CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

The twentieth century has often been described as the information and knowledge age due to the rapid development in information and communication technology (ICT). These changes have caused great impacts in our lives, thus ensuring that the development of ICT will continue in the new millennium and revolutionalise all aspects of human endeavours. According to Lasonen (2001), globalization, internationalization and development of ICT will shape the occupational structure, influence education and training programs as well as pose challenges in curriculum design in terms of cultural diversity and cosmopolitan education. Our society's future and survival depend on the nation's ability to withstand the forces of globalization, internationalization and development of ICT.

Science and technology is an important tool to withstand the forces mentioned above (Soon 2003). As stated by Goldberg et al. (2001), in a global and knowledge based economy, the levels of scientific and technical skills needed in all countries are constantly increasing. For a country like Malaysia which is moving into an advanced post-industrial and knowledge-based society, there is a need for Malaysians to meet the ever growing demands of highly skilled and trained personnel in science and technology who are also well versed in the use of ICT. Training institutes must work in tandem with the government policy makers in order to tailor programmes that can produce the manpower with the skills and knowledge required in order for our country to be able to compete in the ever increasing competitive and borderless world. One of the most appreciated methods is developing the curriculum and training materials based on what the industry wants. The traditional education methods of acquiring scientific knowledge are no longer adequate to cope with the development of science and technology of the twenty first century (Chiu, 2007).

In response to the rapid accelerated advancement and development of ICT, the Malaysian government has a national ambition called Vision 2020, the purpose of which is to attain a fully developed-nation status by the year 2020 (Mahathir, 1998). However, this is not an easy task to carry out. This ambition can only be realized if the nation can overcome strategic challenges such as the challenge of establishing a scientific and progressive society, a society that is innovative and forward looking, one that is not only a consumer of technology but also a contributor to the scientific and technological civilization of the future. To achieve the substance of Vision 2020, the government has set up a blue print for the Multimedia Super Corridor (MSC). Implementation of MSC which was conceptualized in 1996 is Malaysia's most exciting initiative for the global ICT industry. The MSC Malaysia is divided into three phases from 1996 to 2020. Generally, the main aim of MSC is to act as a dynamic ICT Hub. It tries to attract leading ICT companies of the world to locate their industries in this unique corridor and undertake research to develop new products and technologies and then export them from this base. Malaysia is hoping that by the year 2020, she can move into leadership position in the knowledge economy where twelve intelligent cities will be linked to the global information highway. To spearhead the development of the MSC and give shape to its environment, seven initiatives for multimedia applications have been identified. These initiatives are borderless marketing, smart schools, electronic government, multi-purpose card, telemedicine, research and development as well as worldwide manufacturing webs. Of these, the smart school initiative is a specific response to Malaysia's need to make the critical transition from an industrial economy to a knowledge-based society (Mahathir, 1998). By launching MSC Malaysia on 1st August 1996, our former Prime Minister, Tun Dr Mahathir had pointed out the three core visions of the smart school flagship application (Mahathir, 2007), which are:

(a) Teachers will need to change their role in the electronic classroom from being information providers to counselors to help students develop skills that enable them to know how to make judgment and select information sources.

(b) Key to success in the information age will be making the right judgment between awesome arrays of choices.

(c) Examining our education system to create a curriculum where people learn how to learn for continuing education throughout their lives.

It is hoped that this initiative will enable Malaysia to produce the required skilled personnel who would be able to harness the benefits and the potential of ICT in order to attain the "smart" Malaysian society in 2020. Besides the smart schools initiatives, the Ministry of Education (MOE) Malaysia has also introduced ICT courses in 1999 as an optional subject in all secondary school at Sijil Pelajaran Malaysia (SPM) level which is equivalent to the "O" level with the intention to equip students with the fundamental IT knowledge and skills.

1.1.1 Chemical Education

How does chemistry fit into all these new developments? For a developing country like Malaysia, chemical education is much needed for several reasons:

(a) To satisfy the needs of chemical industries so that targets in development can be met.

(b) Chemistry is also needed to solve problems created by industrialization and to maintain sustainable development.

(c) Public awareness of chemistry and its impact to our lives.

It is hoped that chemical education in our country can provide our younger generation with a strong awareness of the importance of chemistry. Chemical education in Malaysia must also be able to produce both professional chemists that are competent to solve scientific problems created by the industries as well as a society that is chemistry-literate and capable of making good decisions in their daily chores. As reported by Soon and Quek (2003), it is important for the society in general to know basic chemistry so as to understand the applications of various chemical principles in their daily lives. The role of chemistry educators in achieving these targets is crucial to the welfare of the society. Hence, chemistry has to be made more attractive in order to draw more talented people into this field of study.

With the increasing role of science and technology in economic development and environment, chemistry is expected to play a crucial role in scientific and technological development in the new century (Chen, 2002). Kiang (1992) and Grossman (1999) attributed chemists to be the only group of people who could create new chemicals and new materials from different starting materials and thus making new materials with new properties. This is the most important aspect of chemistry. Lagowski (2002) and Wang (2002) stated that chemistry is the central science, related to all branches of science. This is supported by Shani (2003) and Liu (2009) who also said chemistry is almost everywhere and in everything. Goh (2004) stated that chemistry is life as life is chemistry. Recently, the slogan used in the 42nd International Chemistry Olympiad was "Chemistry: The key to our future" and Noyori (2010) also said that chemistry brings us through the chemical industry, cutting-edge products that will enrich our daily life. Thus, it is a well-known fact that chemistry plays a very important role in solving our daily life problems. In general, by definition, chemistry is the science of materials, their formation, behaviour, properties and application. Hence, any subject that deals with materials is based on or related to chemistry. It is the essential science that provides a common thread through almost all fields of applied sciences. Understanding of the chemical structures, their physical characteristics and chemical behaviour at the molecular or atomic levels is important for the development of all branches of modern science which will provide solutions to problems in many aspects of life.

How would ICT development help in chemistry? The easy availability of information via ICT impacts the work of every chemist significantly. In this new millennium, scientists including chemists need to be more multitasking than they used to be in the old days. Scientists including chemists need to measure and communicate, to handle information and model ideas. They need to process information. Zielinski and Swift (1996) stated that no discipline has become more dependent upon computing for its practice than chemistry. They said that the extensive use of computers in chemistry has created an important set of essential competencies required of all chemists. Thus, chemists in their work places must have a core set of computer skills in order to pursue their careers effectively. Chemists should be extraordinary and exceptional in applying computers and its software to their respective research and invention. Advances in computational chemistry, storage and manipulation of data, 3-D structures modeling and simulation have enhanced and contributed tremendously to the work and career of chemists in their research and development.

The advancement of ICT could also help to enhance the learning of chemistry. Soon (2003) said that the rapid advances recently made in ICT have become a very powerful tool in chemistry education and research. In today's ICT enabled learning environment, conventional training programmes to produce technically competent teachers are no longer adequate. Teachers and students must be equipped with ICT knowledge and move from being passive users to active contributors. We can visualize chemical concepts in ways that were impossible only twenty or thirty years ago. Chemical concepts that were once purely mental abstractions (only the gifted could see) can now be visualized and discussed using graphical software tools. We can implement aspect of ICT not because it is ICT but because it offers us a more effective method of presenting and exploring chemical ideas. In chemical education, two aspects, content and processes must be addressed. Content signifies the chemical ideas that we use to interpret and predict. Processes are the experimental methods we use to investigate these ideas. ICT can assist us in both aspects, the presentation of ideas and the means to experiment more effectively and reliably.

In order to provide our students with a quality education and benefit from the applications of ICT in chemical education, it is important that our students be well equipped to face the technology-rich world in which they live in and that teaching must be carried out as more than just mere transmission of information. Students will need to have a solid knowledge in chemistry and apply the knowledge in their work and life. In addition, students should also be information literate and possess the necessary ICT, communication, thinking and problem-solving skills. Frost (1994) said, “when teachers started using technology in class, other advantages became apparent. When their pupils became fluent in using sensors, the computer offered a new insight into science”. They gained something that helped them to understand and encouraged them to explore.

The future prospects of ICT in chemical education have become more and more important and we shall look forward to a very exciting and challenging time in the chemistry classroom. Hence, chemistry teachers in Malaysia should catch up with the trend of the world and use new teaching strategies. Extensive use of ICT in chemistry teaching which transcends boundaries of traditional topic and enable the students to cope with the information age needs to be developed.

1.2 THE IMPORTANCE OF THIS STUDY

The processing of information effectively enhances learning. Students will not be actively engaged with a particular topic and the retention of concepts is minimal if only lecturing is used in teaching and learning. Hence, chemistry educators nowadays need to be more ‘multitasking’ than before. The challenges for chemistry teachers today are to find ways to design a dynamic learning environment that involves active participation of students in doing and thinking. A more effective and interesting method to study chemistry to increase students’ appreciation of how the material world behaves must be developed. These methods should focus on the need for the students’ active participation in learning scientific concepts, developing scientific and thinking skills as well as inculcate moral values and scientific attitudes. To construct a better understanding of the contents, students' active involvement should go beyond taking notes, doing experiments and drilling exercises. More importantly, the students need to be engaged in thinking rather than memorization or rote learning. There is no doubt that rapid advances made in ICT have very important implications for us as chemical educators (Hollingworth, 2002(b); Hollingworth, 2002(c); Soon, 2003; Barak, 2007). With the current advancement in technology and widespread access to personal computers comes a real opportunity to ease the mathematical burden associated with learning chemistry. The trends therefore require a movement away from the content driven curriculum to one that provides individuals with the skills necessary to engage in life long learning. In other words, the education environment as we know it today will have to change with new realities and new learning needs.

From the previous discussion, it is clear that ICT should be and could be used to stimulate students' thinking by making the contents relevant or of greater value. However, there is currently much debate around how best to incorporate ICT into the education program. Rapid advances in ICT demand changes to our education system. Hence, it would be a tremendous advantage for students and teachers to exploit the full potential of ICT so that the learning of chemistry becomes more productive and effective. Although the offer of new tools using ICT in teaching has grown so fast, their practical uses in the class room remain uncommon in chemistry teaching (Rani & Jean Francois, 2009). Knight et al. (2006) stated that computer technology has been absorbed into schools but in many instances teachers simply deliver old lessons in a new format and rarely fully capitalize on this technology in their practice. This phenomenon is also true in Malaysia (Siti Norazlina, 2008; Rosnaini et al., 2011; MOE Malaysia, 2010; Moses et al., 2012).

At present, large quantities of multimedia educational courseware for different subjects are available. The question is, are all the coursewares suitable for our students who come from different cultural backgrounds? Furthermore, the quality of these available coursewares may not have been properly evaluated and their suitability for students has not really been systematically determined. In addition, many of the educational coursewares in the market are developed by multimedia specialists and programmers who may not be experts in the content of the subject. Some coursewares are even just imported from overseas following the syllabi of the country which are not suitable to be used locally. In a paper by Jonassen et al. (1994), they reported that the effectiveness of media should not only focus on the role of the media but also the process of learning and the kind of the learning environment. As stated by Prieto et al. (2011), the increasing presence of multiple ICT in the classroom does not guarantee an improvement of the learning experiences of students unless it is also accompanied by pedagogically effective orchestration of those technologies. In evaluating the value of coursewares, Morse (1991) and Cartwright (1997) believed that not only should the coursewares be well-designed but there must also be a match between the objectives of the coursewares with the understanding of the teacher as to how to apply it as well as the needs or interest of students. In Malaysia, teachers are still at the stage of using pre-prepared software which may not meet their needs (MOE Malaysia, 2010). **Hence, what should be encouraged is for teachers to create their own teaching materials in order to build this much needed capacity.**

There are many computer-based instructional supports in chemistry that addresses some of the teaching and learning difficulties. For example, there are thousands of Java applets (program written in Java) available on the web that illustrate concepts in chemistry. However, the disadvantage of Java applets is that they require a browser or another Java application to run the software (Kamthan, 1999). It is difficult to keep those applets compatible with the many different versions of the Java runtime environment supported by existing browsers (Robert, 2007). Moreover, teachers need to have knowledge of Java, a programming language based on C++ to create their own applet. Beside Java, there are numerous software systems available such as Mathematica, Matlab, Maple, Microsoft Studio, Net 2005, 2008 etc, which can be used as effective teaching tools but the researcher prefers to employ Microsoft Excel software system for the present investigation. This is due to the reason that MS Excel, is one of the software system included in the MS Office product and is available in almost all personal computers running Windows operation system in Malaysian schools. Besides, MS Excel has a user friendly and highly functional Graphical User Interface. The ability to write custom code in languages such as Microsoft's Visual Basic for application has also made MS Excel a very powerful tool to be used. Beginners can easily master its usage with its user friendly features. Users can also modify the spreadsheet according to their needs. According to Gibbs (1994), modern spreadsheet packages such as Excel have provided practical solutions for the general problem of making available the power of computers for data processing by large numbers of students in physical science courses. Lehmann (2002) stated that students can use Excel program to gather data from scientific experiments and then sort it to analyze the resulting patterns, in addition to many other uses. Instruction in programming languages such as FORTRAN, BASIC and PASCAL are no longer necessary for the bulk of data processing involved in chemistry. Spreadsheets have a vital role to play in the development of chemistry literacy as they enable individuals to explore data relationships in a customized manner.

