	4	4	4	4	D	4	D	5	B	5	A	5	A	4	A	3	D	3	C	3	B	1	F	3
202	3	2	3	3	C	2	A	2	B	4	A	3	D	2	B	3	A	3	B	3	B	3	A	3
203	3	2	4	3	C	3	A	2	B	4	A	3	D	3	B	3	A	3	B	3	B	3	A	3
204	5	3	3	3					C	3	B	3	C	3	B	3	A	3	C	3	B	4	F	3
205	4	3	3	3	A	3	C	3	C	3	C	3	D	3	B	3	A	3	B	3			A	3
206	3	3	3	3	C	2	D	2	C	2	B	2	C	1	A	1	A	3	A	2	C	3	B	2
207					A	5	A	5	B	5	A	5	D	1	C	4	B	4	D	4	D	4	B	4
208					D	5	B	4	B	5	A	4	C	5	B	4	D	3	A	3	B	1	A	3

209	2	4	4	4	A	3	B	3	B	3	C	1	C	2	A	2	D	3	C	2	A	3	B	2
210					C	2	B	2	B	1	A	1	D	2	B	2	A	2	A	1	C	1	A	1
211							D	4	C	2	C	1			A	1	B	2	C	2	B	2	E	2
212	3	2	4	2	A	3	D	3	A	4	B	3	B	4	C	3	A	5	A	3	D	5	C	1
213					B	5	A	4	C	4	B	3	A	5	B	3	B	5	D	4	A	4		
214	5	4	4	4	D	3	C	3	C	4	B	4	A	4	C	3	A	3	A	3	C	3	D	3
215	3	2	3	2	C	3	B	4	A	4	B	3	A	5	B	1	D	5	A	3	D	5	A	4
216	3	3	4	5	C	3	D	1	D	3	B	3	C	3	B	3	B	3	C	1	D	5	A	3
217	5	3	3	3					B	2	C	2	C	2	A	2	A	2	C	2				
218	4	4	4	4	B	2	D	3	B	3	B	3	C	1	A	1	B	2	A	2	D	2	D	2
219	2	3	2	2	A	2	D	1	D	1	B	1	D	1	A	1	B	2	A	2	C	2	C	2
220	5	4	3	3	C	4	A	4	D	3	B	3	C	3	C	3	B	2	E	2	B	3	D	3
221	3	3	4	4	C	4	C	2	C	4	C	3	D	3	D	3	A	5	A	4	C	3	D	4
222					D	4	A	3	A	4	C	3	B	2	C	2	A	3	B	3	C	3	F	2
223					B	3	D	2					A	3	B	3	A	2	A	2	A	3	A	3
224					B	3	D	2	B	3	C	3	A	3	B	2	B	5	A	5	D	3	C	2
225					C	3			C	3			A	4							A	3		
226					D	4	B	3	D	4	A	3	B	2	D	2	B	2	B	3	C	3	D	3
227					A	3	D	3	D	5	C	3	A	2	C	4	B	4	A	3	B	2	B	3
228					A	3	D	3	D	3	A	4	C	4	B	3	B	4	C	3	C	4	D	3
229	4	2	3	4	C	4	B	4	B	1	A	1	C	1	B	1	B	1	C	1	C	1	C	1
230	4	3	3	3	A	3	D	3	B	3	B	3	A	3	C	3	A	5	D	5	D	2	E	2
231	4	4	2	3	B	2	A	2	B	3	A	2	D	3	B	2	B	3	B	3	C	3	F	2
232	5	4	5	3	C	2	B	2	D	4	B	4	A	3	C	3	A	4	C	4	B	4	B	3
233	4	4	3	5			D	4	A	4	C	4	C	3	C	4	A	4	D	3	C	5	C	4
234	3	3	3	3	B	3	C	2	B	3	B	3	B	2	B	2	A	3	E	2	C	4	B	4
235							D	2	D	4	B	3	D	3	D	2	D	2	D	3	B	4	D	2
236					A	3	D	3	D	3	B	3	D	3	C	3	A	3	C	3	B	3	D	3
237	2	3	3	4			B	3	C	1	A	2	D	1	A	2	C	1	A	1	C	1		
238	4	4	4	3	D	5	B	4	B	5	C	3	C	4	B	4	A	5	A	4	C	4	E	3
239	4	2	2	2					B	3											A	3	F	5
240	2	3	3	2	D	5	A	5	B	4	A	4	C	1	A	2	A	2	A	3	C	5	C	4
241	2	3	4	2	D	4	C	5	C	2	B	3	A	1	C	1	B	4	D	5	B	2	D	2
242	4	3	3	4																				
243	3	1	3	1	A	1	A	1	B	3	B	3	A	3	A	2	A	4	A	3	B	2	C	2
244	1	1	1	1			C	2	C	2	B	2	C	4	B	5	A	2	E	3	B	1	A	1
245	4	3	3	3					C	1	B	4					A	3						
246	4	3	5	4	C	4	B	2	B	3	B	1	B	2	B	2	B	4	D	4	A	3	C	3
247	5	4	2	3	A	3	D	2	A	5	A	4	D	3	B	4	B	5	A	5	B	3	D	3
248	2	2	3	4	D	1	B	1	B	4	B	4	D	2	B	3	A	5	A	4				
249	5	3	2	1	C	2	B	2	D	5							A	2	E	2	C	3	B	2
250					D	3	A	1	B	5	C	4	B	2	D	2	B	1	E	2				
251					B	2	C	4	B	5	C	4	B	2	D	2	B	3	F	4	A	3	D	4
252	3	2	3	1	C	3	C	4	B	4	B	4	B	3	C	1	D	3	C	2	D	1	B	2
253	4	3	4	4	A	4	A	3	A	3	A	2	D	2	A	3	B	3	C	4	C	3	B	3
254	2	4	1	3	A	2	A	2	B	3	B	3	D	1	A	1	D	2	B	2	C	2	A	3
255	3	3	3	3	B	4	C	4	B	1	B	2	D	2	A	2	B	3	C	3	C	3	B	3
256	3	3	3	3	A	4	A	3					D	3	A	4	B	4	C	5	A	4	B	4
257	2	5	5	3	A	5	A	5	A	3	B	5	D	4	A	5	B	1	C	5	C	4	B	4

258	3	3	3	3	A	3	C	3	B	2	B	3	D	3	A	3	B	5	C	4	B	2	B	2
259	4	4	4	3	A	4	A	4	A	3	B	3	D	3	A	3	B	4	C	4	C	4	B	3
260	4	4	4	4	A	3	A	3	B	3	B	5	D	5	A	5	B	4	C	3	A	3	B	3
261	3	2	3	3	A	3	A	3	A	3	B	3	D	3	A	3	B	3	C	4	C	2	B	3
262	3	3	2	4	A	4	A	4	B	1	B	3	D	1	A	3	B	5	C	5	C	4	B	4
263	4	4	3	4	B	3	C	3	B	1	A	1	D	4	A	1	B	2	C	2	C	3	B	3
264	1	2	2	2	C	2	B	2	B	2	C	2	D	3	A	2	B	3	C	3	B	1	C	1
265	3	4	3	4	A	4	A	4	B	3	B	3	D	5	A	5	B	4	C	4	D	2	C	3
266	3	3	3	3	A	4	A	4	A	5	B	4	D	1	C	1	B	4	A	4	C	3	B	3
267	3	2	3	3	A	3	A	3	A	1	A	1	D	2	A	2	A	2	F	2	C	2	F	2
268	4	3	3	3	A	4	A	3	D	2	B	2	A	5	B	4	B	3	C	4	C	4	F	3
269	3	3	3	3	A	4	A	4	A	5	B	4	D	1	C	1	B	4	A	4	C	3	B	3
270	4	3	3	4	A	1	A	2	B	2	B	3	D	2	A	3	B	4	C	4	C	3	B	2
271	4	3	3	3	A	4	A	4	B	4	B	4	D	4	A	4	B	3	C	3	A	3	B	3
272	3	2	3	4	B	2	A	2	B	3	B	3	D	4	A	4	D	2	F	2	B	3	B	3
273	4	3	2	3	A	2	A	2					D	2	A	3	D	2	B	3	C	3	B	2
274	3	3	4	3	B	3	C	3	D	3	C	3	C	1	A	3	D	2	B	2	D	3	F	3
275	3	3	2	3	D	3	D	2	B	1	B	1	C	1	B	1	B	2	A	2	C	2		
276	3	3	2	3	C	3	B	3	B	2	A	1					A	3	F	2	C	3	B	3
277	5	3	3	3	C	4	B	3	D	2	B	2	A	4	D	3	B	4	C	4	C	3	B	4
278	4	3	3	3	C	3	B	3	D	2	B	2	A	5	D	2	B	4	C	4	C	3	B	3
279	4	3	2	4	A	5	A	5	B	3	B	2	D	5	A	4	B	5	C	5	A	3	B	4
280	4	3	3	3	A	3	A	2	B	1			D	2	A	4	B	2	E	3	C	3		
281	2	2	2	2	D	3	A	2	B	2	A	1	D	4	A	4	A	3	F	3	C	2	F	2
282	4	3	3	4	A	4	A	5	B	3	B	3	D	4	C	3	B	4	C	5	C	2	F	2
283	3	2	3	3	A	4	A	4					A	4	A	1	B	4	C	4	C	4	B	4
284	3	4	4	2	A	2	A	3	C	1	B	4	D	3	A	1	D	3	B	3	D	3	A	3
285	4	3	3	3	A	4	A	4	D	2	B	2	D	4	A	4	B	4	C	4	C	4	A	3
286	5	5	4	4	A	5	A	4	B	4	B	4	D	4	A	5	B	5	C	5	D	4	D	4
287	3	4	3	4	A	4	C	2	B	2	A	3	B	1	A	1	B	4	C	4	C	1	F	1
288	4	4	5	4																				
289	3	2	2	2	A	2	A	2	A	2	B	2	D	2	C	2	C	2	F	2	D	2	D	2
290	3	2	3	4	A	4	A	3	A	2	C	1	D	2	A	1	A	2	E	3	C	2	B	3
291	3	3	3	3	A	1	A	2	B	2	B	1	A	3	A	2	B	5	D	3	C	2	E	2
292	3	2	2	3	A	4	A	3	D	4	B	1	D	2	A	2	B	5	C	4	C	4	B	3
293	4	2	4	4	C	5	C	3	D	1	B	1	D	4	A	4	B	3	C	4	D	4	C	2
294	4	2	2	3	A	2	A	2	B	2	B	2	D	2	A	2	A	1	E	1	D	1	C	1
295	3	2	3	4	D	2	D	1	B	3	B	5	D	4	A	4	B	3	A	3	C	1	A	1
296	3	3	3	3	A	3	A	3	A	2	B	2	D	3	A	3	B	4	C	3	C	3	B	2
297	3	3	4	4	D	4	D	2	B	2	B	4	D	3	A	3	B	4	C	3	C	2	F	3
298	3	2	4	4	A	3	A	4	D	2	B	2	D	4	A	4	A	4	A	3	D	3	C	3
299	1	1	1	1	A	3	A	4	A	4	B	3	D	2	A	2	A	2	A	2	C	2	C	3
300	3	3	4	4	A	3	A	3	D	2	B	2	D	3	A	3	D	3	F	3	A	3	B	3
301	4	4	3	3	A	3	A	3	B	2	B	4	D	4	A	4	B	5	C	5	C	3	C	3
302	3	4	3	3	B	1	B	2	B	2	B	2	D	1	A	1	B	3	A	3	C	1	D	1
303	3	3	2	4	A	1	A	1	D	1	B	1	D	1	B	1	D	4	F	4	C	3	B	2
304	3	2	2	3	C	2	B	2	B	3	B	3	A	4	A	4	B	4	C	4	C	3	B	3
305					C	2	B	2									B	4	E	4	C	3	B	3
306	4	4	3	4	A	3	A	4	D	2	B	2	D	3	A	3	B	4	C	5	C	5	B	4

307	4	4	3	3	A	3	A	3	D	2	B	2					B	4	C	4	C	2	B	2
308	3	2	2	2	A	2	A	1	B	1							D	2	F	2	C	1	B	1
309	4	2	3	3	A	3	A	2	B	2	B	2	D	3	A	1	B	4	C	4	C	2	A	2
310	4	3	3	3	B	3	C	3	C	2	B	2	D	2	A	2	D	2	F	2	C	3	A	2
311	4				B	3	C	2	B	2	B	2	D	3	A	4	B	4	C	5	C	3	B	3
312	4	3	3	3	D	5	D	5	A	3	B	3	C	2	B	1	B	3	C	3	C	2	B	2
313	2	3	3	3	B	4	C	3	C	1	C	2	A	3	C	1	B	2	C	3	C	2	B	2
314	3	4	3	4	A	3	A	3	B	3	B	4	D	4	A	4	C	2	B	2	C	3	A	1
315	3	3	3	3	A	2	A	4																
316	2	2	3	3	B	2	C	2	B	1	B	4	D	4	A	4	B	3	C	4	A	1	B	1
317	2	3	3	3	C	3	C	3	B	1	B	2	D	2	A	2	D	3	F	2	C	3	F	2
318	4	3	3	3	D	1	D	4	D	2	B	2	A	2	C	2	B	3	A	3	C	3	B	2
319	3	2	2	2					D	1			C	1			B	2	A	2	B	1	D	1
320	3	3	3	4	A	2	A	3	B	1	B	1	A	2	B	2	B	2	F	2	C	2	B	2
321	3	4	3	3	A	2	A	2	C	2	C	2	D	2	A	2	B	3	C	3	C	3	B	3
322	3	4	4	4	A	3	A	3	A	3	B	4	D	4	A	4	A	4	F	3	A	4	B	4
323	2	3	3	3	C	2	C	2	D	1	B	3	D	4	A	4	B	4	C	4	C	2	C	2
324	2	3	3	3	B	1	C	1	A	1	B	1	B	1	C	1	B	3	C	2	A	3	E	2
325	3	4	3	4	A	4	A	3	B	4	B	4	D	4	A	4	B	3	C	4	D	2	D	2
326	4	3	3	3	D	3	C	3	D	1	C	1	D	3	A	3	D	1	B	3	A	3	C	2
327	3	3	3	3	C	3	B	3	C	3	B	3	D	3	A	2	D	3	F	3	D	2	A	2
328	4	3	2	3	A	3	A	3	B	3	B	4	D	3	A	4	B	5	C	4	C	4	B	4
329	3	4	3	2	A	3	A	5					D	4	A	3	B	4	C	5	C	4	F	5
330	3	2	3	3	B	3	C	3	B	2	B	2	D	4	A	3	A	2	C	2	C	2	B	2
331	3	2	3	4	C	1	C	2	B	1	B	2	D	1	A	2	A	2	A	3	C	1	B	2
332	2	2	2	2	A	2	A	1	A	1	B	1	D	2	A	3	B	3	C	2	C	2	B	2
333	2	1	3	2	C	1	B	1	A	2	A	1	D	1	A	2	B	2	C	2	C	2	A	1
334	3	3	4	4	A	4	C	3	B	2	B	4	A	5	A	1	B	4	C	4	C	4	A	3
335	4	3	4	3	C	4	B	4	B	2	B	2	D	3	A	3	B	5	C	4	A	3	B	1