MS Excel spreadsheet permits relatively complex calculations that meet the needs of most chemistry courses and many of the smaller research problems. Hence, it has become necessary as they enable scientists including chemists to explore and manipulate the relationships of chemical data in many ways. MS Excel spreadsheets do have many inbuilt statistical and mathematical functions which could be exploited to enhance the effectiveness of teaching and learning chemistry. According to Diamond and Hanrathy (1997), MS Excel provides a marvelous environment for the development of teaching material where teachers can use their creativity to develop their own teaching courseware. MS Excel is especially useful for answering the “what if?” questions such as in changing numbers to examine alternative scenarios. As mentioned earlier, recent spreadsheet software innovation have produced the intuitive graphical interface with pull-down menus, icons and dialog boxes that made it easy to manipulate data and produce result. The dynamic graphing function of MS Excel can quickly perform mathematical calculations and display the results in graphical form. It provides students with visual representations of what the results obtained mean. Also through variation of inputs and modification of parameters, students can immediately see the implications of these changes graphically. It could thus help the teachers to spare a lot of time in describing the topic at hand. Also, with such demonstrations, students would be encouraged to join in the activities, to try out their own ideas and immediately obtain the feedback. They could spend their time experimenting, observing and thinking rather than merely listening, calculating and rote memorizing of facts.

Since MS Excel implements features and functions that are useful for the development of interesting worksheets, teachers are encouraged to explore, adapt and adopt MS Excel as a tool for data analysis and teaching chemical concepts. This will significantly enhance the teaching and learning of chemistry in schools.

1.3 OBJECTIVE OF THIS STUDY

The effective transfer of knowledge from teacher to student is the ultimate educational goal of educational software developers. The effective integration of ICT in teaching and learning depends to a large extent on the teachers' knowledge and familiarity with its potential. Hence, as a chemistry teacher, he or she needs to know exactly how ICT could be used as a teaching and learning tool for their own purposes and to help students to use them.

MS Excel, as a 'world ware', is available in almost all personal computers running Windows operating system. Many studies have been carried out on the application of MS Excel to assist teaching and learning and the finding showed that MS Excel could help to enhance and improve the process of teaching and learning especially for mathematics and science based subjects (Kamisah et al., 2006). However, the use of MS Excel in teaching chemical concepts and problem solving amongst Malaysian teachers is rather lacking (Sharifuddin, 2002). There has not been much work on developing teaching tools using the MS Excel program in Malaysia.

The objective of this research is to explore, develop and demonstrate how MS Excel could be adapted and used by teachers to create simple worksheets which can help in the teaching and learning of chemistry. Simple default functions, controls, charts and macros available in MS Excel were used to create the worksheets that could be used as a tool to experiment and understand chemical concepts better. A few topics chosen from physical and inorganic chemistry in the Form Six and first/second year university syllabi are presented. Teachers can use these worksheets as a teaching tool in the chemistry classroom. The effectiveness of the worksheets developed in this research was also tried out in the field study. It is hoped that these capabilities and capacity of Excel spreadsheets in aiding the learning and understanding of various basic concepts in chemistry will help teachers in delivering abstract chemistry concepts effectively and to motivate students' interest in studying chemistry.

1.4 THE SIGNIFICANCE OF THIS STUDY

Given the advantages of MS Excel program in the teaching and learning of chemistry, it would be beneficial to further explore the potential use of MS Excel program in Malaysian secondary schools. The information gathered in this work will certainly provide valuable feedback to the authorities concerned in the Ministry of Education and the ICT unit in the Curriculum Development Centre, School Division on the feasibility of using the MS Excel program in Malaysian science education curriculum.

By using MS Excel to demonstrate various chemical concepts, it is hoped that teachers will obtain a better picture of the advantages of MS Excel in chemistry teaching and learning since chemical concepts that are abstract and difficult to understand can be delivered more effectively through computer simulation and graphics presentation.

The findings of this study will also demonstrate to chemistry teachers that MS Excel could be used as a tool to help and enhance the quality of their teaching in class and encourage more researchers to widely utilize MS Excel spreadsheets program in chemical education to improve teaching. It is hoped that more teachers will be able to develop the capacity to solve problems and create effective and entertaining teaching aids using this widely available spreadsheet package.

1.5 SCOPE OF STUDY

This study focuses on exploring certain features and functions of EXCEL which can be adopted and adapted for the use in teaching and learning of chemistry in Malaysian schools. Only simple default functions, ‘Active X’ controls, charts wizard, hyperlink function, simple macro and some built in mathematical functions in EXCEL were employed to create worksheets as a teaching and learning tool.

Topics in chemistry were limited to reaction kinetics, gas compressibility, distribution of molecular speed of gas, period three elements, qualitative analysis, spectroscopy and chemical equilibrium chosen from Form Six and first/second year university chemistry. The kinetics worksheets were tested in 12 different schools in Negeri Sembilan, Malacca and Muar whilst the spectroscopy worksheet was tested in various local universities as a field study.

CHAPTER TWO

BACKGROUND OF THE STUDY AND REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

To date, there has not been much research being carried out on the use of MS Excel spreadsheet program in enhancing teaching and learning of chemistry in Malaysia although it is proven to be a powerful software that offers many advantages. Studies concerning the effectiveness of MS Excel in teaching and learning of chemistry are also lacking despite the fact that much work had been carried out internationally. In this chapter, discussion will be focused on the background of this study and related literature review on the use of spreadsheet programs and MS Excel in education.

2.2 THE IMPORTANCE OF ICT IN EDUCATION

As mentioned in the introduction, rapid developments in ICT are leading to the emergence of an information based society. These changes have created great impacts in our lives including the way we learn and think. ICT if used appropriately can facilitate students' collaboration and enhance knowledge building. Many countries now regard understanding ICT and mastering the basic skills and concepts of ICT as part of the core of education. For example in Finland, the effects of implementing new technology to support education and learning have been positive. Almost all teachers and students would be willing to use new technology in teaching and studying (Sinko & Lehtinen, 1999). Tapscott (2003) said that the new generation grows up with technology. They are called "N-Gener" who is comfortable with new technology. Hence, the infusion of ICT into education is gaining popularity as an effective platform for enhancing the teaching and learning process (Mai, 2001).

The role of ICT in education is commonly associated with the process of educational innovation. As mentioned by Neo (2001), the more technologically-innovative is the information delivered to the students, the better their retention and attention levels will be. Hollingworth (2002b) said that use of ICT in the learning process will bring a major shift in the education paradigm that promises advantages over the conventional learning system where, computers in education is slowly taking over those traditional teaching aids such as the overhead projectors, photographic slides, charts and many others. According to Soon (1988), the advantages of computers over the other teaching aids include:

(a) The ability of the computers to store and manipulate a large amount of data within a matter of a few seconds.
(b) Computers can also 'interact' with users/students by the use of appropriate software.
(c) A computer is also flexible in that it may act as an overhead projector, charts, tables, slides all rolled in one.
(d) With the increased availability of education of material and software, computers could be applied within the whole range of the school curriculum.

Whilst Haslina et al. (2000) said that the goals of introducing technology into education are:

(a) To keep the education system at the forefront of technological development and students' skills up to date with those expected in the workforce.

(b) To increase efficiency and productivity in teaching and learning.

(c) To enable more self-directed learning with students as active learners assisted by teachers to construct their own understanding.

Computer simulation and animation are usually excellent tools for education (Chung & Newman, 2000). With the visual power of simulation available in a computer, it can generate images which can help students to understand "Why things are the way they are" (Cartwright, 1997). By using computers in instruction, information can be displayed effectively (Ong, 2000) which enables students to understand concepts easily, especially concepts that are abstract which could be made easier through graphics and computer animation with multimedia effects. Multimedia applications, according to Mohd. Zaliman and Manjit (2001) are able to arrange the information into facts that are non-structured which would enable students to achieve or get information on their own whilst Mohd. Arif et al.(2005) stated that using ICT in the instructions could nurture the creative and innovative mind of students to access information from various resources.

The success of multimedia technology has revolutionized teaching and learning methods from the traditional teacher-student classroom to a virtual setting (Yong Zulina et al., 2000). The role of the educator will evolve into that of facilitator and knowledge director while the students become more independent learners, critical thinkers and better team players and collaborators, with the skills to solve problems and seek information (Tino, 2007). Haslina et al.(2000) observed that using multimedia technologies help students to develop a wider and deeper understanding of the subjects they are learning. Interactive software can also stimulate the utilization of higher level thinking skills. This aspect provides a rich and powerful set of tools where students can use to test and investigate theories of their own apart from progressing through any lesson in the software. Hamidah (2001) strongly agreed with that by saying “Every aspect of human life today is controlled by technology”. The present generation requires an extra skill, namely technology literacy in order to survive in this technology-based era. Therefore, as an educator in this age of digital information and technology, our boundaries for teaching have been expanded to the point that teachers not only have to be proficiently knowledgeable in their fields but also skilled in technologies that are being used to convey the information. A survey of middle and high school teachers in Australia indicated that encouraging teachers, by giving them specific training in the use of ICT, enhanced their teaching methods (Dickson & Irwing, 2002). In the context of science education, it offers possibilities for interaction with the nature and tools for real-time data logging (Juuti et al., 2009). In an article published by the Ministry Of Education of Singapore (MOE Singapore, 2008), it was emphasized that the appropriate use of ICT in mathematics and science can assist in making knowledge come “alive” by making visible the metacognitive or thinking processes of both teachers and students.

With the emergence of countless technologically sophisticated tools and devices in our lives now, there is a serious need to produce ICT skilled future generation urgently. ICT that is used for deeper learning and that support a challenging curriculum will result in improved teaching and learning, increased student motivation and higher levels of student achievement. There is no doubt that the future trend in educational methodology and strategy is towards integrating technology into the classroom rather than the traditional strategy which emphasises on drilling and memorizing facts (Norton

& Wilburg, 2003). It would be a tremendous advantage for students and teachers alike to exploit the full potential of multimedia and ICT so that the learning environment becomes more productive and efficient (Baxi, 2008).

2.3 INTEGRATION OF ICT IN CHEMICAL EDUCATION

One of the goals of research in chemical education is to provide information on how chemistry can be meaningfully introduced to students, to identify the causes of impediments to learning chemistry, how learning and teaching chemistry occurs in the classroom settings and how teachers can improve their instructional techniques in an attempt to promote better chemistry education.

Hollingworth (2002b) and Soon (2003) said that rapid advances recently made in ICT are of particular importance in chemistry education. According to Mahaffy (2005), diverse forces have shaped the teaching and learning of chemistry at the beginning of the 21st century. In response to these forces, new dimensions to learning chemistry must be emphasized. Educators have to accept changes in their interactions with students and have to support students as their roles changes. Therefore, teachers need to be armed with the necessary knowledge and skills to stimulate the learners and to develop their technological skills. As stated by Bucat (2003), chemistry is a complex subject and understanding chemistry is characterized by a wide variety of dimensions of knowing, and understanding the complexity of interaction between them. Chemistry needs to be understood from a variety of interacting perspectives. Thus, teaching chemistry requires unique demands. Chemistry teachers have to be smart to use the most appropriate strategies to ensure the understanding of concept by students. In most cases, to make students understand invisible concepts, visualization is imperative. Lerman (2001) is of the same opinion when he said that in chemistry, visualization is extremely important since the subjects deal with atoms and molecules which are invisible. Over the centuries, different models have been produced to help scientists, students and the general public visualize the invisible. Recently, when we talk about chemical visualization, we typically mean computer models.

The educational value of the ICT in chemical education was confirmed by various empirical studies. For example, a study done by Waddick (2002) showed that for seven years at Otago Polytechnic, the entire first year chemistry course that has been taught using ICT was successful not only in supporting students learning but also in improving students attitudes towards chemistry. Study done by Aksela (2005) provided evidence that rich learning environment through computer-assisted inquiry approach could engage senior secondary level students in meaningful chemistry learning and higher-order thinking. An experimental study which involved college students of engineering in University of Mindanao carried out by Jubilo (2007) indicated that students who used the general chemistry software instructional aid have gained significant scores in the post test as compared to those who did not use. Norasiken and Halimah (2007) investigated the effectiveness of VLab Chem virtual laboratory software also indicated that students from an experiment group using VLab-Chem virtual laboratory based on constructivism-cognitivism-contextual approach showed higher achievement than the control group that using conventional lab. In a case study conducted by Barak (2007) to investigate chemistry instructors' perceptions towards ICT and their activities while practicing newly introduced technologies, he showed that instructors agreed that integrating ICT learning environments was successful and should be recommended into the chemistry curriculum in post secondary school. Oyelekan and

Olerundare (2009) from University of Ilorin, Nigeria have done a research to validate a computer instructional package on electrochemistry for secondary schools in Nigeria. In the study, the contents of electrochemistry for secondary school were packaged into a CD-Rom which were used for teaching and learning in the class. The result of the research showed that the package was found to produce a very good performance level of the students when used for electrochemistry instruction. A similar study was also carried out by Sa'adah (1998) to see the effectiveness of using interactive multimedia program in electrochemistry for Form Four Malaysian students. She observed that students find electrochemistry difficult to master since they could not imagine or observe what happens at the microscopic level in an electrochemical reaction. Interactive multimedia program that has been developed for electrochemistry helped students achieve better conceptual understanding of the processes that occurs in the electrochemical cells. Kargiban and Siraj (2009) had also carried out a study to survey the experts' view towards integration of ICT in chemistry teaching in Iranian high school. The findings showed that the surveyed experts had very positive views and comments towards ICT for its effectiveness in changing the learning environment. It provides new opportunities for chemistry teaching and opportunities for interaction and communication. In addition, the findings obtained in King's study (2011) verifies that the ICT-integrated environmental learning has a more significant effect on the students' chemistry learning.