Student	GC				Question																			
	1	2	3	4	11				12				13				14				15			
					A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)
					C		D		C		D		D		B		D		C		C		A	
1	4	3	3	4	C	4	D	1	C	3	D	2	D	3	B	2	D	3	C	4	C	4	A	4
2	4	3	3	5	B	1	B	1	A	4	D	3	C	5	A	4	B	5	E	5	B	3	B	3
3	4	3	4	3	A	5	B	4	B	2	D	2	A	5	D	5	B	3	E	4	C	5	A	5
4	4	4	3	3	B	4	B	4	B	4	A	2	A	3	D	4	D	4	A	4	B	2	A	3
5	4	3	3	4	B	3	B	3	A	4	B	3	C	3	C	3	D	4	B	4	C	5	A	4
6	4	3	3	3	B	4	B	3	C	5	D	3	A	4	C	3	D	4	C	4	C	4	A	5
7	5	4	5	3	B	5	C	4	C	2	B	1	B	3	C	4	C	4	C	3	C	5	A	5
8	4	3	5	4	A	4	A	4	A	5	A	5	A	4	A	2	D	5	C	5	C	5	A	5
9	5	4	4	4	B	5	A	4	C	4	B	2	A	4	A	5	D	5	C	4	D	3	A	3
10	5	3	4	4	B	3	A	4	B	3	A	3	A	3	C	4	D	1	B	4	C	1	C	3
11	4	3	4	4	C	4	A	2	C	4	D	3	B	1	D	4	D	4	C	5	B	3	C	4
12	5	4	5	4	B	4	A	3	B	3	B	4	C	3	C	2	D	4	B	3	C	2	C	2
13	3	2	3	4	B	5	B	4	C	1	D	1	A	3	A	3	B	4	D	4	C	5	A	4
14	4	2	4	3	B	4	B	2	B	4	A	4	D	4	C	3	D	3	B	2	C	3	A	1
15	2	3	3	3	B	2	A	1	D	1			A	1	A	1	B	1	D	1	A	3	D	3
16	4	4	3	4	B	5	B	4	A	3	C	2	A	4	C	4	D	5	C	4	B	2	C	3
17	4	4	4	4	B	4	A	3	B	3	A	3	D	3	B	3	D	3	C	3	B	3	C	3
18	4	2	4	3	B	5	B	4	B	2	C	2	A	5	D	3	C	5	C	3	B	3	A	2
19	4	3	4	4	B	1	B	1	B	1	B	1	A	1	B	1	C	1	A	1	C	3	B	1
20	3	2	4	4	B	4	B	3	B	1	C	1	A	3	A	2	D	3	B	3	D	2	C	3
21	3	3	3	4	D	1	C	2	A	2	C	1	D	5	B	2	D	4	A	3	A	2	A	1
22					B	2	B	2	A	3	C	3	A	5	C	4	C	3	D	5	B	4	B	4
23					B	2	B	2	A	3	C	3	A	5	C	4	C	3	D	5	B	4	B	4
24							B	3	B	5	A	5	C	4	A	3	C	5	C	4	D	4	B	4
25	4	2	3	3	A	5	A	3	A	3	D	4	A	3	C	2	D	5	C	3	B	5	D	3
26	4	3	3	3	B	4	A	3	C	2	A	2	A	3	C	3	D	3	C	2	C	3	A	3
27	4	4	3	5	A	5	B	5	A	4	A	4	A	3	A	3	C	4	C	4	C	5	A	5
28	4	4	3	3	C	4	B	3	C	5	D	4	C	4	D	4	B	4	A	3	C	4	A	4
29	3	4	3	3	D	5	B	4	A	3	A	4	A	5	A	5	D	4	C	4	C	4	A	4
30	3	3	3	4	D	3	B	3	A	5	A	3	A	3	A	3	D	5	C	3	C	3	A	3
31	4	2	3	3	B	4	A	4	A	3	A	3	D	4	B	3	D	4	C	3	C	3	A	3
32	5	3	3	3	A	5	A	4	C	3	D	3	C	3	C	3	C	5	B	3	B	3	C	3
33	4	3	4	4	C	4	B	5	A	5	A	4	A	4	A	4	C	4	C	4	C	5	A	4
34	4	5	4	4	A	4	B	5	A	4	A	5	A	4	A	4	C	5	C	4	C	5	A	4
35	4	3	3	3	A	5	D	3	C	5	D	5	D	5	B	5	D	5	C	4	C	5	A	5
36	2	4	4	4	B	5	B	5	B	5	D	5	A	5	D	5	D	5	E	5	C	5	A	5
37	5	2	3	4	B	4	B	3	A	3	D	4	A	3	C	4	B	3	E	3	C	4	A	4
38	2	3	4	4	B	3	B	3	C	1	A	2	B	3	C	2	D	5	B	3	B	5	D	5
39	4	3	4	2	B	4	B	4	A	3	A	1	B	4	B	2	D	4	B	2	C	4	D	3
40	4	3	3	4	B	3	A	3	C	3	D	4	D	4	B	3	D	5	C	2	C	4	A	2
41	4	3	2	4	B	5	A	4	B	3	D	4	B	4	C	3	D	4	C	5	C	5	A	5
42	4	3	4	4	B	4	A	4	C	4	D	4	A	4	D	4	D	4	B	4	C	4	A	4
43	4	3	3	2	B	5	B	5	C	5	D	4	C	3	D	3	C	4	B	4	C	4	C	4
44	5	2	4	3	A	5	A	3	B	3	D	3	B	5	C	4	D	4	C	5	C	5	C	5
45	3	3	3	3	B	3	B	3	B	4	D	3	C	4	C	3	B	4	D	3	B	3	C	3
46	5	3	3	3	B	4	A	4	C	5	D	3	A	5	C	4	D	3			C	4	A	3
47	3	3	2	4	B	3	B	3	A	4	D	4	A	2	A	3	C	4	B	2	C	3	B	3
48	5	3	3	2	C	3	A	4	C	4	B	4	A	3	C	3	D	5	C	5	A	5	C	4
49	3	3	3	3	B	3	B	3	C	3	D	4	A	3	B	3	D	5	C	4	C	4	A	3
50	4	3	4	4	C	2	D	2	C	3	A	3	D	3	B	3	D	3	C	3	B	2	B	2
51	2	3	4	5	B	3	A	3	C	3	D	3	C	4	C	3	D	4	C	4	C	4	A	3
52	5	4	2	3	C	5	C	1	B	3	A	5	A	4	D	4	D	5	C	5	C	3	B	4
53	3	2	3	3	A	3	A	3	C	3	D	3	B	3	B	3	C	3	E	3	B	3	D	3

54	4	3	3	3	A	4	B	3	C	4	D	4	D	4	B	5	D	5	C	5	C	5	A	5
55	4	2	3	3	B	4	D	5	A	5	B	5	A	4	C	4	C	2	C	2	B	4	D	4
56	4	4	3	4	B	5	A	3	B	5	B	3	A	5	B	5	B	5	B	4	B	5	B	3
57	5	4	4	4	C	5	B	4	B	5	D	2	A	4	A	5	B	5	F	3	B	5	A	5
58	2	3	3	2	B	2	C	2	A	2	A	2	D	4	D	3	C	2	D	2	C	3	D	2
59	3	2	3	3	B	3	C	3	B	2	C	1	C	2	B	2	D	3	C	3	C	4	A	4
60	4	2	3	4	B	4	A	1	A	1	B	2	A	2	C	2	C	2	E	1	D	3	D	3
61	3	3	2	2	C	3	D	3	B	4	C	3	B	3	D	2	A	4	F	2	A	4	B	3
62	5	2	4	5	B	4	A	4	C	1	B	1	A	2	C	2	B	3	C	3	B	3	A	3
63	4	4	4	4	A	4	C	3	B	3	D	3	A	5	C	3	D	5	E	4	D	4	A	3
64	4	4	5	4	B	3	D	5	B	4	D	3	A	3	C	4	B	3	C	3	B	3	B	1
65	3	2	3	4	A	5	A	4	C	2	A	1	A	2	B	1	D	4	C	3	B	5	A	5
66	4	4	4	4	B	5	B	5	C	5			B	4	B	5	D	5	C	4	A	4	B	4
67	4	3	4	4	C	4	C	4	C	4	D	3	A	5	C	5	C	4	C	5	D	4		
68	4	3	3	4	C	5	B	5	B	5			A	5	C	5	B	4	E	3	D	3	B	2
69	4	4	4	3	B	5	A	4	C	4	C	3	A	5	C	5	D	4	C	4	A	2	B	3
70	5	5	5	4	C	3	B	3	B	3	C	4	D	3	B	3	D	4	D	4	C	4	C	4
71	4	3	4	2	B	5	B	4					D	5	B	4	B	5	D	4	B	5	D	5
72	5	5	4	4	C	1	D	2	A	3	B	3	A	4	A	4	B	3	E	4	A	4	A	3
73	4	4	4	3	A	4	A	3	B	4	A	4	A	5	C	5	C	5	B	5	A	5	C	5
74	4	3	4	3	B	3	B	3	B	3	C	2	A	4	C	3	C	3	C	3	B	2	D	2
75	4	3	5	5					B	5	D	5	A	4	C	4	B	5	E	4				
76	4	3	3	3	C	3							A	5	C	4	D	5	B	4	B	5	C	4
77	4	3	3	3	A	5	A	3	C	1	D	1	A	3	C	3	D	5	B	4	B	4	C	4
78	3	4	5	4	A	3	C	2	B	5	C	3	D	5	C	5	C	3	D	3	B	2	C	5
79	5	3	4	4	C	4	D	4	B	4	D	4	C	4	C	4	A	4	D	4	A	4	C	4
80					B	3	C	2	B	1	A	1	C	4	C	4	B	3	E	3	C	1	B	1
81	5	3	3	4	B	4	B	3	B	3	C	2	A	4	C	4	B	4	F	3	C	4	B	3
82	3	2	3	3	A	3	C	3	C	3	B	3	B	3	C	4	A	1	B	3	B	3	C	2
83	4	5	3	3	B	1	B	2	B	1	B	1	B	4	C	2	D	1	B	3	C	2	A	4
84	4	3	3	3	B	2	A	1	C	3	D	2	A	4	A	3	C	4	B	3	A	1	A	1
85	4	3	3	4	A	5	A	4	B	1	C	4	A	1	C	2	C	4	B	3	A	2	A	1
86	5	2	5	3	C	5	A	5	B	5	A	3	A	5	C	5	A	4	E	4	D	5	D	5
87	5	4	4	4	A	4	B	3	A	4	D	2	C	4	B	2	D	5	C	3	C	5	C	3
88	4	3	3	3	D	3	A	3	A	3	A	4	A	4	C	4	C	5	C	4	B	3	C	4
89	5	2	2	2	B	4	D	3	A	3	A	3	A	3			A	4	D	4	C	4	A	2
90	5	5	4	4	C	2	B	3	B	3	C	3	D	4	B	4	D	5	D	4	C	3	C	3
91	4	4	3	3	B	4	A	3	C	2	D	3	D	5	B	5	B	4	E	1	C	2	A	2
92	3	3	3	3	C	3	D	3					A	2	A	2	D	2	D	2	C	1	D	1
93	3	3	3	3	C	3	D	3	B	3	A	3	A	3	C	3	C	3	B	3	C	3	A	3
94	3	3	3	3	D	1	A	1	C	1	D	1	A	3	C	3	D	4	C	4	B	3	D	2
95	3	3	3	3	B	2	A	1	A	4	A	1	A	5	C	3	D	5	C	3	B	2	A	1
96	5	5	4	4	B	5			B	2	B	2	A	5	D	5	D	5	B	5				
97	3	2	3	3	C	2	D	2	D	2	C	2	A	3	C	3	B	2	E	4	A	4	B	3
98	3	3	2	3	C	2	B	3	A	3	C	2	A	4	C	3	C	3	D	3	B	1	C	1
99	3	4	3	3	B	2	B	2	A	4	C	4	B	4	C	4	C	3	D	5	B	5	A	4
100	5	5	4	4	A	5			A	5	A	4	A	5	C	5	D	5	C	4			B	4
101	3	2	3	3	C	3	A	2	B	3	B	1	A	3	C	3	B	3	C	3	B	3	C	2
102	5	3	4	3	A	2			A	4	A	3	A	5	C	4	D	5	C	4	B	4	B	4
103	4				B	5			A	4			A	5			D	5			C	2		
104	4	2	2	2	A	3	C	3	A	3	D	3	A	2	C	3	B	1	B	1	D	3	A	3
105	4	3	3	3	B	5	A	3	A	3	D	2	C	3	B	3	B	4	E	2	D	2	D	3
106	4	2	4	4	B	5	B	5	C	3	D	3	D	5	B	5	B	4	E	3	B	4	D	3
107	4	3	3	4	C	2	B	2	A	3	D	3	C	4	D	3	B	1	E	1	D	1	D	1
108	4	3	3	5	B	3	B	3	A	2	D	3	D	4	A	4	C	3	B	4	B	5	C	5
109	5	3	4	3	A	2			A	4	A	3	A	5	C	5	D	5	C	4	B	4	B	4
110	3	3	3	3	B	2	B	2	A	3	C	3	A	5	C	4	C	3	D	5	B	4	B	4

111	3	3	4	3	B	3	B	3	A	3	C	4	A	5	C	4	D	3	B	3	B	3	B	3
112	5	3	4	3	B	2	B	2	A	3	C	3	A	5	C	4	C	3	D	5	B	4	B	4
113	3	3	3	3	B	2	B	2	A	3	C	3	A	5	C	4	C	3	D	5	B	4	B	4
114	4	3	2	3	B	2	B	2	A	3	C	3	A	5	C	4	C	3	D	5	B	4	B	4
115	3	3	2	3	A	3	A	3	B	3	C	1	D	4	B	4	D	5	B	5	B	5	C	5
116	4	5	4	4									D	5	B	4	D	5	B	4	C	5	A	5
117	4	4	4	5	B	4	B	3	C	3	D	3	A	5	C	4	D	5	B	3	C	5	A	5
118	2	2	2	3	B	3	B	3	C	2	C	2	A	3	A	3	B	2	B	2	B	4	B	4
119	4	3	4	4	A	4	A	3	B	4	D	3	A	4	C	4	B	3	C	2	D	2	A	2
120	4	2	4	5	B	3	B	3	B	2	D	2	B	4	D	2	D	4	B	2	A	4	C	4
121	4	3	4	5	C	3	B	3	C	4	D	3	A	3	B	3	C	3	C	3	B	2	C	3
122	4	3	3	3	B	3	B	3	C	3	D	2	A	5	C	4	D	5	D	3	B	5	C	4
123	4	3	3	3	B	2	C	1	B	2	B	2	A	4	B	3	D	2	C	1	C	2	C	1
124	4	2	5	5	B	3	B	3	B	3	D	4	B	4	D	4	D	4	C	4	B	3	B	3
125	5	4	4	4	B	5	C	3	B	4	B	3	D	5	B	5	D	5	B	4	C	5	A	5
126	4	3	3	3	B	3	D	4	B	3	A	3	D	4	D	3	D	4	D	3	B	3	D	3
127	4	3	3	3	B	3	D	4	B	4	A	3	D	4	B	3	D	4	D	3	B	3	D	3
128	4	4	4	3	A	4	D	5	B	5	A	4	D	5	B	5	D	5	B	5	C	2	D	4
129	4	5	4	3	C	2	B	3	B	5	B	2	D	4	B	5	D	3	B	5	C	4	A	3
130	4	3	4	4	C	2	B	3	A	2	D	3	A	2	C	3	D	4	C	3	B	4	A	4
131	4	3	4	4	A	3	D	3	B	5	A	4	D	5	B	5	D	5	B	3	C	3	D	3
132	4	4	3	4	B	5	B	5	B	4	A	3	D	5	B	5	D	5	B	5	B	3	D	3
133	3	3	4	4	C	4	C	2	B	5	D	5	D	2	D	2	D	4	D	3	B	2	D	2
134	3	4	3	3	C	2			B	5	C	2	C	4	B	3	B	5	D	2	D	5		
135	4	3	4	3	C	4	B	4	B	3	D	3	D	3	B	4	D	2	B	3	B	3	D	3
136	3	3	3	3	C	4	B	3	B	4	D	3	D	4	B	4	D	3	B	4	B	3	D	3
137	4	3	3	3	B	3	D	3	B	2	A	3	A	3	D	3	C	2	C	1	C	4	D	3
138	4	3	4	3	B	5	B	3	B	5	A	4	A	5	A	2	A	5	C	3	B	4	D	3
139	5	5	5	5	A	5	A	5	B	4	C	3	B	5	A	4	D	5	C	5	C	5	A	5
140	5	3	3	4	A	4	A	5	C	4	D	5	A	4	C	4	B	3	C	5	C	5	D	4
141	4	3	4	4	B	4	B	4	B	3	A	3	A	5	A	4	C	5	D	3	B	4	D	2
142	4	4	3	3	C	3	B	3	B	3	C	2	D	4	D	3	D	5	D	3	B	3	D	3
143	4	3	3	3	C	3	B	3	B	4	D	2	D	3	B	4	D	4	B	4	B	3	D	3
144									B	5	C	3	D	5	B	5	D	5	B	5	B	4	C	4
145					D	2	A	1	B	5	C	4	D	4	B	5	D	3	B	5	B	4	D	4
146	4	4	5	4	B	3	B	2	B	5	B	2	D	5	B	3	D	5	C	3	C	3	D	3
147	4	4	3	4	B	3	B	3	B	4	B	4	A	4	A	4	D	4	B	4	A	4	C	3
148	4	2	5	5	B	5	C	5	A	5	B	2	B	2	C	2	C	4	C	4	B	5	A	5
149	5	4	4	4	A	3	D	3	B	5	A	1	D	5	B	4	D	4	B	5	B	5	D	5
150	5	4	4	4	A	5	D	4	B	5	A	4	D	5	B	5	D	5	B	5	B	4	D	4
151	5	3	5	5	B	5	B	5	B	5	A	4	B	5	C	5	D	5	C	5	C	4	A	5
152	4	2	3	3	C	3	C	3	C	3	C	3	B	5	D	5	D	3	D	3	D	4	C	4
153	5	4	4	5	A	5	A	5	C	3	D	4	D	3	B	4	C	5	B	5	C	4	A	5
154	4	2	2	3	A	5	B	3	B	5	D	3	D	2	D	2	B	3	E	2	A	4	A	4
155	4	3	4	3	B	3	B	2	B	4	B	3	A	4	C	4	C	3	D	2	A	2	C	2
156	3	3	2	2	A	2	B	2	D	2	C	3	A	2	C	2	D	3	D	3	B	2	B	2
157	5	4	5	5	C	4	A	2	B	2	D	2	B	5	D	5	A	5	B	2	B	2	B	2
158	4	3	3	2	A	5			C	5			C	4			C	2			B	3		
159	5	3	3	3	B	1	C	1	B	3	A	2	C	3	B	2	C	2	D	3	D	5	A	3

160	4	3	4	3	A	3	B	3	D	2	C	3	A	3	A	3	C	4	B	2	B	3	C	4
161	3	3	3	3	A	1	B	1	A	1	B	1	A	1	B	4	A	1	B	1	A	1	B	1
162	4	3	4	3	C	3	B	2	B	5	A	3	A	4	A	4	C	2	C	2	D	5	D	4
163	5	3	3	4	B	5	B	4	C	3	B	2	A	5	B	4	C	5	A	3	D	3	C	2
164	5	4	4	4	B	5	A	4	B	3	D	3	C	4	C	5	B	3	E	4	C	3	B	4
165	4	3	3	3	B	4	B	4	C	3	C	3	C	4	B	3	C	2	C	3	C	4	B	2
166	5	4	5	5	C	4	B	4	A	4	B	3	B	4	A	4	C	5	D	4			D	5
167	5	4	2	2	B	2	C	3	C	2	B	2	A	5	B	3	D	5	B	5	B	5	D	5
168					B	3	D	3	C	3	B	3	A	4	C	4	B	4	E	4	D	3	D	3
169	4	4	5	4	A	5	C	4	A	5	A	4	A	5	C	4	A	3	B	3	B	2	D	3
170	5	1	3	4	B	5	A	3	B	1	D	3	C	3	C	2	C	5	C	5	B	4	C	5
171	5	4	5	5	D	3	C	4	A	4	B	3	D	5	B	5	D	5	B	4	B	4	C	4
172	4	4	5	5	A	4	B	4	A	4	D	4	A	3	A	3	D	4	C	3	A	3	B	3
173	5	4	5	4	C	2	C	2	B	3	B	4	B	5	C	5	D	2	B	2	B	4	A	4
174	5	3	4	5	B	5	C	3	B	5	B	4	A	5	C	5	A	5	D	4	D	5	C	3
175					C	3	C	3	B	3	D	2	B	3	C	3	D	4	F	3	B	3	B	2
176	3	3	2	4	A	5	B	5	B	4	B	4	A	3	C	4	B	2	D	4	A	3	A	4
177	5	4	2	5	B	5	B	2	C	5	D	2	A	5	C	4	C	5	C	5	D	1	A	1
178	4	4	2	4	B	5	A	4	C	3	A	3	A	5	C	4	C	5	D	4	D	3	B	3
179	5	4	4	4	B	4	A	3	C	4	D	3	B	4	C	4	D	4	B	3	C	2	D	2
180	5	4	3	4	B	2	A	2	B	2	C	2	D	1	B	1	C	1	B	1	B	2	C	2
181	5	4	4	3	B	4	B	4	C	2	B	2	C	5	B	5	A	5	A	3	B	2	C	2
182	3	3	2	3	C	2	A	3	D	3	C	2	A	3	C	2	B	3	E	3				
183	4	3	5	4	B	3	C	3	C	4	D	3	C	3	A	4	C	3	C	3	D	4	A	3
184	4	4	4	5	C	3	B	4	B	4	A	5	B	5	D	5	B	5	A	5	D	4	C	4
185	4	3	4	4	A	4	A	2	B	3	C	2	B	4	D	3	A	4	D	3	B	5	C	5
186	4	4	3	3	B	5	A	5	C	3	C	3	B	4	B	4	A	3	B	3	B	4	C	3
187	5	3	3	4	B	5	B	1	B	3	B	2	B	5	C	5	C	4	C	4	B	5	A	3
188	3	3			A	5			B	5			A	2			A	3			C	2		
189					A	5			B	4			A	3			D	5			B	2		
190					B	1	A	2	B	2			B	1	C	1								
191	4	5	4	4	C	4	D	4	D	2	C	2	B	1	C	2	C	4	D	4	D	2	B	2
192	4	5	4	4	C	4	D	4	D	2	C	1	B	1	C	2	C	4	D	4	D	2	B	2
193					A	1	B	1	B	1	D	1	A	1	C	1	B	3	E	1	A	1	C	1
194	4	4	3	4	C	3	B	3	B	4			A	1	A	2	B	1	D	2				
195	4	2	3	3	B	3	B	3	B	4			A	3	A	3	B	3	F	3				
196	4	4	3	3	B	3	B	3	A	1	C	1	A	2	D	2	D	1	C	1	C	2	D	2
197	4	2	3	3	B	3	B	3	B	3	A	3	A	3	A	3	D	3	C	3	A	3	D	3
198	4	2	3	3			C	4	C	1	C	3	A	2	B	2	A	3	D	3	A	3	C	4
199	2	2	3	3	B	1	B	2	D	5	D	4	A	3	A	2	A	1	D	1	B	3	C	3
200					B	4	B	4	B	5	B	4	B	5	C	5	A	3	E	3	D	4	B	1
201	4	4	4	4	A	2	B	4	C	5	C	2	A	4	C	4	C	5	D	1	B	4	B	2
202	3	2	3	3	B	3	B	3	B	1			A	3	A	3	B	3	E	3	B	3	C	2
203	3	2	4	3	B	3	D	2	B	3	A	3	A	3	A	3	B	2	C	1	B	3	C	2
204	5	3	3	3	B	3	B	3	B	3	D	3	D	3	B	3								
205	4	3	3	3	B	3	B	3	B	3	D	3	A	3	B	3	B	3	A	3	A	3	D	3
206	3	3	3	3	C	3	B	3	B	3	B	2	D	3	C	2	A	3	C	3	A	2	C	2
207					B	4	B	5	B	5	B	4	B	5	C	5	A	4	E	4	D	5	B	1
208					C	2	C	4	C	3	B	5	B	3	B	4	B	4	C	3	C	4	B	2

209	2	4	4	4	B	1	D	2	C	4	B	3	B	3	C	4	C	4	B	4	C	3	C	1
210					B	1	B	1	A	4			B	2	B	2	A	1	B	1	C	1	B	1
211					A	2	B	1	B	4	C	2	A	2	C	2	C	3	B	2	D	1	A	1
212	3	2	4	2	A	4	B	3	C	3	B	2	C	3	C	3	B	5	D	2	C	1	D	2
213					B	4			A	3			A	3			D	4	C	4	D	3		
214	5	4	4	4	A	4	B	3	C	3	B	3	A	3	C	3	A	3	F	3	C	2	C	2
215	3	2	3	2	B	5	C	4	C	5	B	3	C	3	A	2	A	4	E	3	D	3	B	3
216	3	3	4	5	A	3	A	1	B	3	D	1	A	3	B	1	D	1	A	1	A	5	D	3
217	5	3	3	3					B	4	B	3	B	3	C	3								
218	4	4	4	4	B	3	B	2	A	2	A	2	A	3	C	3	C	2	E	4	D	2	D	3
219	2	3	2	2	A	1	A	1	C	2	C	2	B	2	D	2	B	3	C	2	B	1	B	1
220	5	4	3	3	C	3	B	3	A	3	B	2	C	2	A	4	C	4	C	2				
221	3	3	4	4	C	4			B	4			B	3			C	3	F	2	D	3	C	4
222					B	4	B	2	B	5	D	3	B	3	C	2								
223					B	3	B	1	B	5	A	3	D	4	D	3	A	2	D	3	C	1	D	3
224					B	5	B	5	B	5	D	5	A	5	C	5	A	2	C	2	C	2	D	2
225					C	4			C	4							B	4			B	3		
226					B	3	C	2	B	5	A	4	C	3	A	4	C	3	B	3	C	3	B	3
227					B	4	D	2	C	4	A	2	B	2	D	3	C	3	D	2	D	4	C	2
228					C	4	C	3	C	3	A	3	B	4	C	3	B	4	E	3	B	3	B	3
229	4	2	3	4	A	1	C	1	B	1	C	1	B	1	C	1								
230	4	3	3	3	B	2	C	2	B	3	D	3	A	2			D	2	E	2	D	2	C	2
231	4	4	2	3	B	3	C	4	B	1	C	4	A	3	C	3	C	2	E	4	D	2	D	3
232	5	4	5	3	C	2	C	2	C	3	C	3	B	3	B	3	B	3	C	3	D	3	B	3
233	4	4	3	5	C	4	B	4	B	4	C	4	B	4	B	5	C	1	C	4	B	1	B	4
234	3	3	3	3	D	4	D	3	B	2	B	1	D	1	D	2	C	2	E	2	D	3	B	3
235					C	3	D	2	B	5	C	4	B	2	C	2	A	5	A	4	B	4	C	4
236					C	3	A	3	B	3	D	3	B	3	C	3	C	3	C	3	C	3	D	3
237	2	3	3	4	B	2	B	2	A	1	C	1	D	2	B	3	B	2			C	2	C	3
238	4	4	4	3	B	5	B	5	B	5	B	3	B	4	C	4	B	4	C	3	C	4	B	2
239	4	2	2	2	C	4			A	2														
240	2	3	3	2	A	2	B	3	B	5	B	4	A	1	C	2	A	5	A	2	D	1	C	3
241	2	3	4	2	D	3	C	2	C	2	A	2	B	3	A	2	C	3	C	3	A	1	C	1
242	4	3	3	4	B	4							A	3	B	2								
243	3	1	3	1	B	1	B	1	B	1	D	2												
244	1	1	1	1	A	1	D	1	B	1	D	1	A	1	D	1	C	1	D	1	A	1	B	1
245	4	3	3	3	A	4	B	4	B	4							A	1						
246	4	3	5	4	C	4	B	4	C	4	B	3	A	3	B	3	C	2	B	2	C	3	C	4
247	5	4	2	3	A	5	B	3	B	5	C	4	A	3	D	2	A	4	F	3	D	5	A	4
248	2	2	3	4					C	3	B	5	B	2	A	4								
249	5	3	2	1	D	4	B	2	B	3	D	2	C	3	B	2	A	4			B	2	A	2
250									C	2	B	4	B	4	B	5	A	1	E	5	C	2	B	3
251					B	2	D	5	C	2	B	4	A	3	D	5	C	2	D	2	A	1	A	1
252	3	2	3	1	B	2	B	2	B	3	A	2	B	1	D	3	D	2	B	2	B	4	A	1
253	4	3	4	4	B	4	A	3	A	3	A	4	A	1	D	1	D	4	C	3	C	3	A	4
254	2	4	1	3	B	4	A	2	A	2	A	3	B	3	C	3	D	4	B	2	D	2	A	4
255	3	3	3	3	B	3	B	3	A	2	A	2	D	3	B	2	D	3	B	3	C	2	A	2
256	3	3	3	3					A	2	D	2	C	3			D	5	C	3	C	4	A	5
257	2	5	5	3	B	4	B	4	B	2	A	5	D	4	B	4	D	5	C	4	C	5	A	5

258	3	3	3	3	C	2	D	2	A	2	A	1	D	2	D	2	D	4	C	4	C	4	A	4
259	4	4	4	3	B	3	C	3	B	4	A	4	C	3	C	3	D	4	B	3	D	3	A	4
260	4	4	4	4									D	4	B	3	D	4	C	5	C	5	A	5
261	3	2	3	3	B	4	A	3	B	3	D	2	D	3	B	3	C	2	C	3	C	3	A	4
262	3	3	2	4	C	3	D	2	A	4	A	1	B	4	D	1	D	4	B	4	C	4	A	4
263	4	4	3	4	A	2	A	2	A	1	A	1	C	3	D	1	C	4	C	3	C	4	A	4
264	1	2	2	2	B	3	B	2	A	2	A	3	D	2	B	2	D	4	C	3	C	3	A	3
265	3	4	3	4	A	4	A	4	A	3	A	5	D	3	B	3	D	4	B	3	C	5	A	5
266	3	3	3	3	A	3	A	3	A	4	A	1	A	1	A	1	A	4	B	1	B	3	D	3
267	3	2	3	3	B	3	A	2	B	2	A	3	C	3	B	2	D	2	B	3	C	3	A	3
268	4	3	3	3	A	5	A	3	A	4	A	4	C	4	D	3	D	4	C	4	A	5	A	4
269	3	3	3	3	A	3	A	3	A	4	A	1	A	1	A	1	A	4			B	3	D	3
270	4	3	3	4	A	3	D	3	B	2	A	1	D	3	B	2	D	4	C	2	C	4	A	3
271	4	3	3	3	A	3	A	3	B	3	A	3	C	3	D	2	D	3	B	3	C	5	A	5
272	3	2	3	4	B	3	B	3	D	2	B	2	C	3	B	3	D	4	C	2	A	4	A	4
273	4	3	2	3	A	2	A	2	A	2	A	2					D	3	C	2	C	4	A	4
274	3	3	4	3	C	4	A	4	B	4	A	3	D	1	C	3	B	2	B	3	A	3	C	3
275	3	3	2	3	B	2	B	1	B	1	C	1	B	2	B	2	B	2	C	1	C	4	A	3
276	3	3	2	3	B	1	A	1	B	2	A	2	A	1	A	1	D	3	C	3	C	3	A	3
277	5	3	3	3	B	4	A	4	B	4	A	3	C	3	B	3	D	4	C	4	A	3	A	4
278	4	3	3	3	B	3	A	3	B	4	A	4	C	3	B	3	D	4	C	3	A	2	A	3
279	4	3	2	4	B	4	B	4	A	1	A	2	C	3	D	2	D	3	C	2	C	4	A	5
280	4	3	3	3	B	1	A	2	A	1	A	2	A	1			C	2	C	3	C	4	A	5
281	2	2	2	2	B	2	B	2	A	2	D	1	C	1	D	2	D	2	B	2	C	2	A	3
282	4	3	3	4	D	1	B	3	A	4	A	3	D	4	B	3	D	5	C	5	B	5	A	5
283	3	2	3	3	B	4							D	3	B	3	D	4	C	3	C	4	A	4
284	3	4	4	2	A	3	D	3	A	3	D	3	D	3	B	3	D	4	B	4	C	4	A	4
285	4	3	3	3	C	4	D	3	D	3	A	5	D	3	B	3	C	4	B	1	C	4	A	5
286	5	5	4	4	A	4	A	4	A	5	A	5	B	4	D	4	D	5	C	5	C	5	A	5
287	3	4	3	4	A	2	D	2	A	1	A	1	C	2	D	2	D	3	C	3	C	4	A	3
288	4	4	5	4					B	3	D	2	B	3	D	2								
289	3	2	2	2	B	2	B	2	A	2	A	2	B	2	C	2	D	2	C	2	B	2	A	2
290	3	2	3	4	B	2	A	2	A	3	B	2	D	1	B	2	D	4	B	1	C	5	A	4
291	3	3	3	3	A	3	D	2	B	3	B	1	C	2			C	3	E	2	C	1	C	1
292	3	2	2	3	B	4	A	3	A	2	A	5	D	4	B	2	D	5	C	4	C	5	A	5
293	4	2	4	4	B	2	A	1	B	4	A	4	D	4	B	3	D	4	B	4	C	5	A	5
294	4	2	2	3	A	3	C	2	B	1	C	1	D	3	A	3	D	3	B	3	C	4	A	4
295	3	2	3	4	A	5	D	5	A	1	D	2	C	4	B	4	B	2	C	2	B	1		
296	3	3	3	3	B	3	B	3	B	2	A	3	C	3	B	3	D	4	C	3	C	4	A	4
297	3	3	4	4	A	3	A	3	B	4	A	4	D	3	B	3	C	4	C	1	C	4	A	4
298	3	2	4	4	B	3	A	3	D	3	B	1	B	2	D	2	A	4	D	2	B	3	C	4
299	1	1	1	1	B	2	C	2	B	2	C	2	D	2	B	2	B	3	A	1	B	3	C	3
300	3	3	4	4	C	3	A	3	A	3	A	3	C	4	D	4	D	4	C	4	C	4	A	4
301	4	4	3	3	B	4	B	5	A	2	A	1	C	4	C	4	B	3	C	5	C	5	A	5
302	3	4	3	3	B	1			B	3	A	3	B	2	D	2	B	2	C	1	A	3	A	4
303	3	3	2	4	A	4	A	4	A	4	A	4	D	3	A	3	D	4	C	4	C	5	A	5
304	3	2	2	3	A	3	B	2	D	3	B	3	B	2	D	2	B	2	A	2	C	4	A	4
305											A	1	B	3			D	4	C	4				
306	4	4	3	4	A	4	A	3	B	4			D	4	D	3	D	4	B	4	C	4	A	4