2.4 ARE MALAYSIAN TEACHERS PREPARED FOR ICT?

Zhao et al. (2004) showed evidence to suggest that attitudes of teachers towards ICT are directly related to computer use in the classroom. Success of students' learning in using ICT depends largely on teachers' attitudes toward ICT as well (Teo, 2006). Many countries now regard the mastering of ICT as an inevitable part of education. Are our teachers and students ready for this radical shift of approach to learning and problem solving? What innovation is taking place in our schools that will create opportunities for exploring and developing new strategies in teaching and learning? Although ICT plays an important role in the teaching and learning process in this new era, its use in Malaysian secondary schools is only in its infancy even though the introduction of computers in education and other various computer- related projects have begun since the early 80's in more advanced countries. Although there has been a strong push to have teachers trained and to supply educational software and hardware into the hands of teachers, many obstacles to implement the use of ICT in schools still exist. By launching the smart school program in the year 1996, it is hoped that teachers in smart schools can make full use of ICT in their instructions by changing their role in the classroom from being an information provider to a facilitator in helping students to develop skills that would enable them to solve problems.

Several studies have been carried out in Malaysian smart schools to investigate teachers' perception on implementing ICT in teaching and learning and the computer literacy of teachers in schools. A study carried out by Hee and Norahidah (2001) in three smart schools in Terengganu State indicated that computer literacy of teachers involving 52 respondents is moderate. Majority of the teachers knows how to use basic computer program such as MS Word and MS Power Point. Another study carried out by

Zahidi and Mohd Rosly (2001) in Tengku Muhammad Faris Petra Science School which involved 40 smart school teachers showed that 95% of the teachers agreed that using new technology with computer animation can improve students' learning. From 40 respondents, 67.5% of the teachers have computer skills and responded positively towards using computers in the process of teaching and learning. Mohd Izham et al. (2001) had carried out a survey to examine the use of computer assisted learning (CAI) software in teaching and learning science among 80 teachers from different smart schools from three states (Pahang, Selangor & Wilayah Persekutuan). The result of this study indicated that science teachers have positive attitudes towards the use of CAI software in teaching and learning science. They also have knowledge in using the software but they lack the skills to develop software on their own. In the same year, Sathiamoorthy (2001) carried out a study to investigate the level of computer integration into teaching and learning. A sample of 74 teachers from 12 smart schools across the country that participated in this study showed high awareness of the innovation. Over all, 49% of the smart school teachers possessed high managing ability in computer integration. In addition, study done by Samuel and Zaitun (2006) to investigate the utilization and integration of ICT tools in teaching at three smart schools in the Kuala Langat District and a study carried out by Mahani (2006) to assess the level of usage of electronic information sources and services by smart school teachers in Selangor state revealed that respondents were only moderately competent in ICT skills. Majority of them had a middle level of competency in operation software application and programming languages. The results of their study also showed that teachers were mainly dependent on CD-ROMs supplied by the Ministry Of Education. A study carried out by Ministry of Education in 2010 to investigate the usage of course wares supplied by Curriculum Development Centre to all smart schools in Malaysia also showed that low utilization of course wares in the classroom for all the subjects although most of the teachers in smart schools were aware of the importance of ICT in education. Teachers who use the coursewares were found to have not integrated the coursewares innovatively in their teaching (MOE Malaysia, 2010). Study carried out by Rosnaini et al. (2011) in three smart schools in Malaysia showed that ICT-integrated learning environment is still at moderate level.

Beside smart schools, there were also studies carried out to investigate the application of ICT in local secondary schools and the results showed that although most of the Malaysian teachers show positive attitude towards application of ICT in teaching and learning, they still lack the technological skills and require improvement (Norizan, 2000; Aidah, 2001; Norida, 2001; Norizan & Mohd Amin, 2001; Mohd Jasmy et al. 2003; Norin, 2004; Liew, 2005; Nurmala, 2006). Teachers are still very much dependent on the coursewares supplied by Ministry Of Education which may not fulfill the objective of the lesson. As stated by Norizan (2000), teachers in schools today not only have to have the knowledge of computer-based technology but must also be competent in various computer applications. According to Rosmah et al. (2001), many teachers in schools are aware of the importance and advantages of ICT but some teachers felt reluctant to use new technology in class giving reasons such as time constraint to finish the syllabus, not enough computers in school and unavailability of suitable software.

From the studies carried out on Malaysian schools, it is clear that at this moment, the use of ICT as a tool to enhance teaching and learning in Malaysian schools is still minimal (Tan, 2000; Hee & Norahidah, 2001; Khalijah et al., 2001; Cheah, 2002; Sharifuddin, 2002; Mohd Arif et al., 2005; Md Nor & Rashita, 2011) although most of the teachers are aware of the importance of ICT and have positive attitude towards integrating ICT in teaching and learning. Nevertheless, the global tendency has shown that MS Excel have been widely used to solve chemical problems and chemical data analysis and has been proven to be a useful teaching and learning tool (Siti et al. 2007). The use of MS Excel which has shown their pedagogical potential has been extensively reported in many education journals. Teachers must be encouraged to use MS Excel to create their own teaching materials that satisfy their needs.

2.5 CHEMICAL EDUCATION IN MALAYSIA

Malaysia can only achieve the status of a developed nation if strategic challenges such as establishing a scientific and progressive society, a society that is innovative and forward looking, one that is not only consumer of technology but also a contributor to the scientific and technological civilization of the future, could be overcome. Hitherto, Malaysia has a relatively low base of scientifically and technologically competent manpower ratio of research scientists to total population; viz 400/million population whilst for Japan it is 6000/million, Germany 4700/million, United Kingdom 3500/million and South Korea 2200/million (Khalijah et al., 2001). The identification of students with the potential to excel in science is crucial as we need to ensure the country's human capital growth is in line with the targeted vision and mission of the nation (Othman et al., 2009). It is expected that it is only through science education that our science and technology capacity could be built upon, with chemistry being one of the major subjects for science students (Khalijah et al., 2001).

However, the scenario of chemistry education in Malaysia portrays a sad picture. There is declining enrolment of students in studying chemistry followed by lower enrolment of pure science students at upper secondary as well as at university level (Khalijah et al., 2001; Wan Yaacob & Mat, 1996). Based on the statistics reported in the Eighth Malaysia Plan (RM 8: 2000-2005), there were only 29.4% of science students in higher education institution. In the Ninth Malaysia Plan (RM 9: 2005-2010), the enrolment of science students at upper secondary school remained at 29.4% whilst the enrolment of science students at pre-university level is only at about 20%. In Sin Chew Jit Poh, Education Minister, Tan Sri Muhyiddin (27 January 2012) said that Deputy Education Minister, Dr Mohd Puad Zarkashi recently reported as saying there was a 37% drop in students taking up science and mathematics and a 29% decline for pure science subjects since 2007, and this situation had continued at the university level. Higher Education Minister, Datuk Seri Mohamed Khaled Nordin in New Sunday Times (12 February 2012) had said that the critical drop in interest in science subjects may stunt efforts to improve technological innovations to make Malaysia a high income country. He had also said that the Science and Technology Human Capital Direction Plan 2020's requirement of 60 per cent from the science stream and 40 per cent from the arts stream had yet to be achieved (Dermawan & Kyra, 2012)

The practice of 'open system' in the Malaysian education system at the upper secondary level in particular have resulted in the enrolment of students taking art-based subjects (such as economics, accountancy, commerce and language-related course, just to name a few) surpassing those who opted to pursue the science-based subjects despite the fact that a significant number of them are actually qualified to do so. Many science students have moved into the art stream in the upper secondary stage since they are not confident in studying science subjects (Lee, 2003). They have the opinion that art-based subjects are supposedly ‘relatively easier’ to study and score. And by taking ‘easier’ subjects, the students are more likely to ace exams and get good results, allowing them to gain easier path for university entrance (Othman et al., 2009).

One major factor contributing to few students choosing science is that the curriculum fails to sustain and develop interest of the students in science. Science presented in school seems to be out of phase with the most recent developments of science and technology, boring and unchallenging. A survey carried out by the School Division in the Ministry of Education (MOE) indicated that one possible reason why students give up studying science is that the transmission of facts are carried out in a manner that does not develop the students’ epistemological understanding of science (MOE Malaysia, 2001). Also of importance is the issue of assessment and evaluation. It is felt that heavy dependency on simple numerical data garnered from our traditional assessment practices that currently dominate our educational system serves to undermine many of the aims and objectives of the science curriculum. In short, the current practice does not promote acquisition of science knowledge and skills competently, instead it is rather examination oriented. Furthermore, admission to public universities depends on academic achievements in the public examinations. Eligibility for grants and financial aids are also based to some extent upon the results on the public examinations. Thus, most schools work hard to ensure that a high percentage of their students achieve academic excellence in the public examinations since the schools’ reputation are at stake.

In addition, the lack of understanding and over-emphasis of factual content, which is often not related (or relevant) to the meaningful context being taught probably contributed to making science curriculum in Malaysian schools appear irrelevant to students (Musa, 2007). Many teachers are pressured to finish their syllabus way before the end of the academic year to make sure ample time is given for the students to prepare for their examinations. Many students in fact, merely memorize chemistry concepts without actually learning them. A study done by Liew (2000) on the science students at Universiti Kebangsaan Malaysia showed negative attitude towards chemistry. Basically, students find chemistry a very difficult subject with many abstract concepts especially those involving atoms, molecules or ions in which students find hard to grasp since they could not be visualized easily. Furthermore, the chemistry awareness and understanding in the Malaysian society is still relatively very low (Tang, 1992; Wan Yaacob & Mat, 1996). The result of this poor public knowledge of chemistry may have also contributed to the low enrolment in chemistry at all levels in Malaysian educational system.

Many students in secondary schools and in the universities have difficulties in understanding chemistry. Chemistry can be a difficult subject to teach since students often have negative preconceived ideas about chemistry. Teachers find it difficult to bridge the gap between theory and real chemical processes in a way that promotes interest in the subject. Chemistry, being a molecular science subject with many concepts and processes is difficult to grasp since they are not visible to the naked eyes (David et al., 2000). Hence, visualization would be extremely important in chemistry learning since atoms and molecules could then come alive for the students. According to Deratzou (2006) and Sharipah et al. (2007), visual ability is a prerequisite and essential task in learning and understanding chemistry because visualization process creates a connection between abstract theories and practical knowledge of the students. The concepts underpinning scientific knowledge are often abstract and visualizing a concept or exploring the effect of changing the parameters in a situation, for example, can help students understand scientific phenomena.

It is important to challenge those common misconceptions in introducing and nurturing ideas of chemistry as a central science that can and does contribute to better health and living standards for humanity. In order to meet such challenges, a more systematic and innovative approach has to develop for chemistry education in Malaysia. A good strategy or approach used in chemistry education would contribute to attract, motivate and arouse the interest of students to study chemistry. Thus, teachers must continuously strive to create a more conducive learning environment that enhances students' critical thinking, problem solving and ICT skills. It is hoped that more quality chemistry teachers in Malaysia can come out with new ideas or new methods of teaching where ICT plays a major role in making chemistry more interesting could be produced.

2.6 SPREADSHEETS

2.6.1 A Brief History Of Spreadsheets

In 1978, a Harvard Business School student, Daniel Bricklin, also the 'father' of electronic spreadsheets, came up with the idea for an interactive visible calculator (VisiCalc). He wanted a program where people could visualize the spreadsheet as it is being created so he programmed the first working prototype of his concept in integer basic. This program helped users input and manipulate a matrix of five columns and 20 rows. He then recruited an MIT acquaintance to improve and expand the program which packed the code into a mere 20K of machine memory, making it both powerful and practical enough to run on a microcomputer. On May 1979, VisiCalc which was the first commercial spreadsheet program, running on an Apple II computer was introduced (Leeson, 1994). Visicalc recalculated the numbers automatically in seconds. The ability to ask “What if this happens?” or “How will these changes affect my calculations?” made owning a microcomputer a necessity. VisiCalc became an instant success and provided many businesses an incentive to purchase personal computers.

The market for electronic spreadsheet software grew rapidly in the early 1980s but VisiCalc stakeholders were slow to respond to the introduction of IBM PC that used an INTEL computer chip. In early 1983, Mitch Kapor developed the second generation of spreadsheet program called Lotus 1-2-3. Lotus 1-2-3 made it easier for spreadsheet to be used and it added integrated charting, plotting and database capabilities. Lotus 1-2-3 established spreadsheets as a major data presentation package as well as a complex calculation tool by introducing naming of cells, cell ranges and spreadsheet macros.

The next milestone in spreadsheet innovation is the Microsoft Excel spreadsheet. Excel was originally written for the 512K Apple Macintosh in 1984-1985 and was one of the first spreadsheet to use a graphical interface with pull-down menus and a point and click capability using a mouse pointing device. The Excel spreadsheet with a graphical user interface was easier for most people to use compared to the command line interface of PC-DOS spreadsheet products. Microsoft launched the Excel 2.0 for MS-DOS version 3.0 for windows operating system in 1987 and was one of the first application products released for it. When windows gained popularity with version 3.0 in late 1989, Excel become Microsoft’s flagship product. For nearly three years, Excel remained the only windows spreadsheet program and only received competition from other spreadsheet products in 1992.

2.6.2 What Is A Spreadsheet?

What is a spreadsheet? A spreadsheet consists of rows, usually identified with numbers and columns identified with letters. According to Pogge and Lunetta (1987), spreadsheet program is a matrix cell where the position of every cell can be determined with columns such as A, B, C, ….. And rows such as 1, 2, 3, ….. Grauer and Sugrue (1987) defined spreadsheet as the computer equivalent of paper ledger sheet which consists of a grid made from columns and rows. Simonson and Thompson (1997), on the other hand, described spreadsheet as a ledger used to key in numbers and words in columns and rows as x and y axis. Sanders (1987), Leharne and Metcalfe (1989) depicted spreadsheet as a big chalk board with hundreds of columns and rows while Geisert and Futrell (1995) and Mariam (1995) portrayed spreadsheet as a super conductor that consists of columns and rows in the grid form called cells. It is a program that could handle data with numbers or without numbers or both. Mathematical and physics formulae could be used to make complex calculation easier and faster. Lockard and Abrams (2001) and Power (2004) described spreadsheets to be a large sheet of paper known as electronic paper with columns and rows that organize data which could be manipulated and saved in computer.