307	4	4	3	3	C	2	A	1	B	3	A	5	D	3	B	3	B	3	B	2	B	2	A	3
308	3	2	2	2	B	1			B	1	A	2	C	1	C	1	D	3	C	2	C	2	A	2
309	4	2	3	3	B	2	B	2	B	3	A	3	D	4	B	3	A	3	B	3	C	4	A	4
310	4	3	3	3	B	3	A	3	B	4	A	4	B	1	B	1	D	4	B	3	A	5	A	5
311	4				A	3	A	3	D	2	A	3	D	4	B	2	A	3	B	2	A	3	A	4
312	4	3	3	3	A	3	A	2	A	3	A	5	A	4	A	3	D	5	C	4	C	3	A	5
313	2	3	3	3	A	3	A	2	A	2	D	2	B	3	D	2	B	3	C	2	C	4	A	3
314	3	4	3	4	C	2	C	3	B	2	D	1	D	2	B	2	B	3	A	3	C	4	A	4
315	3	3	3	3	A	3	A	3	A	3	A	1	D	3	D	3	D	3	C	3	C	4	A	4
316	2	2	3	3	B	4	A	3	A	4	A	3	D	3	B	2	D	4	C	4	C	2	A	3
317	2	3	3	3	A	3	D	2	A	2	A	3	D	2	B	3	C	2	C	3	A	3	A	3
318	4	3	3	3	B	3	B	3	A	3	A	1	D	4	B	4	A	4	C	4	A	4	A	5
319	3	2	2	2	D	1	B	1	A	2	A	3	D	2			A	2	C	3	A	2	A	2
320	3	3	3	4	B	2	A	3	A	5	A	5	D	2	B	1	D	5	C	4	C	3	A	3
321	3	4	3	3	B	3	B	1	B	4	A	1	D	3	A	3	A	4	B	4	C	5	A	5
322	3	4	4	4	C	2	B	2	B	4	A	4	D	4	A	4	D	3	C	3	C	4	A	4
323	2	3	3	3	A	4	A	4	B	2	A	4	D	4	A	3	D	4	B	4	C	5	A	5
324	2	3	3	3	A	3	A	4	A	1	B	1	A	4	A	2	D	4	B	2	C	4	A	5
325	3	4	3	4	A	1	D	1	A	1	D	1	D	3	B	3	A	3	C	3	C	4	A	4
326	4	3	3	3	B	4	B	4	C	3	A	2	D	4	B	2	B	3	C	4	C	5	A	5
327	3	3	3	3	C	1			B	2	A	4	D	4	B	3	D	3	C	3	C	3	A	4
328	4	3	2	3	B	3	B	2	B	2	A	2	D	2	B	3	A	2	B	3	B	2	A	2
329	3	4	3	2	B	2	B	2	A	4	A	5	D	2	B	2	A	3	C	4	C	5	A	5
330	3	2	3	3	B	1	D	1	B	4	A	4	D	3	B	3	A	3	B	4	A	4	A	4
331	3	2	3	4	B	3			B	3	A	3	C	2			A	4	B	4	A	3	A	2
332	2	2	2	2	D	2	A	2	B	2	D	2	C	1			D	2	C	2	C	3	A	3
333	2	1	3	2	A	2	A	1	B	2	D	1	D	2	B	1	D	3	C	2	C	3	A	2
334	3	3	4	4	A	4	A	2	B	4	B	3	A	3	B	2	D	3	B	3	C	3	A	4
335	4	3	4	3	B	4	A	2	B	1	D	1	C	3	B	3	A	3	C	5	C	5	A	5

Student	GC				Question																							
	1	2	3	4	16				17				18				19				20							
					A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)	A	CR(A)	R	CR(R)
					B		D		B		A		D		A		C		C		C		F	
1	4	3	3	4	B	4	D	4	A	3	C	3	D	4	A	3	C	1	B	1	D	5	E	1
2	4	3	3	5		4	C	4	A	3	A	3	A	5	B	4	D	3	A	3	B	3	E	3
3	4	3	4	3	B	3	B	3	D	2	C	3	D	5	C	5	C	4	B	5	A	5	C	3
4	4	4	3	3	B	5	D	5	A	2	C	4	D	2	B	2	B	1	A	1	B	3	E	2
5	4	3	3	4	B	4	B	4	C	4	B	3	D	4	A	4	C	2	A	2	A	5	D	3
6	4	3	3	3	B	5	D	4	A	5	C	4	D	4	A	3	B	1	C	1	A	5	A	4
7	5	4	5	3	B	5	D	5	A	4	C	2	C	3	B	4	C	4	A	3	A	4	C	3
8	4	3	5	4	B	4	D	5	B	5	A	4	A	5	A	4	B	2	B	2	A	1	C	1
9	5	4	4	4	B	5	D	4	A	3	C	2	A	3	B	3	C	5	B	5	A	5	E	4
10	5	3	4	4	D	4	A	5	C	1	C	1	A	3	D	3	B	1	B	5	A	2	E	4
11	4	3	4	4	B	5	D	4	A	5	C	4	D	5	A	5	B	2	B	4	B	3	C	3
12	5	4	5	4	B	4	A	3	D	4	B	3	A	4	A	3	C	2	A	3	B	2	E	2
13	3	2	3	4	B	4	D	5	A	3	C	3	D	3	A	3	B	1	C	1	A	2	D	2
14	4	2	4	3	C	3	C	3	A	2	B	1	A	3	A	4	C	2			B	4	B	4
15	2	3	3	3	B	2	D	3	C	4	C	4	D	3	A	3	C	1	B	1	A	5	D	1
16	4	4	3	4	D	4	C	3	C	3	C	4	D	5	A	3	B	4	A	3	B	5	B	4
17	4	4	4	4	B	3	D	3	D	4	C	4	D	3	A	3	D	3	B	3	A	3	C	3
18	4	2	4	3	A	1	D	1	A	4	C	3	A	2	D	1	B	4	C	3	A	3	D	2
19	4	3	4	4	B	1	A	1	A	3	D	3	A	3	C	2	A	3	C	2	B	1	C	1
20	3	2	4	4	D	1	D	1	D	3	C	3	D	3	C	3	B	1			A	1	D	1
21	3	3	3	4	B	2	C	1	B	2	B	2	C	3	B	2	C	1			B	3	D	2
22					A	4	B	5	A	5	C	5	A	5	D	3	D	4	C	3	C	4	A	4
23					A	4	B	5	A	5	C	5	A	5			D	4	C	3	C	4	A	4
24					B	5	A	5	B	5	A	5	C	3	A	4	D	3	C	4	C	4	A	4
25	4	2	3	3	B	5	A	5	B	5	A	4	D	3	A	2	C	4	B	3	A	3	C	3
26	4	3	3	3	B	3	A	2	A	4	C	3	B	3	D	2	B	2	A	2	D	3	B	3
27	4	4	3	5	B	4	D	4	A	4	C	4	D	4	C	4	A	5	A	5	A	5	C	5
28	4	4	3	3	B	4	D	4	B	5	A	5	D	5	A	5	D	3	C	3	A	5	F	3
29	3	4	3	3	B	5	D	4	B	4	A	4	D	4	C	4	C	4	B	4	A	4	C	1
30	3	3	3	4	B	5	D	4	B	4	A	4	D	5	C	5	C	3	B	3	A	3	C	3
31	4	2	3	3	D	3	D	3	A	4	C	4	D	3	A	2	B	1	C	1	C	4	F	4
32	5	3	3	3	B	3	A	3	B	4	A	3	D	3	A	3	C	3	B	3	A	3	C	3
33	4	3	4	4	B	4	C	3	A	4	C	4	D	4	C	4	A	4	A	4	A	4	B	4
34	4	5	4	4	B	5	D	5	A	4	C	4	D	4	C	4	A	4	A	4	A	4	C	4
35	4	3	3	3	B	5	D	5	B	5	A	5	D	5	A	5	A	2	A	2	A	5	C	2
36	2	4	4	4	B	5	D	5	A	1	C	5	D	5	A	5	B	5	C	5	C	1	F	5
37	5	2	3	4	B	3	D	3	A	4	C	3	A	2	D	2	B	3	B	3	B	4	B	4
38	2	3	4	4	B	5	D	2	A	2	C	1	C	1	B	1	A	1	C	2	A	1	C	2
39	4	3	4	2	A	3	B	1	A	3	B	2	A	3	D	1	C	4	B	3	A	4	D	2
40	4	3	3	4	D	5	D	5	B	3	A	3	D	4	A	4	C	4	B	3	A	5	C	3
41	4	3	2	4	B	5	D	5	C	2	A	2	D	5	A	4	B	4	A	3	A	5	E	5
42	4	3	4	4	D	4	B	4	B	4	A	4	D	4	A	4	C	4	C	4	C	4	F	4
43	4	3	3	2	B	5	D	5	B	5	A	5	D	5	A	4	C	4	C	4	A	4	A	4
44	5	2	4	3	B	5	D	5	B	5	A	4	D	5	A	4	C	4	C	4	C	5	F	5
45	3	3	3	3	C	3	A	3	A	3	C	3	A	3	C	3	A	3	A	3	D	3	D	3
46	5	3	3	3	B	3	D	3	B	2	C	2	C	3	C	2	B	1	C	1	A	3	B	2
47	3	3	2	4	B	4	B	4	B	2	C	2	D	2	C	2	B	2	C	2	D	3	C	3
48	5	3	3	2	D	3	B	3	A	4	B	3	B	3	C	2	B	3	B	2	D	5	D	3
49	3	3	3	3	B	4	D	4	D	2	A	3	D	4	C	3	B	3	A	3	D	4	B	3
50	4	3	4	4	D	3	B	4	A	4	A	4	C	3	A	2	C	2	B	2	B	4	E	4
51	2	3	4	5	B	5	D	5	B	4	A	3	A	4	C	3	B	4	C	3	A	5	E	4
52	5	4	2	3	A	5	D	5	B	5	C	4	A	3	B	3	B	1	A	5	D	5	B	5
53	3	2	3	3	C	3	C	3	A	3	C	3	A	3	A	3	B	3	B	3	A	3	F	3

54	4	3	3	3	B	5	D	5	A	3	C	3	D	5	A	3	C	5	A	4	A	4	D	4
55	4	2	3	3	B	2	D	2	A	3	C	5	A	3	C	5	B	5	B	4	A	3	E	5
56	4	4	3	4	C	5	C	4	C	5	B	5	C	5	C	4	B	5	C	4	C	5	B	5
57	5	4	4	4	C	1	D	1	B	2	C	1	A	3	D	5	C	3	B	2	B	5	E	5
58	2	3	3	2	A	3	D	3	A	2	C	3	C	2	B	3	B	5	A	5	C	3	A	3
59	3	2	3	3	B	4	A	4	D	3	C	3	A	1	D	1	C	1	A	1	B	4	F	3
60	4	2	3	4	D	1	D	1	A	5	C	3	A	1	B	1	B	2	A	2	B	2	D	3
61	3	3	2	2	D	4	B	3	B	3	C	3	A	5	C	4	B	4	B	4	C	3	D	3
62	5	2	4	5	B	4	D	4	C	2	A	3	C	3	C	3	C	4	B	4	A	4	C	3
63	4	4	4	4	A	1	C	1	D	1	C	1	C	2	C	2	A	1	A	1	A	2	C	2
64	4	4	5	4	A	3	B	3	B	4	B	2	B	2	B	3	B	2	B	2	C	3	B	2
65	3	2	3	4	B	4	D	4	B	3	C	2	A	4	D	4	B	4	C	2	C	5	A	3
66	4	4	4	4	D	4	B	4	A	5	C	5	D	5	A	5	D	4	A	4	A	5	C	5
67	4	3	4	4	D	4	D	3	B	3	C	3	A	3	C	4	C	4	C	4	C	4	A	4
68	4	3	3	4	B	3	A	3	A	2	C	2	A	3	C	2	B	1	B	3	D	3	C	2
69	4	4	4	3	D	4	B	3	A	4	C	3	D	4	A	3	D	4	A	3	A	5	C	3
70	5	5	5	4	B	4	D	3	D	3	C	3	C	4	B	4	A	2	C	2	D	3	B	3
71	4	3	4	2	D	3	D	4	A	5	C	5	A	4	D	4	A	1	C	4	D	3	B	3
72	5	5	4	4	D	4	D	3	A	3	A	3	A	5	A	4	B	2	C	3	A	2	B	3
73	4	4	4	3	B	4	D	4	A	3	A	3	A	2	D	2	B	4			B	4	F	4
74	4	3	4	3	B	3	D	3	D	4	C	4	A	2	D	2	C	1	B	1	A	1	F	1
75	4	3	5	5	A	4	A	3	D	3			B	2							A	2	D	2
76	4	3	3	3	B	5	D	5	A	5	C	5									C	5	F	5
77	4	3	3	3	B	4	D	4	B	3	A	3	D	3	A	3	C	4	B	3	A	4	E	3
78	3	4	5	4	B	2	C	2	A	3	B	3	D	3	B	4	D	1	C	3	A	2	B	3
79	5	3	4	4	B	4	B	4	D	4	C	4	D	3	C	3	B	3			B	3	D	3
80					B	2	D	2	B	3	C	3	A	4	D	4	A	1			A	3	C	3
81	5	3	3	4	B	3	D	3	C	4	A	4	D	3	C	3	A	2	A	2	A	2	B	2
82	3	2	3	3	B	4			C	3	B	3	B	3	D	3	B	2	B	3	A	3	D	3
83	4	5	3	3	B	3	D	4	D	1	B	4	C	2	B	2	B	1	B	4	A	2	D	1
84	4	3	3	3	B	4	D	3	A	4	C	3	B	2	C	2	D	2	B	2	A	4	E	3
85	4	3	3	4	D	3	D	2	D	2	C	1	A	2	D	2	C	1	A	1	A	3	D	2
86	5	2	5	3					D	4	C	4	D	3	C	3	D	3	B	3	B	2	A	2
87	5	4	4	4	B	3	D	3	B	3	A	3	D	2	C	3	B	3	C	2	A	2	C	2
88	4	3	3	3	B	4	D	4	B	4	A	4	D	4	A	4	C	3	A	4	A	3	C	3
89	5	2	2	2	B	4	D	4	A	4	C	2	D	1	C	1	B	4			B	3	C	2
90	5	5	4	4	B	3	D	3	D	2	C	2	C	3	B	3	A	2	B	2	D	3	C	3
91	4	4	3	3	C	3	B	2	D	3	C	3	A	2	B	3	C	1	B	2	B	4	C	2
92	3	3	3	3	C	1	C	1	C	2	C	2	C	2	C	2	B	1	A	1	B	1	C	1
93	3	3	3	3	D	3	A	3	A	3	C	3	A	3	C	3	A	3	B	3	A	3	D	3
94	3	3	3	3	B	2	D	1	A	3	C	1	A	1	A	1	C	1	C	1	B	1	F	1
95	3	3	3	3	B	3	D	3	B	2	A	2	D	2	A	2	B	1	B	1	B	1	B	1
96	5	5	4	4	B	5	A	1	A	5	A	1	C	5	D	1	B	5	A	5	C	1	F	1
97	3	2	3	3	D	3	B	3	A	3	C	2	C	4	B	3	B	4	C	4	D	4	C	4
98	3	3	2	3	D	2	C	2	B	3	C	3	D	2	B	3	B	4	C	4	D	3	C	4
99	3	4	3	3	A	4	B	4	B	5	C	5	D	4	B	4	B	3	C	3	D	4	C	4
100	5	5	4	4	B	4	D	5	A	5	C	5	A	5	D	5	C	4	A	4	C	4	A	4
101	3	2	3	3	D	3	C	2	B	2	C	2	D	3	B	2	B	2	C	2	D	3	C	3
102	5	3	4	3	D	4	B	4	A	5	C	5	A	5	D	3	C	5	A	4	C	4	A	4
103	4				B	5	B	5	A	3	C	3	C	5	C	5	B	1	A	1	A	1	C	1
104	4	2	2	2	C	2	C	4	B	3	C	4	A	3	B	3	B	4	C	4	A	5	D	3
105	4	3	3	3	C	2	B	1	D	4	C	3	A	3	B	3	A	4	B	2	B	3	C	2
106	4	2	4	4	B	4	D	3	A	5	C	4	C	5	A	3	A	5	B	4	C	3	D	3
107	4	3	3	4	C	1	D	1	D	4	C	3	A	4	D	3	C	3	C	3	C	3	C	3
108	4	3	3	5	C	5	B	3	A	3	C	3	A	3	A	2	D	2	A	3	A	3	C	2
109	5	3	4	3	D	4	B	4	A	5	C	5	A	5	D	3	C	5	A	4	C	4	A	4
110	3	3	3	3	A	4	B	4	A	5	C	5	A	5			D	4	C	3	C	4	A	4