Generally, spreadsheets are made up of columns and rows. The column is defined as the vertical space that goes up and down the window. The row is defined as the horizontal space that goes across the window. Their intersections are called cells. Each cell is identified by the column letter, followed by the row number, such as A1 or

AC 5576. This identification is called the cell address. So, "A1" is the cell address for the cell at the intersection of column A and row 1. Each cell could contain various types of data such as text, numbers and/or formulae. The active cell is the cell where the cursor is currently located. Some programs call the cursor a "cell pointer" or "highlight bar". The cursor is moved around the spreadsheet with various keys or a mouse.

2.6.3 Features Of A Spreadsheet Program

Schwinge (1985) described a spreadsheet program as being able to sort data as numbers or alphabets. With this function, users could key-in raw data directly without first sorting them manually. In addition, texts, formulae and numbers could be copied or transferred in a short time. Spreadsheets also provide various mathematical, logical and manipulative statistical functions that can be used in formulae within cells to calculate and manipulate data. Leharne and Metcalfe (1989) also list down the features mentioned by Schwinge but with the addition that enable the spreadsheet program to be used together with word processors and databases. This technique was also corroborated by Beare and Hewitson (1996) who reported the ability of spreadsheet work as a database just like a library which could save and build many functions. The cell are named so that formula created in it could be seen as normal algebra (=b*h) or as words (=base*height). In addition, any changes made in the cell will automatically be recalculated in the spreadsheet program using the last result and the latest graph or chart on the screen will be displayed.

Geisert and Futrell (1995) have listed the following special features of a spreadsheet program:

- Program could be printed in various forms, either on paper or banner.

- Spreadsheet program can display various forms of graph either in two-dimensions or three-dimensions based on the data given.
- Program can produce descriptive statistic and enable inference analysis like Chi square analysis, correlation or t-test.
- Texts document from word processing can be transferred into spreadsheet program and put them into boxes.

According to Colemon (1996), spreadsheet program could enhance student's understanding on graphs since they could observe and discuss about the type or shape of graph. Through this, the students could discover how changes in certain parameters could affect changes in the graphs.

In Malaysia, only a few researchers have raised their opinion regarding the use of spreadsheet program in education. Chan and Lam (1990), Norita (1994) and Mariam (1995) attest spreadsheet programs to have many special features which are user friendly and could be used in teaching which will bring major benefits to the students as compared to traditional teaching strategy. Sivarani (1989), in the study regarding 'Spreadsheets in the Teaching of Science' discovered some specialty of spreadsheet program and concluded them to be as follows:

- The ability to edit content in each particular cell without retyping the whole figure or information again to that cell. When the value in one cell changed, it will automatically be recalculated. This facilities enable students to observe the effect of the changes made and give respond to the question 'what if' or 'how if'.
- The function of recopying the data whether in the form of value, label or formula to another cell or even to different row/column automatically. Formula copied into cell can be done just by *drag and drop*.

- The ability to work with multiple worksheets where a few worksheets can be display on screen at the same time. It also enables data from different workbooks to be used at the same time.
- Spreadsheet program has different stages of protection function; the first being the user keying in the password to start the program. The other protections enable user to lock certain range of cells which they don't want the data to be changed. This function can prevent the data in certain cells from being changed accidentally.
- The function of linking in spreadsheet program enables the main worksheet to be linked with many other worksheets together.
- Spreadsheet program has the macro and program writing ability. Thus, users can use spreadsheet program to develop a template.
- Spreadsheet program has built-in formula called the program function. Users will not have to repeat typing the same formula that is commonly used.
- Spreadsheet program can be used as a database where every row in the worksheet acts as separate record.
- Spreadsheet program enable user to present the data in various forms of graphs such as line graph, histogram, bar chart, pie chart and etcetera.
- Many spreadsheet packages have the same structure and command. Hence, it is easier to convert from one spreadsheet program to another spreadsheet program.
- Spreadsheet program provides a powerful printing function such as 'set-up string' function, etc.
- Users do not require a very good knowledge about computer program in order to use spreadsheet program.
- The data manipulation ability in spreadsheet program provide open exercises for students to do hands-on activities with 'how if' questions.

A long time has passed since these descriptions of spreadsheets. At this moment, the functionality of spreadsheets has surpassed these 'archaic' descriptions and one program has paved its way to dominance in the spreadsheet market – MS Excel.

2.6.4 Microsoft Excel

Although there are quite a number of spreadsheet programs available in the market for the past 15 years, with the emergence of the Windows 95, MS Excel spreadsheet program have appeared to be the most popular microcomputer applications to date. According to Hart-Davis (2007) MS Excel is the most widely used spreadsheet application in the world.

According to Parker and Breneman (1991), Microsoft Excel is an integrated spreadsheet, database and graphics software package. It is a powerful computational tool that extends user ability to perform a variety of tasks for science and engineering including chemistry such as;

- develop worksheets to store, compute and manipulate data
- create charts of difference types, including line and scatter
- establish and analyze databases
- create own macro designed for a specific task

Baker (1995) defined MS Excel as one of the spreadsheet program that can manipulate data and present the relationship among the data. Meor Zainal and Marini (1996) affirmed MS Excel to be a spreadsheet program which is the most popular in the market and is widely used in finance, scientific data analyses and illustration of data in the form of charts.

According to Parsons et al. (2002), MS Excel is a computerized spreadsheet which stores electronic spreadsheet in document called a workbook. A workbook is a collection of related spreadsheets. MS Excel not only provides tools for storing numbers and other kinds of information but its real power come from manipulating all these information. The fundamental operation of a spreadsheet is performing calculations on data. MS Excel program performs mathematical operation through formulas and functions. It has most of the mathematical functions needed by users. In addition, MS Excel spreadsheet represents an extremely fast and efficient method for inputting data for both numerical calculation and graphical presentations of results.

In the Wikipedia Encyclopedia (2010), Microsoft Excel (Microsoft Office Excel) is defined as a spreadsheet application written and distributed by Microsoft for Microsoft Windows and Mac OSX. It features calculation, graphing tools, pivot tables and a macro programming language called VBA (Visual Basic for Applications).

MS Excel is a key part of the Microsoft Office suite of applications. We can use MS Excel for anything from a small spreadsheet of household finance to monster tables of all company's products, customers or sales. Ms Excel can be used either on its own or together with the other Office applications. MS Excel is the first spreadsheet that allowed the users to define the appearance of a spreadsheet (fonts, character attributes and cell appearance). It also introduced intelligent cell recomputation, where only the cells dependent on the cell being modified are updated. MS Excel has the basic features of all spreadsheet to organize data manipulation like arithmetic operation. It has a battery of supplied functions to answer statistical, engineering and financial needs. It can also display data as graph form and also allows sectioning of data to view its dependencies on various factors from different perspectives by using pivot tables. It has been a very widely applied spreadsheet for these platforms especially since version 5 in 1993. Since 1993, MS Excel has included Visual Basic for Applications (VBA), a programming language based on visual basic which adds the ability to automate tasks in MS Excel and to provide user-defined functions (UDF) for use in worksheets. From the programming aspect, VBA allows user to employ a wide variety of numerical methods, for example, to solve differential equations of mathematical physics and then reporting the results back to the spreadsheet. VBA is a powerful addition to the MS Excel application which, in the later versions, included a fully featured integrated development environment. Besides, the macro recording can produce VBA code replicating user actions, thus allowing simple automation of regular tasks. VBA allows the creation of forms in worksheet controls to communicate with users. The later versions even allow the use of basic object-oriented programming techniques. MS Excel forms part of Microsoft Office. The current versions are Microsoft Office Excel 2010 for Windows and 2008 for Mac.

2.7 APPLICATIONS OF SPREADSHEET PROGRAM IN TEACHING AND LEARNING OF CHEMISTRY

Since 1980's, there has been many studies related to the application of spreadsheets in mathematics and science teaching. Among the studies, some are really field studies whilst some are just discussion based on the researcher's opinion. From the result of all these studies, it is observed that use of spreadsheets are advantageous and could be used beneficially in biology, physics, chemistry and mathematics education since they have the ability to make the process of teaching and learning more interesting and effective.

William et al. (2007) had facilitated the methodical construction of a spreadsheet for color analysis which demonstrated a rigorous colorimetric analysis of a conventional spectrophotometric laboratory exercise using a spreadsheet program. Spreadsheet program is much easier to use compared to conventional method for colour management. Schaink and Venema (2007) present a spreadsheet experiment which illustrates various aspects of the van der Waals equation of state. They stated that with this spreadsheet, the students are able to play around with the van der Waals equation to see how this equation works.

Beside Schaink and Venema, Shalliker and friends (2008) have created an HPLC simulator using spreadsheet program to demonstrate the optimization of separation through an understanding of the relationship between solvent strength and resolution. The simulated HPLC experiment allows students to gain an appreciation of separation as a function of solvent strength. It also illustrates the concept of selectivity in separation, demonstrating that changes in clution orders can occurs as the solvent strength changes. The simulation exercise also allows a substantial number of experiments to be undertaken in a time frame that is a fraction required for the real experiment.

Hoffmann (2009) had used spreadsheet program to create an on line interactive spreadsheet along with a guided tutorial that demonstrates a number of basic NMR and Fourier transform concepts. Users can generate free induction decay (FIDs) and study the effect of changing frequency, number of protons present and phase setting on the

FID. Users can also study the effect of applying a line broadening function on the FID and explore the details of obtaining a spectrum from Fourier transformation. In addition, users can explore Fourier transform artifacts from improper sampling and Fourier transforming the FID.

Harvey (2009) examines the use of spreadsheet to emulate diffusion and thermal conductivity. He found that diffusion and thermal conductivity processes can be emulated using spreadsheets that use columns for increments in distance and rows for increments in time. With the initial values in the first row of each column, the next row can be calculated using incremental transfer equations to determine values for the next row. Spreadsheet had saved a lot of time for calculation in this case.

Sim (2010) used a spreadsheet program to explore different means of calculating and visualizing how the charge on peptides and proteins varies as a function of pH. The concept of isoelectric point is developed to allow students to compare the results of their spreadsheet calculations with others computer programs that are freely available on the internet and are designed to calculate the same parameter. He believes such comparisons allow students to explore the underlying assumptions of their model and to speculate on ways in which their model might be improved. He also discussed how the spreadsheet approach can be adapted to treat this protein (oligomeric protein hemoglobin) satisfactory.

2.8 APPLICATIONS OF MS EXCEL IN TEACHING AND LEARNING OF CHEMISTRY

In this section, discussion will be focused on the advantages and applications of spreadsheets in chemistry education. Basically, spreadsheets that will be discussed are based on Microsoft Excel. The use of Excel spreadsheets has been extensively reported in the educational journals and conferences. The result of these studies have pointed that MS Excel program is very useful in chemistry teaching due to its extensive ability in processing and presenting data. In addition, various chemical systems could also be facilely modeled. For example, back in 1988, Ghosh et al.(1988) from Maine University investigated the simulation of gas chromatography experiment from mass spectrometer using the Excel spreadsheet program. The result showed that integration of spreadsheet program in teaching mass spectrometry has helped students who have difficulties in understanding the idea and utility of mass spectrometry.

Van Houten (1988) reported that Excel could be used as a teaching tool because of its ability to solve a variety of chemistry problems including calculation and plotting of graphs. Topics that normally use Excel include kinetics, titration curves, isothermal gas law and calculations of atom/molecule orbital. In his article ‘Molecular orbitals on a spreadsheets’, Van Houten stated that spreadsheets enable students to be introduced to the molecular orbital’s calculation. In addition, he also reported that Excel spreadsheets are easier to write, use and edit with its graphical interface.

Brosnan (1989) mentioned that problems involving calculations particularly those that require many repetitions and are difficult to solve could be simplified by Excel. Brosnan also pointed out the following advantages in using Excel spreadsheets in chemistry teaching:-

- Students could concentrate on the chemistry concepts related to experiment rather than wasting their time to do calculations.
- Students involvement have increased
- Students could test questions/models with many data using Excel.

In his study, Brosnan used Excel to determine the empiric formula for magnesium oxide where he created a template with formulae, tables and texts to calculate and display all data for the students.

Linda (1993) performed a study to prove the Boyle's Law ($V \propto \frac{1}{p}$ or $pV = k$) in which she asked her students to use Excel spreadsheets to key in the data (pressure and volume). By writing the formula into the spreadsheet, the pV and 1/V values were automatically calculated. As a follow-up to the classic Boyle's law experiment, Scott (2008) had developed an interactive Excel spreadsheet, "The Boyle's Law Simulator", as a discovery learning tool to explore experimental error as a post-laboratory activity after performing the Boyle's law experiment. Students can investigate experimental error in the virtual realm of a spreadsheet. Researchers found that students engage in numerous higher-order thinking and science process skills as they work through the simulation.

McGee and Mattson (1993) used Excel in a polymer practical course where students were asked to synthesize and investigate the characteristics of the polymer molecule. Excel was used to handle all the data from the experiment. The results of the experiment were then presented in the form of tables and graphs to illustrate the basic principles of chemistry needed.

Guyton (1994) and Chesick (1994) introduced the use of Excel in plotting pH titration curve. Excel spreadsheets were used to illustrate the pH titration curve between strong acid and strong base; strong acid and weak base and strong base and weak acid. The program helped to make the topic easier to teach since students could observe the changes in the parameter on the curves immediately. Furthermore, the spreadsheet also helped the students to determine the suitable indicator required for a particular titration based on the pK value of indicator. Chesick also reported that students could use such program to determine the equilibrium constant by spectrophotometry and potentiometry which involve lots of calculations. This is done by Joshi (1994) where he used Excel to solve chemical equilibrium problems. He gave examples in his study regarding heterogeneous chemical equilibrium involving ideal gases at constant pressure and temperature in which he used macro functions in his calculation. He advocated that the 'how if/what if' function in a spreadsheet program could help students understand chemistry principles better so that they can follow classes in general chemistry, analytical and physical chemistry.

Gibbs (1994) used Excel to calculate complex data and plot graphs for most of his experiments involving chemical and physical quantities such as absorption of light, heat, pressure and conductivity where he demonstrated the usefulness of Excel spreadsheets in setting up a model to be compared with experimental results. In addition, Wink (1994) investigated the use of matrix inversion in Excel spreadsheet to obtain various chemical equations. He said that spreadsheet program make it easy to carry out many calculation on chemical systems. Students can use matrix inversion operation of MS Excel to solve a set of linear equation for the currents obtained when applying the Kirchhoff's rules to a multi-loop circuit.

Condren (1994) carried out a different study on group calculation theory for molecular vibration by using spreadsheets. Here, students were asked to compare the IR-Raman Active stretching value from the experiment. He found that the use of spreadsheet can help students to better understand the application of theory in practical works.

Montgomery (1994) used Microsoft Excel in stereochemistry for complexes with five coordination where geometry for a phosphorus complex was calculated. Students were given the length and bond angle of that complex and then asked them to find the bond angle between each atom in that complex in order to determine its geometry and give explanation on the factors that support the geometry they obtained. Hanks et al.(1995) carried out a study on the interaction and inter-molecular combination of a complex molecule by setting molecular models using MS Excel. Their results indicated that students' response towards such activities was very positive. Most students found such activity very interesting, thus they put more effort in preparing their reports.

In 1996, Hauek proposed the use of Microsoft Excel 4.0 which incorporated additional function i.e., a parser to interpret molecular formulae and a database with relative atomic mass value for elements. Thus, using this spreadsheet program, relative molecular mass for a molecule can be determined. This function is also a useful tool in chemistry for the preparation of a solution with certain molarity.

Kaess et al. (1998) used Microsoft Excel 5.0, together with Visual Basic 3.0 for a chemistry course in their university. Their first attempt of using such program is in quantum chemistry which involved lots of mathematical calculations, in which students usually face difficulty in understanding the relation between theory and concept. However, with the use of spreadsheets, students could observe the changes in molecular spectra as they change variables such as temperature and molecular mass. This seems to help the students understand more about quantum theory and at the same time develop various computer skills.

Harris (1998) used Microsoft Excel program to plot a non linear curve (rectangle curve). He emphasized the importance of the use of spreadsheet program in plotting non-linear curves which needs to be learnt by students. Arena and Leu (1999) performed similar studies as Harris where they reported the use of Excel spreadsheet in nonlinear regression analysis and concluded that the use of Excel for this purpose is convenient as this program is readily available compared to the use of computer programs written in traditional programming languages like Basic or FORTRAN.

MS Excel was also successfully used in kinetics studies. For example, Bruist (1998) had used Microsoft Excel 5.0 in his study ‘Use of spreadsheets to simulate enzyme kinetics’ to display the amount of carbon with relative atomic mass -14 (^{14}C) and nitrogen with relative atomic mass-14 (^{14}N) changes with time. The graphical functions in Excel could illustrate the kinetics of enzyme, mechanism of reaction and relate chemistry phenomena with mathematical equations well. Denton (2000) had used

MS Excel Solver to analyze the experimental data from kinetics investigation. Students were asked to determine the best fit values of V_o, V_∞ and k using a curve fitting solver. Based on the results of the study, the excellent agreement that is observed using solver analysis with those obtained using other curving-fitting methods confirmed the reliability of this approach. Moreira et al. (2006) designed an MS Excel spreadsheet that enabled a prompt calculation of the k value for different extents of reaction and if a well-established relationship between the measured property and concentration is known, assess the adequacy of a first order behavior. It can also be used to solve pseudo-first order conditions or easily changed to address different reaction orders. They reported that the tools provided in their spreadsheets can perform all the tasks above effectively. MS Excel Solver was used by Howard and Cassidy (2000) to demonstrate the use of a least-squares curve-fitting technique for volumetric analysis using microelectrodes. They found that the application of curve-fitting techniques using MS Excel Solver a useful method of introducing students to concepts in volumetry through practical experience.

Students enrolled in both general chemistry for majors and general chemistry for non majors at New York City Technical College has been introduced to Excel spreadsheets by Brown (2001) with the purpose of increasing their understanding and appreciation of solubility and some of its ramification. The result of the study showed that students were very satisfied with the new learning technique since the activities gave them opportunities to learn more about solubility in addition to developing their mathematics, computer and graphing skills. Similar studies were carried out by Guinon et al. (1999) where they used Microsoft Excel for Windows for evaluating the solubility of sparingly soluble salts of weak acids under different conditions.

Lim (2005a) and Agapova et al. (2002) have shown how MS Excel spreadsheet could help in the simulation of linear-molecule spectra to explore the dependence of rotational band spacing and contours on average bond lengths in the initial and final quantum rotational states. The use of the MS Excel spreadsheet program here enables students to do a mathematical "experiment". Nazarenko and Nazarenko (2005) have also demonstrated the usefulness of running Excel in Windows environment to a personal computer in their work with interfacing of various spectrometers with analog outputs.

Pal et al. (2007) used visual basic of application in MS Excel to evaluate the performance analysis of an arsenic separation plant which was involved in the removal of arsenic from drinking water. The software has been validated by carrying out extensive investigation in a laboratory-scale experimental set up and by comparing the experimental finding with the software-predicted values. The finding showed an overall correlation coefficient of the order of 0.98890 indicating the capability of the software in analyzing plant performance with reasonable accuracy. The advantage of the software is that it doesn't require familiarity with any new environment. Through visual graphics, it permits very quick performance analysis of the individual units as well as the overall process. They believed that this simulation package will be extremely useful in raising the level of confidence in designing and operating arsenic separation plants. Besides that, the flexibility in input data manipulation and capability of optimization of the major operating variables are the other advantages of the software.

Garcia-Molina et al. (2007) studied the application of wet oxidation for the treatment of solutions containing 4-chlorophenol and suggested a kinetic model in order to allow the prediction of the concentration of the compounds involved in the process throughout the reaction. Microsoft Excel was used as a tool to find the initial feasible values in their study. In 2008, Page and his friends attempted to perform Restricted Hartree-Fock SCF calculations using MS Excel on a two body, two-electron system, which make use of standard minimal Gaussian basis sets for hydrogen and helium to explore the tendency of the underlying self-consistent field (SCF) procedure in computational chemistry becoming a “black box” for student (Page et al., 2008).

In Malaysia, there are only a few studies that have been carried out on the application of spreadsheets in teaching and learning of chemistry. Gan (1998) accessed students’ perception towards the use of spreadsheet in a study entitled ‘The concept of pH in strong and weak acid solution in chemistry’. The spreadsheet was developed using Microsoft Excel 97 program and used as a tool in teaching and processing experimental data. His results indicated that the software is attractive to students and that it was able to help them learn concept of pH in a much better way.

Fourty Lower Six science students from Sekolah Menengah Tinggi Kajang were involved in a study carried out by Kumareson (1998) on the used of spreadsheet with Microsoft Excel 5.0 program to determine the relative atomic mass of elements. In this study, the students’ computer literacy was taken into account in determining their perception towards the use of spreadsheets in chemistry. The overall result showed that students found spreadsheets enjoyable and can help them in calculations.

How (1998) used Microsoft Visual Basic 4.0 to develop a courseware in teaching chemical bonding and found the facilities of the CAI (computer assisted instruction) courseware to be most effective in teaching chemical bonding. The study also identified some advantages of CAI courseware as a self-teaching/learning method suitable for teaching process/activities and may be used to achieve various teaching objectives and convey concepts of chemistry more effectively.

Microsoft Excel 97 program was used by Suzila (1998) in kinetic chemistry lessons where students compared their results and plot graph using spreadsheets whilst Huzaifah (1998) had used spreadsheets to teach Charles Law in which he developed a template with formula for students to key in data. Spreadsheets helped to plot the graph accurately. From both Suzila's and Huzaifah's studies, spreadsheets have been shown to be able to help students save time in plotting graphs and doing the calculations. Students can spend more time discussing chemistry concepts rather than doing the calculations.

Yu (1998), Tan (2000) and Pushpa Rani (2000) have all used Microsoft Excel program to carry out similar studies in determining the empirical formula of a compound. In their study, they developed their own worksheets using Microsoft Excel. After carrying out the experiment, their students were asked to key in data into the computer and the spreadsheets helped to calculate and present the results in tables for discussion and report.

Ong (2000) studied the perception of students in studying physical chemistry (thermo-chemistry) through Excel spreadsheet and revealed that the students were very receptive towards the program. They found spreadsheets to be very effective in processing data and the results could be displayed in a most attractive manner.

Arifin (2012) had used Excel VBA to develop a program, 'GChem' to assist chemistry students learn basic concepts in chemistry. Two modules were developed namely 'Electrochemistry module' and 'Acid-base module'. Students can conveniently use these modules from a laptop or personal computer even without the internet connection. A preliminary survey on students at the Faculty of Applied Science in Universiti Teknologi MARA showed that students found this application helpful in their study.

From the above review, like many other subjects, chemistry has benefited from the effects of recent advancement in computing and technology, especially by the use of computer software. Calculations that were once considered complicated and time consuming are now becoming routine with minimum effort. The revolution of spreadsheet program since 1970s until the emergence of Windows has made MS Excel the most widely used spreadsheet application worldwide. The powerful and user friendly features in the recent version of MS Excel that shows pedagogical potential have been extensively reported in the educational literature. Hence, chemistry teachers in Malaysia should be made aware and encourage to use this 'world ware' tool to enhance their pedagogical capability and ability. If they can be convinced and enabled to create their own teaching and learning materials of chemistry that meet the learners' needs and enhance the learners' capability, students' interest in learning chemistry will be greatly improved.

CHAPTER THREE

DEVELOPMENT OF EXCEL WORKSHEETS: METHODOLOGY

3.1 INTRODUCTION

MS Excel has many special features and functions that can be used to create teaching aids to enhance teaching and learning of chemistry. The following discussion will focus on the functions that have been used to create the workbooks in this thesis. The workbooks are based on topics chosen from Form Six and first/second year university syllabi. Each workbook developed will be discussed based on the theoretical background of the topic and the EXCEL functionalities used there in. The spreadsheet program used is MS Excel 2003.

3.2 MICROSOFT EXCEL FUNCTIONS

3.2.1 Logical Functions

The logical functions in MS Excel enable users to test logical conditions and return a logical result in the form of text or numbers. Basic logical functions available in MS Excel include IF, AND, OR, NOT, TRUE, FALSE and IFERROR. By combining these logical functions with other functions, a user can make MS Excel take action that is appropriate to the conditions evaluated.

Extensive use of “IF” function is demonstrated in this study in creating interactive graphs in “Chemical Kinetics” workbook and the “Spectroscopy” workbook. The ‘IF’ function was also used in “Chemical Equilibrium” and “Qualitative Analysis” workbook.

For example, in the “Chemical Equilibrium” workbook, ‘IF’ function was used to return the result of equilibrium if the concentration of any substances in the equilibrium has been changed at a fixed temperature as shown in the example below:

$N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$

The equilibrium constant for the reaction involving nitrogen and its oxides, K_{eq}, is 0.212 at 373 K. When the concentration of the reactant or product is being changed at 373K, the equilibrium is disturbed. This non equilibrium concentration will produce a value that is not equal to K_{eq} which does not satisfy the equilibrium expression. If a system is not at equilibrium, it will proceed in the direction necessary to achieve equilibrium again. By performing the “IF” analysis in a worksheet as shown, the user gets immediate answers to the questions:

$Q = K_{eq}$; *=IF(B20=D20,"**equilibrium**","")*

$Q > K_{eq}$; *=IF(B20>D20,"**shift towards” reactant**","")*

$Q < K_{eq}$; *=IF(B20<D20,"**shift towards” product**","")*

Where Q is the reaction quotient for non equilibrium condition and K_{eq} is the equilibrium constant for the reaction at 373 K.

MS Excel not only recalculates all formulas in a worksheet when new data is entered, but also redraws instantaneously any associated charts/graphs. Detailed discussion of the use of "IF" function will be given later in this chapter.

3.2.2 Graphing

Graphing experimental data or to show relationship between two parameters is common in presenting/analyzing scientific data. Nothing can be as helpful as displaying data in graphical form. Information presented in the form of pictures, charts or graphs is much easier to grasp and understand compared to rows of figures in a worksheet because the mind perceives, processes and recalls visual information more quickly than textual or numerical information (Perkinnson, 2012; Stephen, 2010). A well conceived chart can make sensible a range or incomprehensible numbers. The later version of MS Excel can cope with most of the normal requirements of scientific graphing. Users can quickly and easily create a chart simply by selecting the data to be plotted and choosing the chart type that is most appropriate with just a few strokes. From educational point of view, MS Excel actually provides a very powerful tool for teaching chemistry which can help students to explore graphically the importance of various parameters in an equation.