111	3	3	4	3	D	3	D	2	A	4	C	3	A	3			C	3	A	3	C	3	A	3
112	5	3	4	3	A	4	B	4	A	4	C	5	A	5			C	4	A	3	C	4	A	4
113	3	3	3	3	A	4	B	5	A	5	C	5	A	5			D	4	A	3	C	4	A	4
114	4	3	2	3	A	4	B	5	A	5	C	5	A	5			D	4	C	3	C	4	A	4
115	3	3	2	3	B	3	A	4	A	3	C	2	D	4	B	3	B	1	C	2	A	1	A	1
116	4	5	4	4	B	5	D	3	B	3	A	5					C	5	C	5	A	4		
117	4	4	4	5	B	4	B	4	B	1	C	2	D	5	C	3	C	3	B	2	A	1	A	1
118	2	2	2	3	C	2	C	2	D	2	D	2	C	2	C	2	C	2	C	3	A	3	A	3
119	4	3	4	4	C	3	C	2	D	3	D	2	A	3	C	2	C	3	A	2	D	3	B	2
120	4	2	4	5	B	4	B	1	A	4	C	4	A	2	B	2	C	3	B	2	A	3	C	2
121	4	3	4	5					D	4	C	2	A	4	C	3	D	3			D	3	A	3
122	4	3	3	3	D	5	D	5	A	3	C	3	A	5	C	3	A	2	B	2	A	5	F	5
123	4	3	3	3	D	3	D	2	A	3	C	4	A	3	C	2	A	3	B	3	A	2	F	2
124	4	2	5	5	B	3	A	4	A	4	C	4	A	3	C	3	A	3	B	3	A	3	C	3
125	5	4	4	4	B	4	D	4	A	5	C	4	B	3	A	3	A	5	C	4	A	5	E	4
126	4	3	3	3	B	4	D	3	B	3	D	2	C	4	C	3	B	3	C	3	A	4	A	3
127	4	3	3	3	B	3	D	4	B	3	C	2	C	4	B	3	C	3			A	4	C	3
128	4	4	4	3	B	3	D	5	B	5	C	3	C	5	B	4	C	3			A	5	C	4
129	4	5	4	3	B	4	D	3	B	5	C	1	B	3	D	4	A	3	C	1	A	5	C	4
130	4	3	4	4	D	3	B	4	B	3	C	2	A	3	B	3	C	3	B	4	A	3	C	2
131	4	3	4	4	B	3	D	3	B	5	C	4	C	5	B	4	C	4			A	5	C	3
132	4	4	3	4	D	5	D	4	D	5	B	4	C	4	D	4	C	5	B	4	A	3	C	3
133	3	3	4	4	D	2	D	1	D	5	C	2	A	4	C	3	B	2	A	2	A	5	C	3
134	3	4	3	3	B	2	A	5	C	2	D	2	A	4	B	4	C	3	C	2	A	5	B	3
135	4	3	4	3	C	2	D	3	D	3	C	3	C	4	A	3	C	3	C	4	A	3	F	3
136	3	3	3	3	C	3	D	3	D	3	C	3	C	3	A	3	C	3	C	3	A	3	F	3
137	4	3	3	3	D	4	D	2	A	3	B	3	A	3	B	2	C	2	A	2	D	2	B	2
138	4	3	4	3	B	4	D	3	C	3	C	2	B	3	C	3	C	5	A	4	A	4	F	3
139	5	5	5	5	D	5	B	5	D	5	B	5	A	5	C	3	C	5	A	5	A	5	E	5
140	5	3	3	4	D	5	B	4	D	5	B	5	A	4	C	3	D	5	B	4	A	4	E	3
141	4	3	4	4	B	4	D	4	C	5	C	4	B	3	C	3	C	4	A	4	A	5	F	4
142	4	4	3	3	D	5	D	4	A	3	C	3	A	4	C	4	A	2			A	5	C	3
143	4	3	3	3	C	3	D	3	D	4	B	3	C	5	A	4	C	5	C	4	A	5	F	3
144									D	5			C	5							A	4	C	4
145					C	3	A	2	B	5	B	3	C	4	B	1	C	4	C	3	A	3	C	3
146	4	4	5	4	B	2	C	4	B	5	A	4	C	5	B	3	C	3	B	4	A	5	B	3
147	4	4	3	4	B	3	A	3	B	3	B	3	D	4	A	3	D	3	A	3	A	3	C	3
148	4	2	5	5	A	4	C	4	A	4	C	4	D	3	A	3	D	4	A	4	A	2	C	2
149	5	4	4	4	B	4	D	4	B	5	C	5	A	5	B	4	C	3			A	5	C	4
150	5	4	4	4	B	3	D	5	B	5	C	3	A	5	B	4	C	3			A	5	C	4
151	5	3	5	5	D	5	B	5	A	4	C	4	D	5	A	5	D	4	A	4	A	5	C	4
152	4	2	3	3	D	4	B	5	D	5	D	4	C	3	D	3	C	3			D	4	E	4
153	5	4	4	5	B	5	D	5	B	5	A	5	A	5	D	5	A	5	C	5	C	5	F	5
154	4	2	2	3	A	3	A	3	D	3	C	3	D	2	C	2	C	2	C	2	C	2	C	2
155	4	3	4	3	D	4	A	3	B	3	C	2	A	4	D	4	C	2	C	2	B	3	B	2
156	3	3	2	2	B	4	D	4	D	3	B	3	D	4	B	4	C	3			B	3	D	2
157	5	4	5	5	C	3	B	3	C	3	A	3	A	2	B	2	A	2	B	2	D	2	B	2
158	4	3	3	2	C	3			A	2			D	1			B	1			D	3		
159	5	3	3	3	B	2	B	2	D	3	C	3	D	3	D	2	B	5			A	4	B	2

160	4	3	4	3	D	3	B	2	D	4	D	2	A	5	D	4	D	5	B	3	D	4	B	5
161	3	3	3	3	B	1	A	1	B	1	C	1	A	1	C	1	D	1	A	1	A	1	C	1
162	4	3	4	3	A	2	B	3	D	4	C	3	C	4	B	2	A	1	B	2	C	4	B	3
163	5	3	3	4	B	2	C	3	D	5	C	3	D	3	C	2	B	2			C	2	B	4
164	5	4	4	4	A	2	A	3	D	3	C	3	B	3	D	2	C	3	B	3	B	4	E	3
165	4	3	3	3	C	3	C	4	C	3	C	2	B	4	C	4	A	3	B	3	B	2	C	2
166	5	4	5	5	D	4	C	4	B	3	B	3	B	4	A	3	C	2	B	3	A	2	B	4
167	5	4	2	2	B	5	D	5	B	5	D	5	A	3	B	2	B	3	A	3	A	3	E	2
168					C	4	B	3	D	3	C	3	A	2	C	2	C	2	C	2	A	3	A	3
169	4	4	5	4	C	2	B	1	B	1	A	1					B	1	C	1				
170	5	1	3	4	B	4	A	4	D	1	C	4	C	2	C	4	C	1	A	5	A	5	C	2
171	5	4	5	5	B	5	D	5	A	5	C	4	C	4	D	3	B	3	C	3	B	3	D	3
172	4	4	5	5	B	4	D	4	A	3	C	3	C	3	B	3	B	3	C	3	A	3	D	3
173	5	4	5	4	D	5	C	4	B	1	C	1	A	4	C	4	B	4	B	4	C	5	D	4
174	5	3	4	5	B	4	C	3	D	5	B	4	A	5	B	4	C	3	B	4	B	5	B	3
175					C	2	B	2	D	3	C	3	D	4	B	3	C	2			D	3	C	3
176	3	3	2	4	B	3	C	3	D	4	B	3	A	4	C	4	A	2	C	2	A	3	B	3
177	5	4	2	5	B	4	A	2	C	5	C	5	A	4	C	2	B	5			B	3	C	1
178	4	4	2	4	B	4	B	5	D	3	A	4	D	5	A	5	C	3			B	4	B	4
179	5	4	4	4	B	3	D	4	B	3	A	3	C	2	B	2	C	1	B	1	A	2	B	2
180	5	4	3	4	A	1	C	1	D	1	C	1	A	3	C	1	D	1	B	1	D	1	B	1
181	5	4	4	3	B	3	C	3	B	2	C	3	D	2	C	2	B	3	C	3	D	2	B	2
182	3	3	2	3	C	2	D	2	D	2	C	3	A	3	C	3	C	2	C	2	A	2	A	3
183	4	3	5	4	B	3	A	4	A	4	C	3	C	4	A	3	D	3	B	4	A	3	D	3
184	4	4	4	5	C	5	A	5	D	3	B	3	A	3	C	3	C	3	B	5	D	3	B	3
185	4	3	4	4	D	3	A	1	A	2	D	2	B	2	C	1	D	1	A	2	C	1	C	2
186	4	4	3	3	C	4	C	3	D	3	B	3	A	4	B	3	C	5	A	5	B	4	B	3
187	5	3	3	4	A	1	C	2	C	4	D	3	C	5	B	3	A	1	A	1	A	1	B	1
188	3	3							D	5			D	3			B	2			A	5		
189									D	4			A	5	D	5					A	5	D	4
190									D	2			A	2			C	2			B	1	D	2
191	4	5	4	4	A	4	D	4	C	2	D	2	C	1	D	2	C	5	C	5	A	4	B	4
192	4	5	4	4	A	4	D	4	C	2	D	2	C	1	D	2	C	5			A	4	B	4
193					A	1	B	1	A	1	A	1	C	1	D	2	C	3	C	3	A	4	B	4
194	4	4	3	4	B	1	C	2	D	4	B	2	A	5	B	4	C	3						
195	4	2	3	3	B	4	C	3					A	1	B	5	C	1	B	3	B	3	D	3
196	4	4	3	3																				
197	4	2	3	3	C	3	C	3	C	2	C	3	A	3	D	3	C	3	B	3	B	3	D	3
198	4	2	3	3	A	4	C	4	A	1	C	4	B	2	B	1	B	1	C	1	A	3	B	3
199	2	2	3	3	A	1	C	3	A	1	B	2	A	1			A	5	B	4	A	2	B	2
200					C	1	B	4	D	5	B	4	A	1	B	4	B	1	B	3	A	4	A	4
201	4	4	4	4	B	4	C	2	C	4	D	2	A	4	B	2	A	3	A	3	A	4	D	5
202	3	2	3	3	B	2	C	2	D	2	B	2	A	3	B	3	B	3			B	3	B	2
203	3	2	4	3	A	2	B	1	D	3	B	3	A	3	B	3	B	3	B	1	B	3	B	2
204	5	3	3	3	B	3	C	3	D	3	C	3	A	5	A	5	B	3	C	4	B	1	C	1
205	4	3	3	3	B	3	D	3	D	3	B	3	A	4	A	4	D	3	B	3	D	3	D	3
206	3	3	3	3	B	2	C	2	A	2	C	2	A	3	B	2	B	1	A	1	B	2	C	2
207					C	1	B	4	D	5	B	4	A	1	B	4	B	1	B	3	A	4	A	4
208					B	4	A	3	D	5	B	4	C	5	D	4	B	4	A	3	A	4	E	4

209	2	4	4	4	B	3	A	3	C	2	C	3	B	3	B	4	C	2	B	2	B	3	D	3
210					B	2	B	2	B	1	B	1					B	2	A	3	B	1	B	1
211					A	1	C	1	D	3	B	2	C	2	B	2	C	1	B	1	B	2	D	2
212	3	2	4	2	B	3	C	4	D	4	B	2	A	4	D	4	C	2	B	2	B	2	A	1
213					B	4	B	4	C	3			D	4							A	5	D	4
214	5	4	4	4	D	3	D	2	B	3	B	2	C	3	D	3	C	2	A	2	D	3	D	2
215	3	2	3	2	C	4	C	3	D	4	C	4	A	5	B	3	B	3	B	2	B	4	B	4
216	3	3	4	5	C	3	C	1	D	3	C	1	B	1	B	3	C	1	C	3	B	5	C	3
217	5	3	3	3	A	3	B	3	A	3	A	3	A	4	B	4	B	2	A	2	B	2	B	2
218	4	4	4	4	B	2	B	2	A	4	A	4	B	3	A	3	B	2	C	4	D	4	D	5
219	2	3	2	2	A	1	C	1	A	2	B	2	A	2	B	2	B	2	B	5	C	2	C	2
220	5	4	3	3	A	3	C	3	D	3	B	4	B	4	B	4	C	3	B	3	D	3	C	4
221	3	3	4	4	C	3	B	2	A	2	B	4	C	4	A	4	C	3	B	3	C	3	F	3
222					A	3	B	2	D	4	C	2	D	3	D	3	B	2	A	2	A	3	D	2
223					C	3	A	2	B	3	C	2	B	3	C	4	C	3	C	1	B	3	E	3
224					B	2	A	2	C	2	C	2	C	3	B	2	B	2	C	2	B	2	B	2
225					B	3			D	4			D	4			C	1			A	3		
226					C	2	A	2	C	4	D	3	A	3	B	3	B	2	A	3	B	3	B	2
227					D	2	C	4	D	4	C	3	C	4	D	4	C	2	B	1	D	3	E	4
228					D	3	B	3	D	4	B	3	D	3	B	4	A	1	C	4	D	3	E	3
229	4	2	3	4	C	1	C	1	C	1	B	1	A	1	C	1	B	1	A	1	B	1	D	1
230	4	3	3	3					C	3	C	3	A	4	B	4	B	2	B	2	A	2	E	2
231	4	4	2	3	B	2	B	2	A	4	A	4	B	3	A	3	B	2	C	4	D	4	D	5
232	5	4	5	3	B	4	C	2	C	3	B	2	C	2	D	2	B	1	A	1	B	2	D	2
233	4	4	3	5	B	4	D	5	D	4	C	5	C	3	C	3	C	4	C	4	D	4	D	4
234	3	3	3	3	B	3	C	3	A	1	B	2												
235					B	3	C	2	D	4	B	3	A	4	B	4	A	2	B	2	C	1	B	2
236					C	3	B	3	D	3	B	3	C	3	B	3	C	3	B	3	B	3	C	3
237	2	3	3	4	B	1	B	2	D	5	D	2	B	1	B	1	B	1	B	2	C	1	B	2
238	4	4	4	3	D	4	A	3	D	5	B	4	C	5	D	4	B	4	A	3	A	4	E	4
239	4	2	2	2									D	4			C	5						
240	2	3	3	2	C	2	A	4	D	3	C	4	A	5	B	4	C	3	A	3	B	3	D	5
241	2	3	4	2	C	2	D	2	D	5	B	4	B	1	C	2	A	1	C	1	A	4	C	5
242	4	3	3	4	B	4																		
243	3	1	3	1	B	2	B	1	A	1	A	2									A	2	B	1
244	1	1	1	1	C	1	C	1	A	1	B	1	B	1	D	1	C	1	A	1	B	1	E	1
245	4	3	3	3					D	1			A	1	B	1	B	3	B	4				
246	4	3	5	4	B	5	B	4	D	4	C	5	C	1	A	3	C	1	A	3	A	1	E	4
247	5	4	2	3	C	2	B	3	D	5	C	3	B	4	B	3	A	2	A	3	A	5	D	5
248	2	2	3	4	C	5	B	4	C	3	C	5	C	1	A	4	A	5	A	1	B	2	C	2
249	5	3	2	1	B	2	B	2	D	4	D	2	A	4	B	4					A	2	C	2
250					C	3	D	4	D	2	A	5	B	3	A	4	A	5	C	2	D	1	F	5
251					B	2	C	2	C	2	C	2	D	3	C	4	A	2	C	4	C	4	C	5
252	3	2	3	1	A	1	C	1	B	3	B	1	C	4	B	2	B	2	A	3	C	1	C	1
253	4	3	4	4	B	4	D	4	B	4	A	4	D	2	A	2	B	1	C	1	A	1	C	1
254	2	4	1	3	B	4	D	3	B	2	A	2	A	5	C	2	C	3	C	3	A	1	F	3
255	3	3	3	3	B	3	D	3	B	2	A	2	D	3	A	3	B	2	C	2	B	1	B	1
256	3	3	3	3	B	3	D	5	B	4	A	3	D	2	A	2								
257	2	5	5	3	A	4	D	3	B	5	A	5	D	5	A	4	C	4	B	5	A	2	C	2

258	3	3	3	3	B	3	D	3	B	3	A	3	D	3	A	1	C	1	C	1	C	1	D	1
259	4	4	4	3	B	3	A	3	D	3	A	3	D	2	A	2	C	3	B	3	A	3	C	2
260	4	4	4	4	B	5	D	5					D	3	A	3	C	4	B	4				
261	3	2	3	3	B	2	D	2	D	2	A	2	D	3	A	3	C	3	A	3	A	1	F	1
262	3	3	2	4	A	2	A	2	B	3	A	3	A	2	D	2	A	4	C	4	A	1	C	1
263	4	4	3	4	B	3	D	3	B	3	A	3	D	4	A	1	C	4	A	1	D	1	C	1
264	1	2	2	2	B	3	A	2	C	1	A	2	D	3	C	1	B	1	A	1	A	1		
265	3	4	3	4	B	4	D	5	B	4	A	5	D	5	A	5	C	4	C	4	A	3	C	2
266	3	3	3	3	A	1	A	1	B	4	A	4	D	4	A	4	A	2	A	2	D	1	E	1
267	3	2	3	3	A	2	A	2	B	2	A	3												
268	4	3	3	3	D	3	B	3	B	4	A	4	D	5	C	4	C	5	C	4	D	1	E	4
269	3	3	3	3	A	1	A	1	B	4	A	4	D	4	A	4	A	2	A	2	D	1	E	1
270	4	3	3	4	B	1	C	1	B	3	A	2	D	2	A	2	C	3	C	1	B	1	E	1
271	4	3	3	3	B	3	A	3	C	2	A	3	D	4	A	4	C	1	A	1	A	3	C	2
272	3	2	3	4	A	1	D	1	A	2	B	2	D	3	A	3	A	1	C	1	D	1	E	1
273	4	3	2	3	B	2	B	2	B	2	A	2	D	3	A	3					A	3	C	2
274	3	3	4	3	B	2	A	3	A	2	A	3	D	1	C	2	B	1	A	3	D	2	C	1
275	3	3	2	3	C	2	C	2	B	1	C	1	B	2	B	1	B	1	B	1	D	1	B	1
276	3	3	2	3	A	1	B	1	B	1	A	3	A	1	D	1	A	1	B	1	B	1	C	1
277	5	3	3	3	B	4	D	4	B	3	A	4	D	4	A	4	B	3	B	3	A	2	C	2
278	4	3	3	3	B	4	D	4	B	4	A	4	D	3	A	3	B	2	B	3	A	3	C	3
279	4	3	2	4	B	5	D	5	B	3	A	3	D	5	A	5	C	3	A	4	A	4	C	5
280	4	3	3	3	B	3	D	3	B	3	A	5	D	3	A	3	C	4	C	4	A	1	F	1
281	2	2	2	2	A	1	A	2	D	2	C	2	D	4	A	3	C	2	B	2	D	1	C	1
282	4	3	3	4	B	4	D	4	C	3	A	4	C	2	C	1	C	2	B	3	B	1	D	1
283	3	2	3	3	B	4	D	4	B	4	A	4	D	4										
284	3	4	4	2	A	3	A	1	B	2	A	3	D	3	C	2	C	1	A	2	B	2	B	2
285	4	3	3	3	B	4	D	4	B	2	A	4	D	4	A	4	B	1	A	1	A	2	D	1
286	5	5	4	4	A	3	A	4	B	4	A	4	D	5	A	4	C	4	C	4	A	4	C	4
287	3	4	3	4	B	4	D	4	A	2	B	3	D	2	A	1	B	1	A	1	A	1	A	1
288	4	4	5	4					D	3			A	2	D	2	C	5	B	5				
289	3	2	2	2	B	2	D	2	B	2	A	2	D	2	A	2	B	2	C	3	B	1	A	1
290	3	2	3	4	C	1			A	1	A	1												
291	3	3	3	3	B	4	D	2	B	1	A	2					B	2	C	2	A	2		
292	3	2	2	3	B	5	D	4	B	4	A	5	D	1	A	1	C	2	C	2	C	1	F	1
293	4	2	4	4	B	4	A	3	B	3	A	4	D	4	A	5	B	2	B	3	B	1	B	1
294	4	2	2	3	A	2	A	2	D	1	D	1	D	2	A	2	C	2	A	3	D	2	F	2
295	3	2	3	4	C	4	D	3	B	4	A	5	D	5	A	5								
296	3	3	3	3	B	3	D	3	B	4	A	3	D	4	A	4	C	3	C	3	C	1	F	1
297	3	3	4	4	B	3	D	4	A	3	C	3	D	4	A	3	B	1	B	4	D	2	E	3
298	3	2	4	4	A	2	A	2	C	3	A	3	C	3	C	1	B	2	B	2	D	2	D	2
299	1	1	1	1	B	2	C	2	B	2	B	2	B	2	C	2	B	2	B	2	C	2	D	2
300	3	3	4	4	C	3	A	3	C	4	A	4	D	4	A	4	A	3	A	3	D	3	D	3
301	4	4	3	3	B	4	D	5	B	2	A	3	D	3	A	1	C	1						
302	3	4	3	3	B	3	D	3	B	1	A	1	D	1	A	1	C	1	A	3	D	1	F	1
303	3	3	2	4	B	1	A	1	B	3	A	3	A	1	C	1	C	2	A	1	D	2	C	1
304	3	2	2	3	D	2	B	2	C	2	B	3	D	3	A	3	C	3	A	3	B	1	D	1
305																								
306	4	4	3	4	C	4	A	4	B	3	A	3	C	3	B	3	B	3	A	3	D	3	C	3

307	4	4	3	3					B	2	A	3	A	2	A	1	B	2	A	1				
308	3	2	2	2	B	1	B	1	B	1	A	1	B	1			A	1						
309	4	2	3	3	B	3	D	3	B	4	A	3	D	2	A	2	C	4	C	4	A	1	E	1
310	4	3	3	3	B	3	D	3	B	4	A	2	D	3	B	3	D	2	B	2	B	2	C	2
311	4				A	3	A	3	B	5	A	5	B	3	C	1	B	2						
312	4	3	3	3	B	3	D	3	B	5	A	5	D	2	C	1	C	2	C	3	A	1	F	1
313	2	3	3	3	B	1	D	1	B	2	A	2	D	2	B	2	C	2	A	3	D	2	C	2
314	3	4	3	4	B	3	D	3	B	4	A	4	D	2	A	3	C	4	C	4	D	2	D	1
315	3	3	3	3	B	3	D	3	B	3	A	3	B	2										
316	2	2	3	3	B	4	D	4	B	4	A	5	D	4	A	4	C	4	C	3	A	3	C	1
317	2	3	3	3	B	3	B	4	B	2	A	2	D	1	A	3	A	3	A	3	D	1	B	1
318	4	3	3	3	B	4	B	4	B	4	A	4	D	2	A	2	D	3	B	2	A	3	C	3
319	3	2	2	2	B	3	B	3	B	3	A	3	B	1			D	2	A	2	B	1	D	1
320	3	3	3	4	B	2	A	2	B	5	A	5	D	3	A	2	D	2	A	2	A	3	C	2
321	3	4	3	3	B	1	A	1	A	3	A	4	D	2	A	2	C	1	A	1	A	1	C	1
322	3	4	4	4	B	2	D	2	B	3	A	3	B	3	C	3	C	3	B	3	A	4	D	4
323	2	3	3	3	B	3	D	4	B	1	A	2	D	2	A	1	A	2	C	1	A	2	C	1
324	2	3	3	3	B	3	D	5	B	1	A	1	B	3	B	1	B	1	A	1	A	1	A	1
325	3	4	3	4	B	4	A	3	B	3	A	3	D	4	A	4	C	3	B	3	A	1	C	1
326	4	3	3	3	B	3	D	3	B	4	A	4					A	4	C	3	B	2	B	1
327	3	3	3	3	B	4	D	3	B	3	A	4	D	3	A	3	C	3	B	1	A	3	D	1
328	4	3	2	3	C	2	D	2	D	2	C	3	D	2	A	2			B	2				
329	3	4	3	2	B	5	D	4	B	5	A	5	D	4			C	2			A	2	C	2
330	3	2	3	3	B	4	D	4	B	1	A	4	D	3	A	1	C	1	A	1	D	2	A	1
331	3	2	3	4	B	3	D	2	B	4	A	4	D	2	A	2	C	1	A	1	D	2		
332	2	2	2	2	A	1	A	1	B	2	C	2	D	3	A	1	C	1	C	1	A	1	F	1
333	2	1	3	2	B	2	D	2	D	2	C	2	D	2	A	2	C	1	A	1	A	3	F	1
334	3	3	4	4	A	4	A	4	B	1	A	3	D	2	D	1	C	2	A	3	A	1	E	4
335	4	3	4	3	A	3	A	3	C	2	A	2	D	3	B	2	D	2	B	1	A	1	D	1

Appendix J. Difficulty level and validity of FTDICK Instrument

A = answer tier
R = reason tier
B = both tier

0 = wrong answer or wrong reason
1 = correct answer or correct reason

Student	Question																													
	1			2			3			4			5			6			7			8			9			10		
	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B
1	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
2	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
3	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**
4	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
5	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**
6	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**
7	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**
8	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**
9	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
10	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	1	0	**0**
11	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
12	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**
13	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
14	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**
15	0	1	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
16	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
17	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**
18	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**
19	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
20	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**
21	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
22	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
23	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
24	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
25	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**
26	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**
27	1	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
28	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
29	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
30	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
31	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**
32	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**
33	1	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**
34	1	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
35	1	0	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**
36	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**
37	0	1	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**
38	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**
39	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**
40	0	1	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
41	0	1	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**
42	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**
43	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
44	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
45	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**
46	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	0	**0**
47	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**
48	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**
49	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**
50	1	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**

51	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
52	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
53	0	1	**0**	1	1	**1**	0	1	**0**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**
54	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**
55	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	1	**1**
56	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
57	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**
58	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
59	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**
60	0	1	**0**	0	1	**0**	0	1	**0**	0	1	**0**	1	1	**1**	1	0	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	0	**0**
61	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	1	**1**
62	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
63	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
64	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**
65	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**
66	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
67	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
68	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
69	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	0	0	**0**
70	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**
71	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**
72	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
73	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**
74	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**
75	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**
76	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
77	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	0	1	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
78	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
79	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
80	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**
81	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**
82	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
83	1	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**
84	0	1	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**
85	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**
86	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	1	**0**
87	0	1	**0**	1	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
88	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**
89	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
90	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**
91	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**
92	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**
93	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
94	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**
95	1	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
96	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**
97	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**
98	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
99	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
100	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**
101	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
102	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**
103	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
104	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**
105	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**
106	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**
107	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**
108	0	0	**0**	1	0	**0**	1	1	**1**	0	1	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	0	**0**
109	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**
110	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**

111	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
112	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
113	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
114	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
115	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
116	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**
117	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	1	**0**
118	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
119	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**
120	1	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**
121	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	1	1	**1**	0	0	**0**
122	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	0	1	**0**	1	1	**1**
123	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**
124	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
125	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**
126	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**
127	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**
128	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
129	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
130	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	0	1	**0**
131	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
132	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
133	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	0	**0**
134	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	1	0	**0**	0	0	**0**	1	1	**1**
135	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**
136	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**
137	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
138	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**
139	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**
140	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	1	1	**1**
141	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
142	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**
143	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**
144	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
145	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
146	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
147	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	0	**0**
148	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
149	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**
150	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
151	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**
152	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
153	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**
154	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**
155	0	1	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**
156	0	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**
157	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**
158	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
159	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	1	**0**	0	0	**0**
160	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**
161	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
162	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**
163	0	1	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	0	0	**0**	1	0	**0**	1	1	**1**
164	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**
165	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	0	**0**
166	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**
167	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**
168	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	0	**0**
169	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
170	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	1	0	**0**	0	1	**0**

171	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**
172	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	0	**0**
173	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
174	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**
175	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**
176	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
177	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
178	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
179	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**
180	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	1	**0**
181	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
182	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**
183	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**
184	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	0	**0**
185	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
186	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
187	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
188	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**
189	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
190	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**
191	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
192	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
193	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**
194	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
195	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**
196	0	1	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
197	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
198	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	1	**0**
199	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**
200	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**
201	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**
202	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
203	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
204	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**
205	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
206	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**
207	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**
208	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
209	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**
210	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**
211	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**
212	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
213	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**
214	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**
215	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
216	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**
217	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**
218	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	0	1	**0**	1	0	**0**	0	0	**0**
219	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	1	0	**0**
220	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**
221	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**
222	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
223	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
224	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
225	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
226	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**
227	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**
228	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**
229	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**
230	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**