In this study, the chart wizard tool in MS Excel was used in "Chemical Kinetics" workbook, "Period Three Element" workbook, "molecular_speed" workbook, "compressibility_gases" workbook, "Spectroscopy" workbook, and "Chemical

Equilibrium" workbook to present graphs and charts. For example, in the topic of chemical kinetics, the chart wizard tool was used to present interactive graphs for "*zero order*" reaction, "*first order*" reaction and "*second order*" reaction. Students can observe the changes to the graphs instantaneously when the parameter set (initial concentration, A_o and rate constant, k) is being changed. The worksheet shown below (Figure 3.1) is the first order worksheet, within the "Chemical Kinetics" workbook.

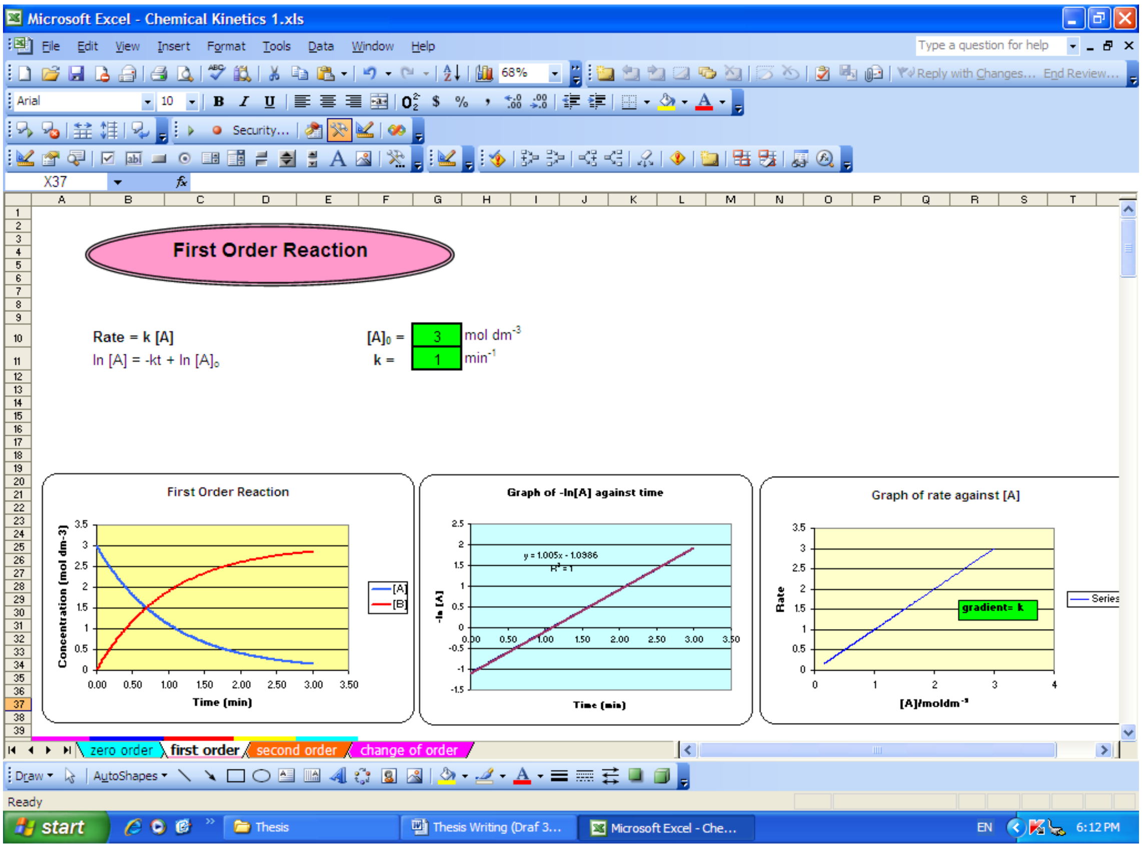

Figure 3.1: First order worksheet

The chart wizard in MS Excel also provides functions which allow users to show two parameters using the same X axis. This function was used to explore the relationship between atomic radii and melting point and the relationship between atomic radii and the first ionization energies of period three elements in the "Period Three Elements" workbook as shown in Figure 3.2 below:

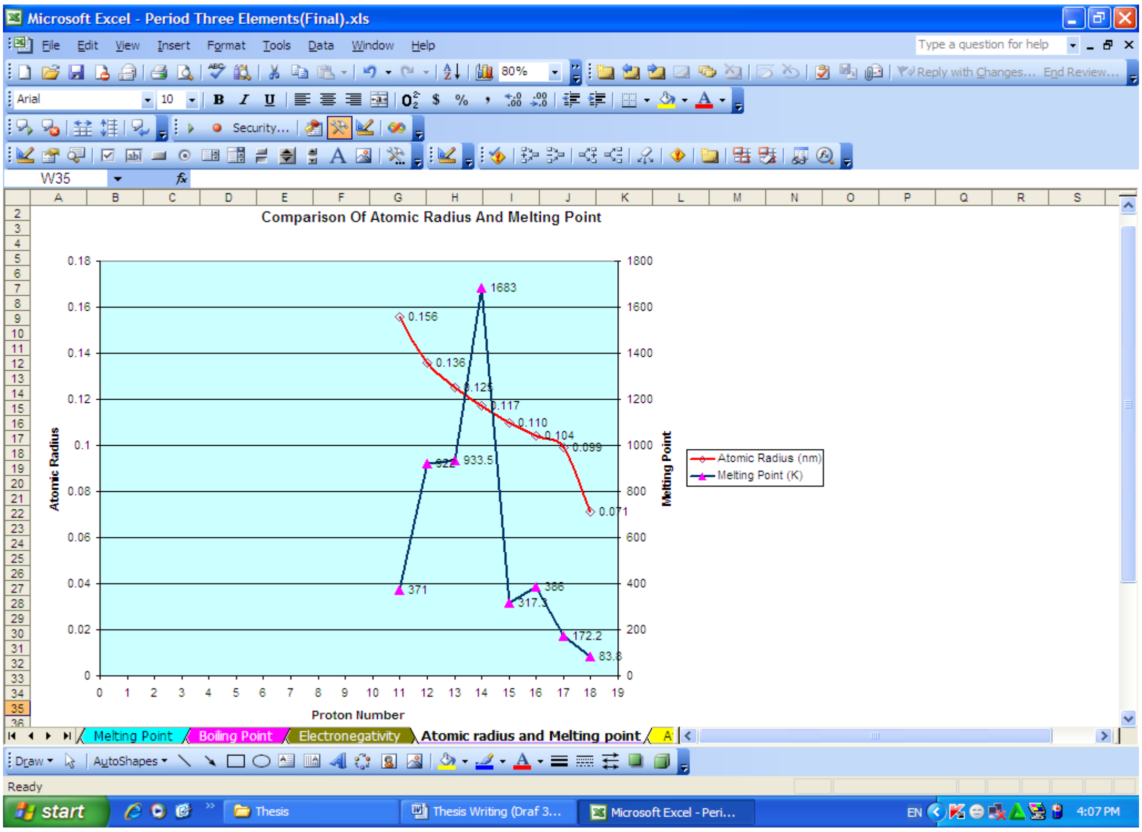

Figure 3.2: Atomic radius and melting point worksheet

3.2.3 Active X Control

Controls found on the Control Toolbox (shown in Figure 3.3) are "Active X" controls.

Figure 3.3: Active X controls toolbox

Active X controls are a set of powerful and very useful built in functions in MS Excel. Active X controls can be used on worksheet forms, with or without the use of VBA code and on VBA User Forms. In general, Active X controls are used when users need more flexible design requirements than those provided by Form controls. Active X controls have extensive properties that users can use to customize their appearance, behavior, fonts and other characteristics. Besides that, users can also write macros that respond to events associated with Active X controls. However, not all Active X controls can be used directly on worksheets. Some can only be used on Visual Basic for Applications (VBA) User Forms. Below are summary of the Active X controls in MS Excel program (Robinson 2006):

TABLE 3.1: Summary of Active X controls

Button Name		Description
	Check box	Turn on or off a value that indicates opposite and unambiguous choice. Users can select more than one check box at a time on a worksheet or in a group box. A check box can have one of three states: selected (turned on), cleared (turned off), and mixed (a combination of on and off states as in a multiple selection).
	Text box	In a rectangular box, users can view, type or edit text or data that is bound to a cell. A text box can also be a static text field that presents read-only information.
	Command button	Runs a macro that performs an action when users click at it. A command button is also referred to as a push button.
	Option button	Option button allows a single choice within a limited set of mutually exclusive choices usually contained in a group box or frame. An option button can have one of three states: selected (turned on), cleared (turned off), and mixed (a combination of on and off states as in a multiple selection).
	List box	Display a list of one or more items of text from which users can choose. List box can be used to display large numbers of choices that vary in number or content. There are three types of list box: a single-selection list box enables on one choice; a multiple-selection list box which enables either one choice or contiguous (adjacent) choices; and an extended-selection list box that enables one choice, contiguous choices and noncontiguous (or disjointed) choices.
	Combo box	Combo box is a combination of a text box with a list box to create a drop-down list box. A combo box is more compact that a list box but requires the user to click the down arrow to display the list of items. It allows users to either type an entry or choose only one item from the list. The control displays the current

		value in the text box, regardless of how that value is entered.
	Toggle button	Indicates a state, such as Yes/No, or such as On/Off. The button alternates between an enable and disable state when it is clicked.
	Spin button	Spin button increases or decreases a value, such as a number increment, time or date. To increase the value, click the up arrow; to decrease the value, click the down arrow. Typically, users can also type a text value into an associated cell of text box.
	Scroll bar	Scroll bar allow user to scroll through a range of values when user click the scroll arrows or drag the scroll box. In addition, users can move through a page (a present interval) of values by clicking the area between the scroll box and either of the scroll arrows. Typically, users can also type a text value directly into an associated cell of text box.
	Label	Identifies the purpose of a cell or text box, displays descriptive text (such as titles, captions, pictures) or provides brief instruction.
	Image	Embeds a picture, such as a bitmap, JPRG of GIF.
	More controls	Displays a list of additional Active X controls available which can be added to a custom form.

Among the Active X functions mentioned above, only a number of related Active X controls were used in this study, such as command button, spin button, option button, combo box, list box, label and scroll bar.

As an example, command buttons were used to run the task “*Go To Main Menu*”, “*Go To Sheet 2 Menu*” and “*Back To Previous Page*” in “Period Three Elements” workbook. When these buttons are clicked, the relevant sheets are displayed. “*Add Item*”, “*Result*”, “*Clear*”, “*Observations*”, “*Clear Observations*” “*Check Answer*” buttons are some other command buttons used in “Qualitative Analysis” workbook to run the task required. Detailed explanation and operation of each Active X control buttons will be explained later in this chapter.

3.2.4 Visual Basic Application And Macros

In addition to the spreadsheet application of MS Excel, there is an extremely powerful programming language built into MS Excel that users can use to design their own applications. MS Excel supports programming through Microsoft's Visual Basic for Application (VBA) which is a subset of Visual Basic (VB). VBA is a programming environment designed specifically for application macros. Programming with VBA allows spreadsheet manipulation that is impossible with standard spreadsheet technique. VBA's biggest advantage is that it's easier to use than most programming languages. Users can write code directly using Visual Basic Editor (VBE) accessed using the VB icon on the developer tab to write macro applications in VBA that do some very powerful things (Shepherd, 2010). The users can also implement virtually any numerical methods in VBA and guide the calculation using any desired intermediate results reported back to the spreadsheet. If users don't want to do any programming, the most common and easiest way to generate VBA code is by using the macro recorder. The macro recorder records the mouse and keyboard actions of the users and generates VBA code that is then contained within a macro. These actions can then repeated automatically by running the macro. The macros can also be linked to different trigger types like keyboard shortcuts, a command button or a graphic. The actions in the macro can be executed from these trigger types or from the generic tool bar options. The VBA code for the macro can also be edited in the VBE. Dialog boxes can be created by simply drawing the appropriate controls onto a document. Beside that, other visual tools enable users to customize menus and toolbars as well. Hence, users have everything needed to create simple scripts even without writing a line of code. Therefore, VBA is a user-friendly programming language which makes programming approachable and achievable to those beginners who are not expert programmers or program developers. It makes the learning process bearable because the learning curve is short, and gives courage to the weak hearted as programming accomplishments are rapidly achieved.

A macro is a procedure written in VBA code that performs certain tasks (Diamond & Hanratty 1997). It is a sequence of Excel commands grouped together and run as a single command. According to McFedries (2004), a macro is a set of instructions that tells a program (such as Word or Excel) what tasks to perform to accomplish some goal. A macro combines all these instructions into a single script that can invoke using a menu command, a toolbar button or a keystroke. There are two kinds of macros; a command macro and a function macro. A command macro carries out a sequence of Excel instructions based on user selection with keystrokes or the mouse. A function macro on the other hand, computes values as part of a 'user defined' spreadsheet function. The commands in a macro are related in the sense that they accomplish a larger task. Macros are a method for accomplishing the following:

(a) automating frequently uses sets of commands.

(b) automating complicated tasks.

(c) reducing the number of steps in a complex operation.

(d) making complex formula bar entries more efficient.

Macros can be simple or very involved depending on the task, energy and enthusiasm of the programmer. Macros can be activated using a button using the form menu, and advanced users can employ user prompts to create an interactive program.

In this study, simple macro was used to run some of the tasks in the workbooks created with simple VBA program which do not require an extensive programming background. For example in the “Period Three Elements” workbook, a simple macro was assigned to run the command for the buttons created. If users/students click on the “Sheet 1” button, it will link to the “Sheet 1” worksheet and display the worksheet immediately.

The VBA code to run the command is as shown below:

Private Sub Commandbutton2.Click( )

Worksheets (“Sheet 1”). Select

End sub

Another example using macro in this study was in creating message boxes in the worksheets. In the “Qualitative Analysis” workbook for example, if students wish to check the answer for the unknown X, students can click at the “Check Answer” button prepared in the worksheet and a message box will appear as “X is Ba^{2+}”.