231	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**
232	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	1	**0**
233	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
234	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**
235	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
236	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	1	**0**	0	0	**0**
237	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**
238	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
239	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
240	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**
241	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**
242	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
243	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**
244	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
245	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
246	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
247	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**
248	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**
249	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**
250	0	1	**0**	1	1	**1**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
251	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
252	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	1	**0**
253	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**
254	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**
255	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
256	0	1	**0**	1	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**
257	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**
258	1	1	**1**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**
259	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**
260	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**
261	1	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**
262	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
263	1	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**
264	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**
265	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
266	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
267	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**
268	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**
269	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	1	1	**1**
270	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
271	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**
272	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**
273	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**
274	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**
275	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**
276	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**
277	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**
278	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**
279	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**
280	1	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**
281	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**
282	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	0	**0**
283	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**
284	0	1	**0**	0	1	**0**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**
285	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	0	**0**
286	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
287	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**
288	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
289	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
290	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**

291	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1	1	0	1	0	1	0	0	1	0	0
292	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1
293	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	0	0	0
294	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
295	0	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0
296	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1
297	1	1	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
298	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
299	0	0	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	1	1	0	0	0	1	0	0
300	0	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	1	0
301	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
302	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	0	0
303	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0	1	1	1
304	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	1	0	1	1	1	1	1	1
305	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1
306	1	0	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1
307	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1
308	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1
309	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
310	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	0	1	0	0
311	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
312	1	0	0	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1
313	1	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
314	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	1	0	0
315	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
316	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0
317	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0
318	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	1
319	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
320	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	1	0	0	0	1	0	0	1	1	1
321	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
322	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	1	0
323	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	0	0
324	1	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	0	0	0
325	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
326	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0
327	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
328	0	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
329	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0
330	0	1	0	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1
331	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1	1	1
332	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1
333	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0
334	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	1	0	1	1	1	0	1	0	1	1	1	1	0	0
335	1	1	1	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	0

Q	1			2			3			4			5		
	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B
DL	0.29	0.29	0.14	0.67	0.59	0.44	0.26	0.16	0.11	0.49	0.48	0.35	0.61	0.52	0.46
V	0.49	0.50	0.50	0.30	0.43	0.41	0.22	0.25	0.27	0.64	0.48	0.68	0.63	0.61	0.71
Q	6			7			8			9			10		
	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B
DL	0.19	0.21	0.11	0.48	0.61	0.30	0.46	0.37	0.28	0.50	0.32	0.23	0.50	0.40	0.27
V	0.24	0.29	0.30	0.17	0.38	0.37	0.50	0.57	0.65	0.38	0.41	0.51	0.41	0.40	0.41

Q = question
DL = difficulty level
V = validity

A = answer tier
R = reason tier
B = both tier

Student	Question																													
	11			12			13			14			15			16			17			18			19			20		
	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B	A	R	B
1	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
2	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
3	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**
4	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
5	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
6	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**
7	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
8	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**
9	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
10	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
11	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
12	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**
13	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**
14	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**
15	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
16	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
17	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
18	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
19	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
20	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
21	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
22	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**
23	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**
24	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	1	**1**	0	1	**0**	0	1	**0**	1	0	**0**
25	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
26	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
27	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
28	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	1	**0**
29	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
30	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
31	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**
32	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
33	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
34	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
35	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
36	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**
37	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
38	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
39	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
40	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
41	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**
42	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
43	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
44	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
45	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
46	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
47	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**
48	1	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
49	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
50	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	0	0	**0**
51	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**
52	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
53	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**
54	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
55	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**

56	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
57	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0
58	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
59	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
61	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
62	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0
63	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
65	0	0	0	1	0	0	0	1	0	1	1	1	0	1	0	1	1	1	1	0	0	0	0	0	0	1	0	1	0	0
66	0	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
67	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1	1	1	0	0
68	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
70	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0
71	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
72	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0
74	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	1	0
75	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1
77	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
78	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0
79	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0
82	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
86	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
87	0	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0
88	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
89	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0
90	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
92	1	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	1	1	1	0	1	0
95	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
96	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	1
97	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
98	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0
99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0
100	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	1	0	0
101	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0
102	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
103	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
104	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
105	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	1	0	0
107	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0
108	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
111	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0
112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
115	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0

116	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**
117	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**
118	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
119	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
120	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
121	1	0	**0**	1	1	**1**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
122	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**
123	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**
124	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
125	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**
126	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
127	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
128	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
129	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
130	1	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
131	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
132	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
133	1	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
134	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
135	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**
136	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**
137	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
138	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**
139	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
140	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
141	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**
142	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
143	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**
144	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
145	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
146	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
147	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
148	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
149	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
150	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
151	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
152	1	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
153	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**
154	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**
155	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
156	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**
157	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
158	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
159	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
160	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
161	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
162	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
163	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**
164	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
165	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
166	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**
167	0	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
168	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
169	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**
170	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
171	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
172	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
173	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
174	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
175	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**

176	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
177	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
178	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**
179	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
180	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
181	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**
182	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
183	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**
184	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
185	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
186	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
187	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
188	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
189	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
190	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
191	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
192	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
193	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**
194	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
195	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
196	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
197	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
198	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
199	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
200	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
201	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
202	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
203	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
204	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**
205	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**
206	1	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
207	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
208	1	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
209	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
210	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
211	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
212	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
213	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
214	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
215	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
216	0	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
217	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
218	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	0	**0**
219	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
220	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
221	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**
222	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**
223	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
224	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
225	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**
226	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
227	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
228	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**
229	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
230	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
231	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	0	**0**
232	1	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
233	1	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**
234	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
235	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**

236	1	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
237	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
238	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
239	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**
240	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
241	0	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**
242	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
243	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
244	0	1	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
245	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
246	1	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**
247	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
248	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**
249	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
250	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	1	**0**
251	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**
252	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
253	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**
254	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	1	**0**
255	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**
256	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
257	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
258	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**
259	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**
260	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
261	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	1	0	**0**	0	1	**0**
262	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**
263	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
264	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
265	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
266	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
267	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
268	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**
269	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
270	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
271	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**
272	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**
273	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
274	1	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**
275	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
276	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
277	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
278	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
279	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
280	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**
281	0	0	**0**	0	1	**0**	0	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
282	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**	1	1	**1**	0	1	**0**	0	0	**0**	1	0	**0**	0	0	**0**
283	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**
284	0	1	**0**	0	1	**0**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
285	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
286	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
287	0	1	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
288	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**
289	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**
290	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
291	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**
292	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
293	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
294	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**
295	0	1	**0**	0	1	**0**	0	1	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**

296	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**
297	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
298	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	0	**0**	0	0	**0**	0	0	**0**
299	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**
300	1	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	0	**0**
301	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
302	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	1	**0**
303	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
304	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	0	**0**
305	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
306	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
307	1	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	0	**0**	0	0	**0**
308	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
309	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
310	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**	0	0	**0**
311	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
312	0	0	**0**	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	0	1	**0**
313	0	0	**0**	0	1	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
314	1	0	**0**	0	1	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
315	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
316	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**
317	0	1	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
318	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	0	1	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
319	0	0	**0**	0	0	**0**	1	0	**0**	0	1	**0**	0	1	**0**	1	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
320	0	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**
321	0	0	**0**	0	0	**0**	1	0	**0**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**	1	1	**1**	1	0	**0**	0	0	**0**
322	1	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	0	0	**0**
323	0	0	**0**	0	0	**0**	1	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	1	**0**	0	0	**0**
324	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	0	**0**	0	0	**0**
325	0	1	**0**	0	1	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	0	**0**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
326	0	0	**0**	1	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	0	1	**0**	0	0	**0**
327	1	0	**0**	0	0	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
328	0	0	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	0	**0**
329	0	0	**0**	0	0	**0**	1	1	**1**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
330	0	1	**0**	0	0	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
331	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	0	**0**	0	0	**0**
332	0	0	**0**	0	1	**0**	0	0	**0**	1	1	**1**	1	1	**1**	0	0	**0**	1	0	**0**	1	1	**1**	1	1	**1**	0	1	**0**
333	0	0	**0**	0	1	**0**	1	1	**1**	1	1	**1**	1	1	**1**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	0	1	**0**
334	0	0	**0**	0	0	**0**	0	1	**0**	1	0	**0**	1	1	**1**	0	0	**0**	1	1	**1**	1	0	**0**	1	0	**0**	0	0	**0**
335	0	0	**0**	0	1	**0**	0	1	**0**	0	1	**0**	1	1	**1**	0	0	**0**	0	1	**0**	1	0	**0**	0	0	**0**	0	0	**0**

Q	**11**			**12**			**13**			**14**			**15**		
	A	R	**B**	A	R	**B**	A	R	**B**	A	R	**B**	A	R	**B**
DL	0.19	0.12	0.04	0.20	0.26	0.09	0.26	0.32	0.19	0.44	0.38	0.22	0.40	0.42	0.28
V	-0.03	0.11	0.04	0.06	0.24	0.26	0.44	0.35	0.43	0.47	0.38	0.45	0.55	0.60	0.68
Q	**16**			**17**			**18**			**19**			**20**		
	A	R	**B**	A	R	**B**	A	R	**B**	A	R	**B**	A	R	**B**
DL	0.54	0.41	0.31	0.35	0.32	0.24	0.37	0.31	0.24	0.41	0.27	0.11	0.12	0.10	0.03
V	0.46	0.51	0.54	0.54	0.60	0.67	0.55	0.58	0.67	0.32	0.22	0.26	-0.04	0.31	0.22

Q = question
DL = difficulty level
V = validity
A = answer tier
R = reason tier
B = both tier

Appendix K. Percentage of students selecting **wrong answer – correct reason (WACR)**

Q	1		2			3			4			5		
WACR	N(%)	CR(B)	WACR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
AE	4.48	3.23	AB	5.07	2.29	AD	2.09	3.36	AC	2.99	3.6	AA	2.99	2.63
BE	1.49	2.7	BB	43.88	3.61	BD	2.99	3.35	BC	35.22	3.88	BA	2.69	2.64
CE	8.96	3.38	CB	3.58	2.75	CD	10.75	3.08	CC	5.07	2.85	CA	5.67	3.92
DE	14.03	3.66	DB	5.97	2.28	DD	0.30	3	DC	4.48	3.7	DA	0.60	2.83
Q	6		7			8			9			10		
WACR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
AC	3.88	3.62	AB	5.97	2.98	AA	4.78	2.78	AC	5.67	2.71	AB	6.27	3.26
BC	10.75	3.57	BB	29.55	3.46	BA	0.90	2.33	BC	22.99	3.51	BB	3.58	2.92
CC	3.88	3.08	CB	17.01	3.64	CA	3.28	2.14	CC	0.60	3.5	CB	27.16	3.31
DC	1.79	3.75	DB	8.36	2.43	DA	28.06	3.2	DC	2.69	2.89	DB	2.69	3.39
Q	11		12			13			14			15		
WACR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
AD	3.88	3	AD	5.07	2.71	AB	4.48	2.87	AC	2.39	3.25	AA	5.67	3.08
BD	3.58	3.04	BD	11.64	2.9	BB	3.28	3.18	BC	4.78	2.78	BA	5.07	3.35
CD	4.18	2.82	CD	8.66	3.24	CB	4.48	3.1	CC	8.36	3.34	CA	28.06	4.02
DD	0.30	3.5	DD	0.30	4.5	DB	19.40	3.42	DC	22.39	3.77	DA	3.28	2.91
Q	16		17			18			19			20		
WACR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
AD	2.09	3.07	AA	3.88	2.81	AA	2.99	3.3	AC	4.78	2.63	AF	4.78	2.56
BD	31.34	3.73	BA	23.88	3.38	BA	1.49	3.2	BC	9.55	2.56	BF	0.90	2.83
CD	2.99	2.35	CA	2.99	2.8	CA	2.99	3.3	CC	10.75	3.08	CF	2.99	3.2
DD	4.78	3.06	DA	1.49	2.9	DA	23.58	3.25	DC	2.09	3.21	DF	0.90	2

Q	= question
Red shaded	= correct answer-correct reason combination
N	= the percentage of students who selected answer-reason combination
CR(B)	= Confidence rating
AE	= answer A, reason R
CB	= answer C, reason B

Appendix L. The percentage of students selecting **correct answer – wrong reason (CAWR)**

Q	1			2			3			4			5	
CAWR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
DA	0.30	2.5	BA	6.87	2.87	CA	2.39	2.81	BA	2.69	2.61	CA	5.67	3.92
DB	6.87	3.22	BB	43.88	3.61	CB	7.46	2.9	BB	6.27	3.43	CB	17.91	2.44
DC	5.67	3.26	BC	8.66	3.05	CC	4.18	3.57	BC	35.22	3.88	CC	5.07	3.31
DD	1.79	4				CD	10.75	3.08	BD	3.28	4	CD	2.09	2.42
DE	14.03	3.66												
Q	**6**			**7**			**8**			**9**			**10**	
CAWR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
BA	5.37	3.61	BA	9.85	2.85	DA	28.06	3.2	BA	6.27	3.19	CA	5.07	2.56
BB	0.90	2.83	BB	29.55	3.46	DB	7.16	2.83	BB	1.79	3.33	CB	27.16	3.31
BC	10.75	3.57	BC	6.27	3.19	DC	6.87	2.8	BC	22.99	3.51	CC	4.78	2.84
BD	1.19	2.5				DD	2.99	3.25	BD	7.76	3.35	CD	4.48	2.97
									BE	9.85	3.64	CE	1.79	3.25
									BF	0.90	3.33	CF	5.07	2.76
Q	**11**			**12**			**13**			**14**			**15**	
CAWR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
CA	2.99	3.1	CA	2.69	2.39	DA	1.79	3.42	DA	0.90	2.83	CA	28.06	4.02
CB	7.16	3.25	CB	5.37	2.92	DB	19.40	3.42	DB	15.52	3.64	CB	3.58	2.67
CC	2.99	2.9	CC	2.69	2.78	DC	1.19	3.25	DC	22.39	3.77	CC	3.88	2.81
CD	4.18	2.82	CD	8.66	3.24	DD	2.99	2.8	DD	2.99	3.5	CD	4.18	2.61
									DE	0.90	3.83			
									DF	0.30	3.5			
Q	**16**			**17**			**18**			**19**			**20**	
CAWR	N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)		N(%)	CR(B)
BA	8.66	2.95	BA	23.88	3.38	DA	23.58	3.25	CA	11.34	2.66	CA	4.18	3.86
BB	6.57	3	BB	2.69	2.5	DB	3.58	3.04	CB	13.13	2.88	CB	1.79	2.83
BC	6.27	2.57	BC	8.06	2.76	DC	7.16	3.04	CC	10.75	3.08	CC	1.79	2.33
BD	31.34	3.73	BD	0.60	3.75	DD	0.90	2.33				CD	1.49	2.7
												CF	2.99	3.2

Q = question
Red shaded = correct answer-correct reason combination
N = the percentage of students who selected answer-reason combination
CR(B) = Confidence rating
DA = answer D, reason A
CB = answer C, reason B

Appendix M. The percentage of students selecting **wrong answer – wrong reason (WAWR)**

Question	1		2		3		4		5	
WAWR	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)
AA	8.96	2.78	1.19	2.25	8.36	2.84	2.99	3.65	2.99	2.63
AB	3.28	3.23	5.07	2.29	6.87	2.7	1.49	3.2	1.49	3
AC	6.57	2.91	3.28	3.45	4.78	3.53	2.99	3.6	2.99	2.93
AD	1.49	2.6			2.09	3.36	0.60	2.5	0.60	1.5
AE	4.48	3.23								
AF										
BA	3.88	3	6.87	2.87	9.25	3.32	2.69	2.61	2.69	2.64
BB	0.90	3.67	43.88	3.61	22.09	3.13	6.27	3.43	6.27	3.1
BC	3.58	2.92	8.66	3.05	10.75	3.01	35.22	3.88	35.22	2.75
BD	2.99	2.65			2.99	3.35	3.28	4	3.28	2.5
BE	1.49	2.7								
BF										
CA	5.97	3.1	0.90	2.5	2.39	2.81	5.67	3.79	5.67	3.92
CB	5.07	3.09	3.58	2.75	7.46	2.9	17.91	3.69	17.91	2.44
CC	7.46	3.44	0.90	2.67	4.18	3.57	5.07	2.85	5.07	3.31
CD	2.99	2.55			10.75	3.08	2.09	3.14	2.09	2.42
CE	8.96	3.38								
CF										
DA	0.30	2.5	2.69	2.67	0.00		0.60	3.5	0.60	2.83
DB	6.87	3.22	5.97	2.28	0.00		0.90	3.17	0.90	2.75
DC	5.67	3.26	4.18	2.54	0.60	4	4.48	3.7	4.48	2.38
DD	1.79	4			0.30	3	1.19	3.75	1.19	3.54
DE	14.03	3.66								
DF										