The VBA code to run the command is as shown below:

Sub Answerforbarium()

MsgBox “X is Ba^{2+}*”*

End Sub

Beside the examples shown above, macros were used to run some tasks in other worksheets too. Detailed explanations for macros and VBA used in this study will be further discussed in the discussion on the development of the related worksheets. Beside the functions mentioned above, built in functions in MS Excel such as “hyperlink”, “LN”, “RANDBETWEEN”, “INDEX”, “EXP”, “SQRT”, “VLOOKUP” and

"HLOOKUP" were used in creating these worksheets as well. How these functions are used will be discussed in the section related to the preparation of the worksheets.

3.3 DEVELOPMENT OF WORKSHEETS

3.3.1 Chemical Kinetics

Chemical kinetics or reaction kinetics is the study of reaction rates of a chemical reaction. Kinetics involves the relationship between factors such as reactant concentration in a solution, the pressure of gaseous reactant, temperature, the surface area of the reactant and addition of catalyst that will affect the velocity at which a reaction proceeds.

Analyzing the factors influencing the reaction rate at different reaction conditions will enable chemists to have a better understanding of how a reaction can occur. This chapter describes how an Excel spreadsheet, with its powerful intuitive graphical interface could be used to describe chemical kinetics in physical chemistry. It is hoped that through this teaching and learning method (Microsoft Excel), students will be able to explore quickly the effects of variation of equation parameters on the graphical display and understand its underlying principles in chemistry.

3.3.1.1 Rate Of Reaction

Reaction rate is the increase in molar concentration of product of a reaction per unit time or the decrease in molar concentration of reactant per unit time (Ebbling & Wrighton 1993). Loh and Sivaneson (2004) defined rate of reaction as the change in concentrations of the product at a given time. Essentially, the reaction rate or rate of reaction for a particular reaction can be defined as how fast the reaction takes place. For example, the oxidation of iron under atmospheric (pressure = 1 atm) condition is a very slow process and could take years to occur while the reaction between silver cation, Ag+, and chloride anion, Cl^- can take place in fraction of a second. For a general reaction, A + B → C, where A and B are the reactants and C is the product, the rate of reaction is given by

$$\text{Rate} = \frac{-d\,[A]}{dt} = \frac{-d\,[B]}{dt} = \frac{+d\,[C]}{dt} \quad ; \qquad (3.1)$$

where $\frac{-d\,[A]}{dt}$, $\frac{-d\,[B]}{dt}$ and $\frac{+d\,[C]}{dt}$

express the change in concentration of A, B, and C, respectively, in a time interval, dt. The negative sign (-) indicates the decreasing concentration of the reactant with time while the positive sign (+) indicates the increasing concentration of the product with time. The unit for rate is mol $dm^{-3}s^{-1}$.

In the Malaysian sixth form syllabus, the most important factor to understand is the effect of concentration on reaction rate. The exact relationship between the rate of reaction and concentration of the reactants in a particular reaction however, can only be determined experimentally. At a fixed temperature, the relationship between concentration and rate is described by a rate law. This rate law represents the change in molar concentration per unit time as a function of a rate constant, k, and the molar concentrations of the pertinent species that affect the rate.

The molar concentration as expressed in the rate law is raised to an appropriate power by an exponent that is frequently an integer. Essential rate laws exist for zero order (for which reaction rates are independent of initial concentration), first order and second order reactions. If a rate law only has a single concentration term and the exponent of that concentration term is unity, then the rate law is designated as first order. When the rate law has a single concentration term and the exponent of that term is two, then the rate law is designated as second order. For example, in the reaction $A + B \rightarrow C + D$, experiment may show that the rate of reaction is proportional to the concentration of A to the power of x, that is

$$\text{Rate} \propto [A]^x \tag{3.2}$$

The rate of reaction may also be proportional to the concentration of B to the power of y, that is

$$\text{Rate} \propto [B]^y \tag{3.3}$$

Thus, the overall equation therefore is

$$\text{Rate} = k\,[A]^x\,[B]^y \tag{3.4}$$

where, k, is the rate constant and the overall equation is called the rate equation. In this example, the order of the reaction with respect to A is x and the order with respect to B is y and the total order of the reaction is x + y.

This study is concerned with the application of MS Excel in mathematical and graphical description of zero order, first order and second order reactions.

3.3.1.2 Zero Order Reaction

If the rate of the reaction is independent of the reactant's concentration, then the reaction is said to be zero order with respect to the reactant. For example: the

change: $A \longrightarrow B$

If the rate is independent of [A], then the rate is zero order with respect to A. Zero order reactions are rare. Usually, zero order reactions happen in electrolysis and photochemical reactions. For example, in the reaction below:

$A \longrightarrow \text{product}$

Rate = $k[A]_o^o$ (3.5)

Rate = k (3.6)

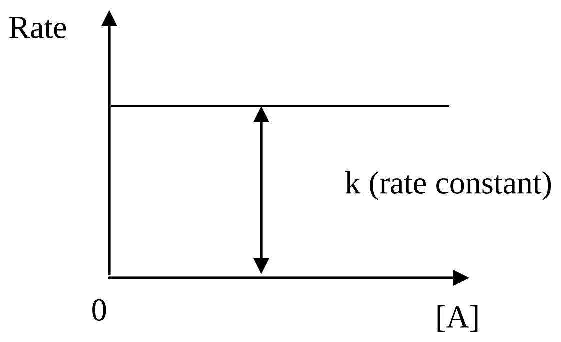

Figure 3.4: Graph of rate against [A] for zero order reaction

$$\frac{-d[A]}{dt} = k \qquad (3.7)$$

At t=0, the concentration of A is the initial concentration, $[A]_o$. The equation then becomes

$$[A] = -kt + [A]_o \qquad (3.8)$$

A graph of [A] plotted against time will give a straight-line as shown below:

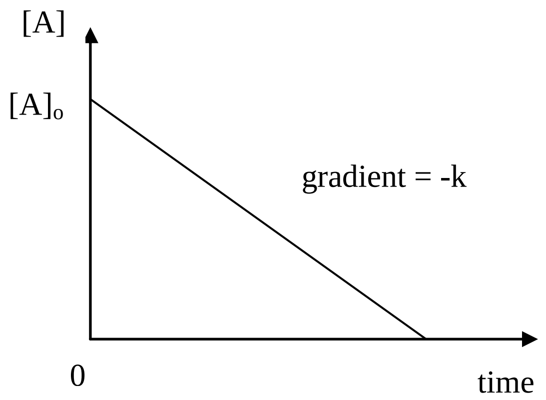

Figure 3.5: Graph of [A] against time for zero order reaction

At half life, $t = t_{½}$, the concentration of A would be half of the initial concentration, $½ [A]_o$

Therefore,

$$t_{½} = \frac{[A]_o}{2k} \tag{3.9}$$

3.3.1.3 First Order Reaction

The behavior of many chemical reactions such as nuclear decay and decomposition reactions can be described by first order kinetics, in which the mathematical terms can be represented by the differential equation,

$$\frac{-d [A]_t}{dt} = k [A]_t \tag{3.10}$$

where $[A]_t$ is the concentration of a substance at particular time and k is the rate constant. The integrated form of this equation is

$$[A]_t = [A]_o e^{-kt} \tag{3.11}$$

where $[A]_t$ is the concentration of substance A at time t and $[A]_o$ is the initial concentration of substance A at time, t = 0. Natural logarithm form of the equation (3.10) can be written as

$$\ln [A]_t = -kt + \ln [A]_o \tag{3.12}$$

From equation (3.12), it can be predicted that,

- the rate at which the substance A disappears is directly proportional to the concentration of A and the proportionality constant is the rate constant.
- the reaction half-life is a constant (ln 2/ k)

The half life ($t_{½}$) of a first order reaction is the time taken for the initial amount of a reactant to fall to half its original value. Thus, when

$$t = t_{½}\ ; \quad [A]_t = \frac{[A]_o}{2} \quad \text{therefore}$$

$$\ln \frac{[A]_o}{2} = -k\,t_{½} + \ln [A]_o$$

$$t_{½} = \frac{\ln 2}{k} = \frac{0.693}{k} \qquad (3.13)$$

The graph of concentration, [A] against time for a first order reaction is a curve as shown in Figure 3.6 and the half-life of a first order reaction is a constant and is independent of the concentration of the reactant. This method is useful for determining if a reaction follows a first order kinetics. In addition, the value of k can be obtained from the graph ln [A] versus time, t (Figure 3.7).

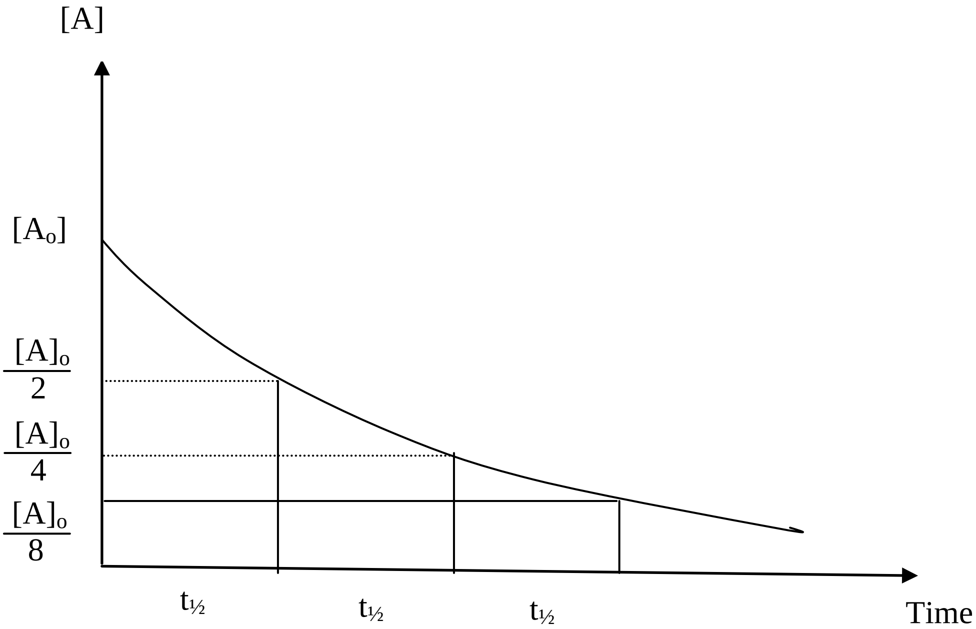

Figure 3.6: Graph of [A] against time for first order reaction

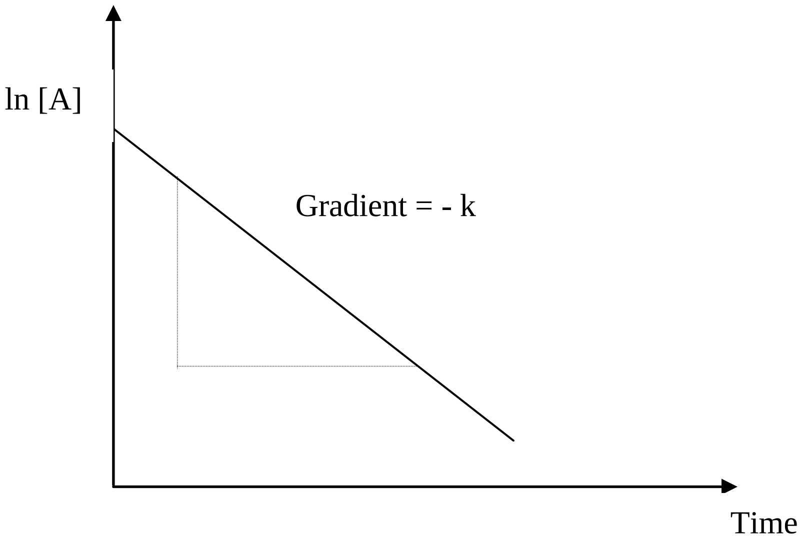

Figure 3.7: Graph of ln [A] against time for first order reaction

The graph of rate against concentration of [A] for a first order reaction is shown below:

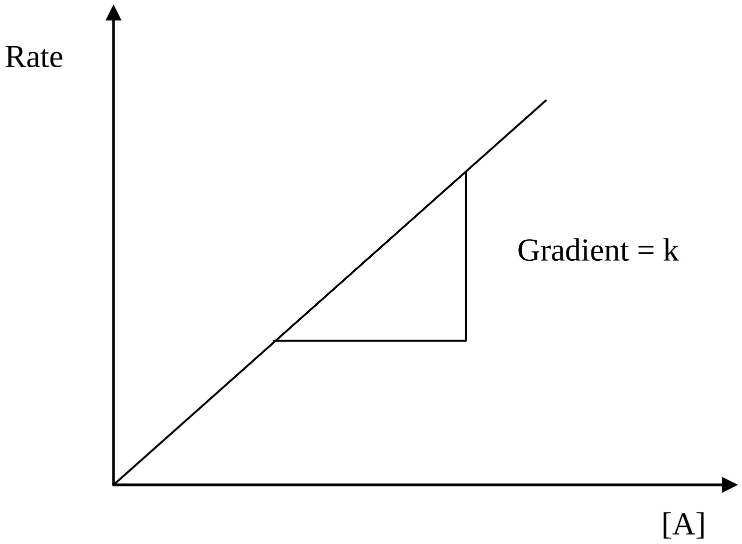

Figure 3.8: Graph of rate against [A] for first order reaction

3.3.1.4 Second Order Reaction

A reaction with a single reactant that proceeds by second order kinetics is governed by the following differential equation,

$$\frac{-d\,[A]_t}{dt} = k\,[A]_t^{\,2} \qquad (3.14)$$

where $[A]_t$ is the concentration of substance, A, at particular time and k is the rate constant. Similar to first order reaction, the graph of concentration, [A] against time for second order reaction is a curve (Figure 3.9)., However, the half-life of a second order reaction is inversely proportional to the amount of substance present. As can be seen from the graph (Figure 3.9), the second half-life (t_2) is double the value of first half-life (t_1).