Red shaded = correct answer-correct reason combination
N = the percentage of students who selected answer-reason combination
CR(B) = Confidence rating
DA = answer D, reason A
CB = answer C, reason B

Question	6		7		8		9		10	
WAWR	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)
AA	31.04	3.38	1.79	2.5	4.78	2.78	7.76	3.02	2.39	2.94
AB	1.19	3.13	5.97	2.98	9.85	2.89	2.69	2.72	6.27	3.26
AC	3.88	3.62	1.19	3	8.66	2.86	5.67	2.71	2.69	3.22
AD	3.88	2.96			2.69	3.06	4.48	3.3	1.79	3.58
AE							6.57	3.18	2.09	3.43
AF							5.97	3.15	1.79	3.25
BA	5.37	3.61	9.85	2.85	0.90	2.33	6.27	3.19	2.39	2.25
BB	0.90	2.83	29.55	3.46	2.39	2.31	1.79	3.33	3.58	2.92
BC	10.75	3.57	6.27	3.19	3.58	2.75	22.99	3.51	2.09	2.14
BD	1.19	2.5			1.19	2.13	7.76	3.35	2.99	2.4
BE							9.85	3.64	0.90	2.67
BF							0.90	3.33	1.49	2.7
CA	2.69	3.22	3.28	3	3.28	2.14	0.90	2.33	5.07	2.56
CB	10.45	2.87	17.01	3.64	5.67	2.34	0.30	2	27.16	3.31
CC	3.88	3.08	5.37	3.17	2.39	2.88	0.60	3.5	4.78	2.84
CD	4.78	2.84			1.79	2.42	0.90	3.67	4.48	2.97
CE									1.79	3.25
CF							0.30	2	5.07	2.76
DA	2.09	3.71	1.19	3.75	28.06	3.2	0.60	3.5	1.79	2.92
DB	1.79	2.83	8.36	2.43	7.16	2.83	3.28	2.32	2.69	3.39
DC	1.79	3.75	2.69	3.06	6.87	2.8	2.69	2.89	2.39	2.56
DD	7.76	3			2.99	3.25	0.90	3.33	1.49	2.5
DE							0.30	4	4.78	3.44
DF							2.39	2.69	1.79	2.83

Red shaded = correct answer-correct reason combination
N = the percentage of students who selected answer-reason combination
CR(B) = Confidence rating
DA = answer D, reason A
CB = answer C, reason B

Question	11		12		13		14		15	
WAWR	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)
AA	10.75	3.38	14.03	3.03	9.85	3.03	0.90	4	5.67	3.08
AB	5.97	3.28	3.28	2.77	4.48	2.87	3.88	2.73	2.09	2.64
AC	2.09	2.86	3.88	2.62	19.10	3.7	2.39	3.25	3.28	3.05
AD	3.88	3	5.07	2.71	3.88	3.38	2.39	3.19	1.19	3.25
AE							1.49	3.5		
AF							0.90	3.17		
BA	12.84	3.19	15.82	3.36	1.19	3.5	1.79	3.08	5.07	3.35
BB	25.07	3.11	7.46	3.14	3.28	3.18	1.49	2.5	6.57	3.14
BC	5.07	2.97	8.06	2.74	8.36	3.21	4.78	2.78	8.96	3.35
BD	3.58	3.04	11.64	2.9	5.37	3.03	2.39	3.06	7.46	3.4
BE							5.67	3.18		
BF							0.90	3.5		
CA	2.99	3.1	2.69	2.39	1.79	3.42	0.60	2.5	28.06	4.02
CB	7.16	3.25	5.37	2.92	4.48	3.1	4.78	3.28	3.58	2.67
CC	2.99	2.9	2.69	2.78	3.88	3.19	8.36	3.34	3.88	2.81
CD	4.18	2.82	8.66	3.24	2.99	2.85	6.27	3.36	4.18	2.61
CE							1.79	2.5		
CF							0.30	2.5		
DA	1.19	1.88	0.60	3.25	1.79	3.42	0.90	2.83	3.28	2.91
DB	1.49	2.7	0.90	2.33	19.40	3.42	15.52	3.64	2.99	2.8
DC	0.90	2.5	1.79	2.17	1.19	3.25	22.39	3.77	2.69	3.06
DD	0.30	3.5	0.30	4.5	2.99	2.8	2.99	3.5	2.39	3
DE							0.90	3.83		
DF							0.30	3.5		

Red shaded = correct answer-correct reason combination
N = the percentage of students who selected answer-reason combination
CR(B) = Confidence rating
DA = answer D, reason A
CB = answer C, reason B

Question	16		17		18		19		20	
WAWR	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)	N(%)	CR(B)
AA	4.78	2.31	3.88	2.81	2.99	3.3	4.48	2.7	3.58	2.71
AB	4.48	3.1	3.58	2.25	10.15	3.16	3.88	2.65	5.37	2.89
AC	2.99	1.95	17.91	3.63	8.36	3.02	4.78	2.63	18.21	2.94
AD	2.09	3.07	0.60	2.5	7.76	3.17			7.16	2.96
AE									5.07	3.5
AF									4.78	2.56
BA	8.66	2.95	23.88	3.38	1.49	3.2	8.96	2.23	0.90	1.5
BB	6.57	3	2.69	2.5	2.69	2.39	8.66	2.53	5.67	2.61
BC	6.27	2.57	8.06	2.76	3.28	2.55	9.55	2.56	4.48	2.13
BD	31.34	3.73	0.60	3.75	1.49	2.5			4.78	2.22
BE									2.69	2.78
BF									0.90	2.83
CA	2.39	3.13	2.99	2.8	2.99	3.3	11.34	2.66	4.18	3.86
CB	3.88	2.73	1.79	2.92	6.57	3.02	13.13	2.88	1.79	2.83
CC	4.48	2.57	4.18	2.93	3.58	2.83	10.75	3.08	1.79	2.33
CD	2.99	2.35	1.79	2.67	3.58	3			1.49	2.7
CE										
CF									2.99	3.2
DA	1.49	3.3	1.49	2.9	23.58	3.25	3.58	2.83	0.60	2.25
DB	5.37	3.64	7.76	3.6	3.58	3.04	3.28	2.73	4.18	2.61
DC	1.79	3.25	11.94	3.04	7.16	3.04	2.09	3.21	4.48	2.63
DD	4.78	3.06	2.09	2.79	0.90	2.33			2.99	3.2
DE									2.69	2.39
DF									0.90	2

Red shaded = correct answer-correct reason combination
N = the percentage of students who selected answer-reason combination
CR(B) = Confidence rating
DA = answer D, reason A
CB = answer C, reason B

Appendix N. The percentage of Indonesian students selecting **wrong answer-wrong reason (WAWR)**

Question	1		2		3		4	
WAWR	N	CR(TB)	N	CR(TB)	N	CR(TB)	N	CR(TB)
AA	11.51	2.76	1.19	2.7	5.16	3.4	3.57	3.6
AB	4.37	3.23			5.56	3	1.59	3.4
AC	8.33	2.93	3.57	3.9	5.56	3.8		
AD	1.98	2.6					0.40	3
BA	5.16	3			9.92	3.4		
BB	1.19	3.67			27.38	3.2		
BC	4.76	2.92			13.10	3.1		
BD	3.97	2.65						
CA	7.14	3.17	1.19	2.5			6.75	4.0
CB	5.95	3.07					23.41	3.7
CC	9.13	3.52	1.19	2.7				
CD	3.97	2.55					2.78	3.1
DA			3.17	2.9			0.79	3.5
DB							1.19	3.2
DC			3.97	2.9	0.79	4		
DD							1.59	3.8

Question	5		6		7	
WAWR	N	CR(TB)	N	CR(TB)	N	CR(TB)
AA			22.62	3.6	1.19	3.3
AB	2.38	3	1.59	3.1		
AC	5.56	2.93			1.19	3.5
AD	0.40	1.5	5.16	3		
BA						
BB	1.59	3				
BC	7.14	2.8				
BD	0.40	2.5				
CA			3.57	3.2	4.37	3
CB			10.32	3		
CC					6.35	3.3
CD			6.35	2.8		
DA			2.38	3.9	1.59	3.8
DB	3.17	2.8	2.38	2.8		
DC	4.76	2.4			2.78	3.4
DD	10.32	3.6	8.33	3		

Question	8		9		10		11	
WAWR	N	CR(TB)	N	CR(TB)	N	CR(TB)	N	CR(TB)
AA			9.13	3.1	3.17	2.94	6.75	3.7
AB	12.30	2.9	3.57	2.7			7.54	3.3
AC	10.71	2.9			3.17	3.3	2.38	2.9
AD	2.78	2.9	5.95	3.3	2.38	3.6		
AE			7.94	3.3	2.38	3.6		
AF			6.35	3.3	2.38	3.3		
BA					3.17	2.3	10.71	3.4
BB	3.17	2.3					26.98	3.2
BC	4.37	2.9			2.38	2.3	5.95	3
BD	1.59	2.1			3.57	2.6		
BE					1.19	2.7		
BF					1.98	2.7		
CA			1.19	2.3				
CB	6.75	2.5	0.00	0				
CC	3.17	2.9						
CD	2.38	2.4	1.19	3.7				
CE								
CF								
DA			0.79	3.5	1.59	3.1	1.19	1.8
DB			2.38	2.3			1.19	3.5
DC					1.59	2.8	1.19	2.5
DD			1.19	3.3	0.79	2.3		
DE			0.40	4	6.35	3.44		
DF			0.40	3	1.98	2.8		

Question	12		13		14	
WAWR	N	CR(TB)	N	CR(TB)	N	CR(TB)
AA	6.75	3.5	11.11	3.2	1.19	4
AB	3.57	3			2.38	2.3
AC	5.16	2.6	25.40	3.7		
AD			4.76	3.6	2.78	3.2
AE					1.98	3.5
AF					1.19	3.2
BA	11.51	3.6	1.59	3.5	1.19	3.8
BB	9.13	3.2			1.19	2.5
BC	9.52	2.9	10.32	3.3		
BD			4.37	3.4	3.17	3.1
BE					7.54	3.2
BF					1.19	3.5
CA			2.38	3.4	0.79	2.5
CB					5.95	3.3
CC			3.97	3.4		
CD			1.19	3.5	8.33	3.4
CE					1.98	2.5
CF					0.40	2.5
DA						
DB						
DC	2.38	2.2				

Question	15		16		17	
WAWR	N	CR(TB)	N	CR(TB)	N	CR(TB)
AA			1.19	3		
AB	2.78	2.6	5.56	3.3	3.97	2.3
AC	3.97	3.1	3.97	2	23.41	3.6
AD	1.59	3.3			0.79	2.5
AE						
BA						
BB	8.73	3.1				
BC	11.11	3.4				
BD	9.13	3.4				
BE						
CA			2.38	3		
CB			5.16	2.7	1.98	3
CC			5.56	2.6	5.56	2.9
CD					2.38	2.7
DA			1.98	3.3		
DB	3.97	2.8	6.35	3.8	10.32	3.6
DC	3.57	3.1	2.38	3.3	14.68	3.1
DD	3.17	3			2.38	3.1
Question	18		19		20	
WAWR	N	CR(TB)	N	CR(TB)	N	CR(TB)
AA			4.37	2.8	3.97	3.1
AB	13.49	3.2	4.76	2.8	7.14	2.9
AC	10.32	3.1			17.06	3.2
AD	9.13	3.4			7.94	3.1
AE					5.95	3.7
BA			9.13	2.5	0.79	1.8
BB	2.78	2.6	8.73	2.6	5.95	2.9
BC	3.17	2.6			5.16	2.2
BD	1.98	2.5			5.16	2.5
BE					3.17	3
CA						
CB	8.33	3				
CC	3.97	3.1				
CD	4.76	3				
DA			3.97	3	0.40	3
DB			3.17	3	4.76	2.9
DC					3.57	3.3
DD					2.78	3.6

Appendix O. The percentage of UK students selecting **wrong answer–wrong reason (WAWR)**

Question	1		2		3		4	
WA-WR	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)
AA	1.20	3.5	1.20	1	18.07	2.3	1.20	4.5
AB					10.84	2.2	1.20	2.5
AC	1.20	2.5	2.41	1.5	2.41	2		
AD							1.20	2
BA					7.23	3		
BB					6.02	2.3		
BC					3.61	2.2		
CA	2.41	2.5					2.41	2.3
CB	2.41	3.3					1.20	3
CC	2.41	2.5						
DA			1.20	1				
DB								
DC			4.82	1.8				
DD								

Question	5		6		7	
WA-WR	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)
AA			56.63	3.1	3.61	1.7
AB						
AC					1.20	1.5
AD						
BA						
BB	1.20	3.5				
CB			10.84	2.6		
CC					2.41	1.8
DA			1.20	2.5		
DB					15.66	1.9
DC					2.41	2
DD	2.41	2.5	6.02	2.9		

Question	8		9		10		11	
WA-WR	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)
AA			3.61	2.7			22.89	3.1
AB	2.41	3.3					1.20	2.5
AC	2.41	2			1.20	2.5	1.20	2.5
AD	2.41	3.5						
AE			2.41	1.8	1.20	2.5		
AF			4.82	2.8				
BA							19.28	2.8
BB							19.28	2.8
BC	1.20	1			1.20	1	2.41	2.5
BD					1.20	1		
CB	2.41	1.3	1.20	2				
CC								
CD								
CE								
CF			1.20	2				
DA					2.41	2.5	1.20	2
DB			6.02	2.3			2.41	1.5
DC					4.82	2.4		
DD					3.61	2.7		
DF			8.43	2.6	1.20	3		

Question	12		13		14	
WA-WR	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)
AA	36.14	2.8	6.02	1.9		
AB	2.41	1.8				
AC					6.02	3.4
AD			1.20	1	1.20	3
BA	28.92	3.1			3.61	2.3
BB	2.41	2.8				
BC	3.61	1.3	2.41	2.5	7.23	2.5
BD			8.43	2.5		
CB					1.20	2.5
CC			3.61	2.7		
CD			8.43	2.6		
CE					1.20	2.5
CF						
DA	2.41	3.3				
DB	3.61	2.3				
Question	**15**		**16**		**17**	
WA-WR	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)
AA			15.66	2.2		
AB			1.20	1	2.41	2.3
AC	1.20	3			1.20	3
BC	2.41	3.3				
BD	2.41	3				
CA			2.41	3.5		
CB					1.20	2.5
CC			1.20	2		
DB			2.41	2.5		
DC					3.61	2.2
DD					1.20	1
Question	**18**		**19**		**20**	
WA-WR	N (%)	CR(TB)	N (%)	CR(TB)	N (%)	CR(TB)
AA			4.82	2.5	2.41	1
AB			1.20	1		
AC	2.41	2.3			21.69	2.3
AD	3.61	1.7			4.82	2.1
AE					2.41	1.8
BA			8.43	1.5	1.20	1
BB	2.41	1.8	8.43	2.2	4.82	1.4
BC	3.61	2.3			2.41	1.5
BD					3.61	1
BE					1.20	1
CB	1.20	3				
CC	2.41	1.8				
DA			2.41	2	1.20	1.5
DB			3.61	2	2.41	1
DC					7.23	1.7
DD					3.61	2.2
DE					6.02	1.6

N = the percentage of students who selected wrong answer-wrong reason combination
CR(TB) = Confidence rating