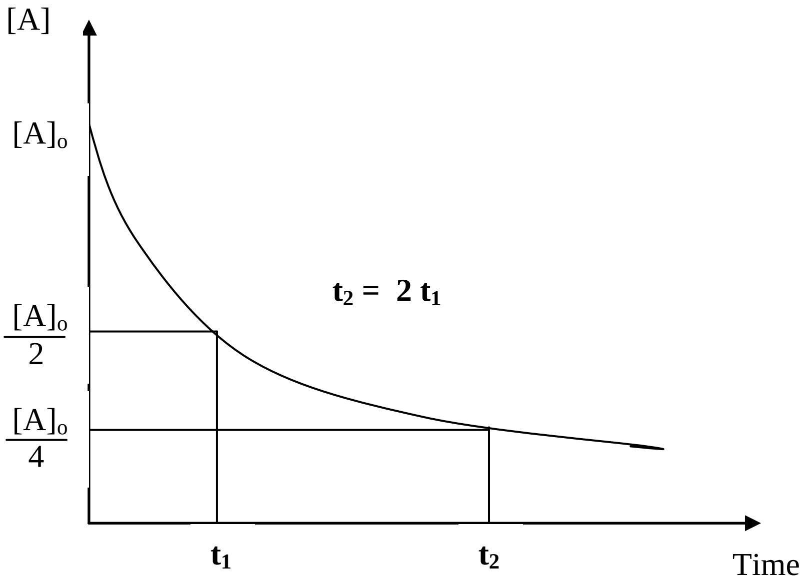

Figure 3.9: Graph of [A] against time for second order reaction

The relationship between the concentration of substance A and time can be written as:

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_o} \qquad (3.15)$$

Similar to first order reaction, the value of k can be obtained from graph. Plotting the graph of 1/[A] against time can be easily done with Excel. Using this equation (3.15), the concentration of substance at any time could be calculated if the rate constant and the initial concentration are known.

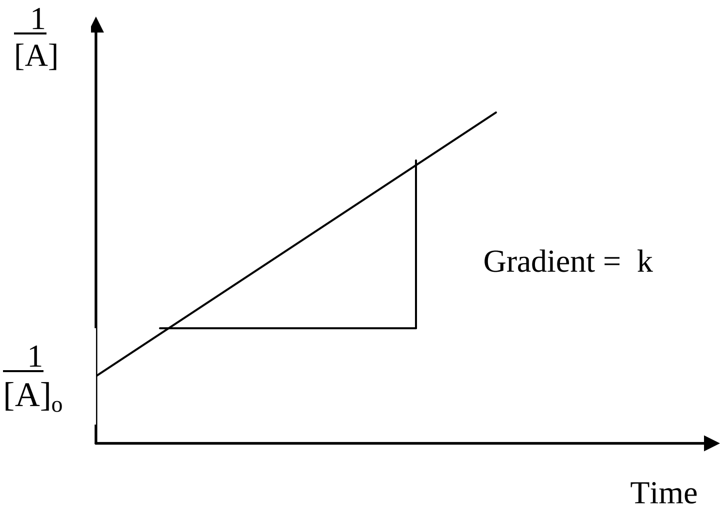

Figure 3.10: Graph of $\frac{1}{[A]}$ against time for second order reaction

However, the graph of rate against [A] for second order reaction is a curve as shown in Figure 3.11.

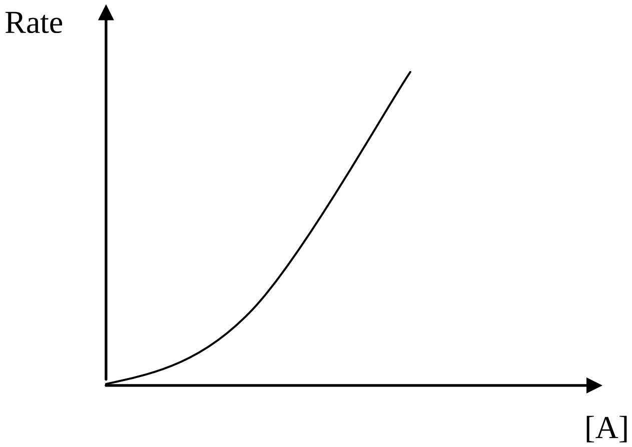

Figure 3.11: Graph of rate against [A] for second order reaction

3.3.1.5 Chemical Kinetics Workbook

In this section, how MS Excel was used to plot the interactive graphs for zero order, first order and second order reaction and how MS Excel could help in solving chemical kinetics problems will be discussed. There are two workbooks that were created using MS Excel. First is an interactive workbook that uses a graphical approach to chemical kinetics that could be used by teachers as a teaching tool in class (Chemical Kinetic 1 workbook) and the second workbook (Chemical Kinetic 2 workbook) solves the chemical kinetics problems for first and second order reaction (refer to CD).

(a) Chemical Kinetics 1 Workbook

In this workbook, the interaction of users is done in a number of ways; i.e via cells with green background where numbers can be entered by typing in a value or by clicking at the terminal arrow (spinner button). The advantage of using MS Excel spreadsheet is that a response will occur on the graph interactively when the parameters are adjusted. This interaction is important in giving a clearer understanding of chemical kinetics to the students.

There are four worksheets within the "Chemical Kinetics 1" workbook. There are "zero order" worksheet, "first order" worksheet, "second order" worksheet and "change of order" worksheet. All the graphs created in these sheets use the chart wizard function in MS Excel. When the teacher/students change the value of A_o or k by typing in a new value in the green boxes provided, the graphs will change interactively. Students can observe the changes immediately and this will give a clearer picture to students the factors influencing the kinetics of reaction in chemical kinetics.

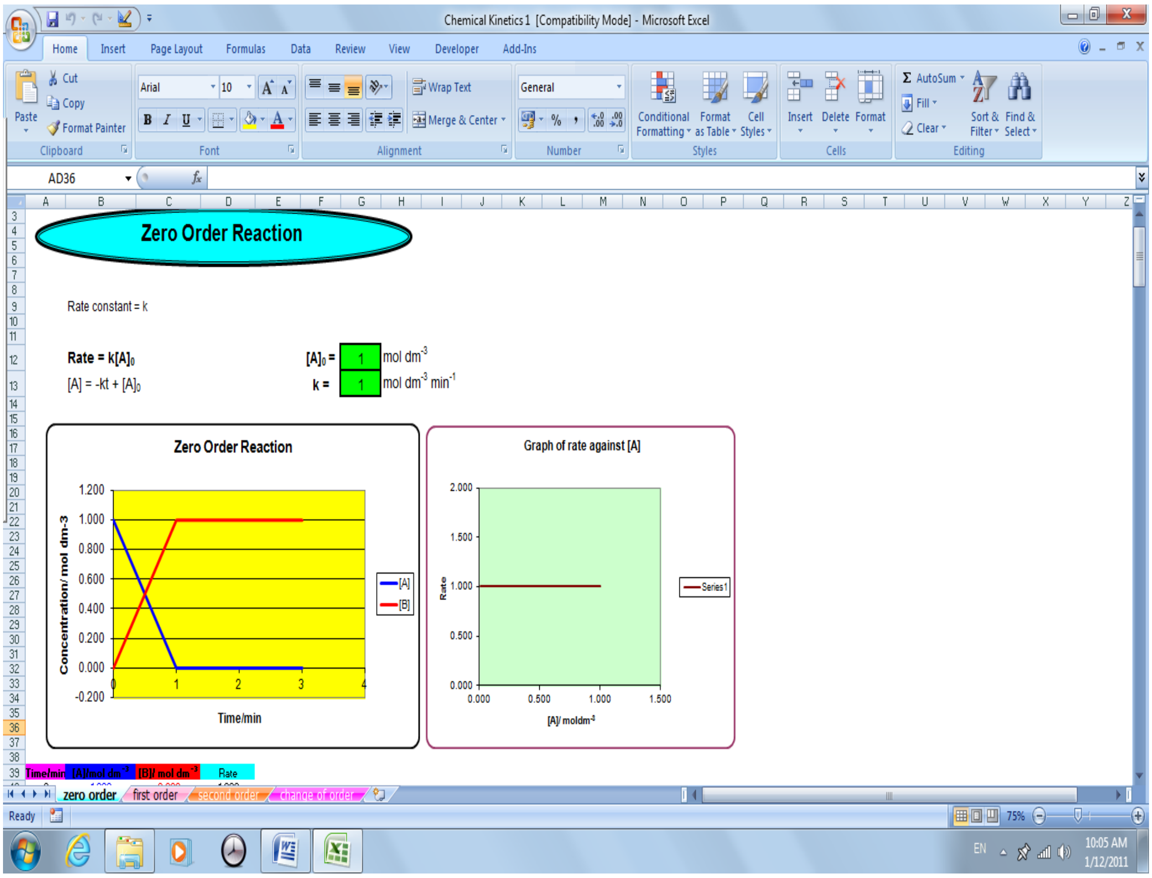

Figure 3.12: Zero order worksheet

In the "zero order" worksheet, the graph of concentration against time and graph of rate against concentration are presented in Figure 3.12. The graphs will respond interactively when the values of A_o or k are being changed. Students can observe the changes of graphs on the screen immediately. The formulae used to compute the graphs are listed below. A_o is a named cell which corresponds to$G$12 cell.

Cell B40 = IF((-$G$13*A40+Ao)>0, -$G$13*A40+*A_o,0)*

Cell C40 = $B$40-B40

Cell D40 = (C41-C40)/(A41-A40)

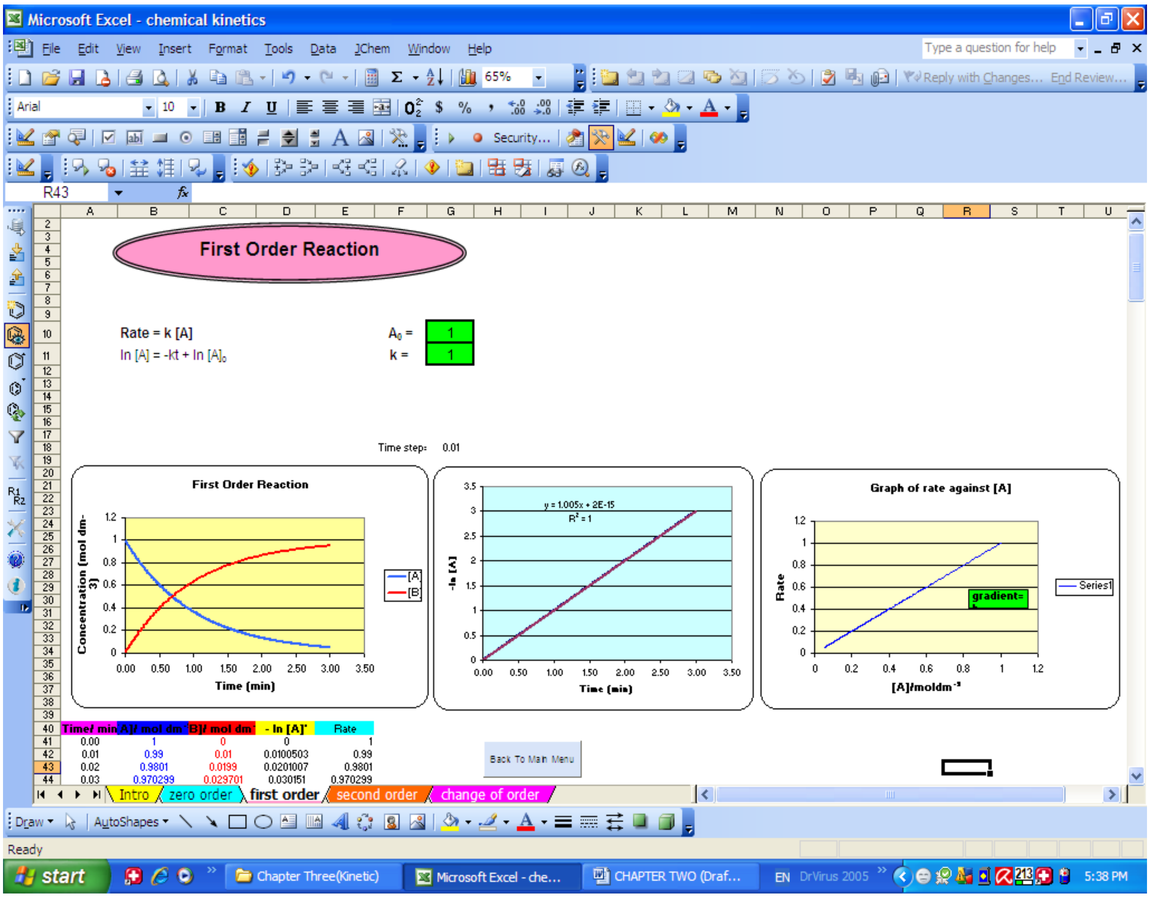

Figure 3.13: First order worksheet

In the “first order” worksheet, three graphs are prepared (Figure 3.13), which are the graph of concentration against time, graph of ln [A] against time and graph of rate against concentration [A]. Similarly, the graphs will respond interactively when the value of A_o or k is being changed. The formulae used to compute the graphs are:

Cell B41 = G10

Cell B42 = B41-$G$11*B41*$G$18

Cell C41 = $B$41-B41

Cell D41 = LN(B41)

Cell E41 = (C42-C41)/(A42-A41)

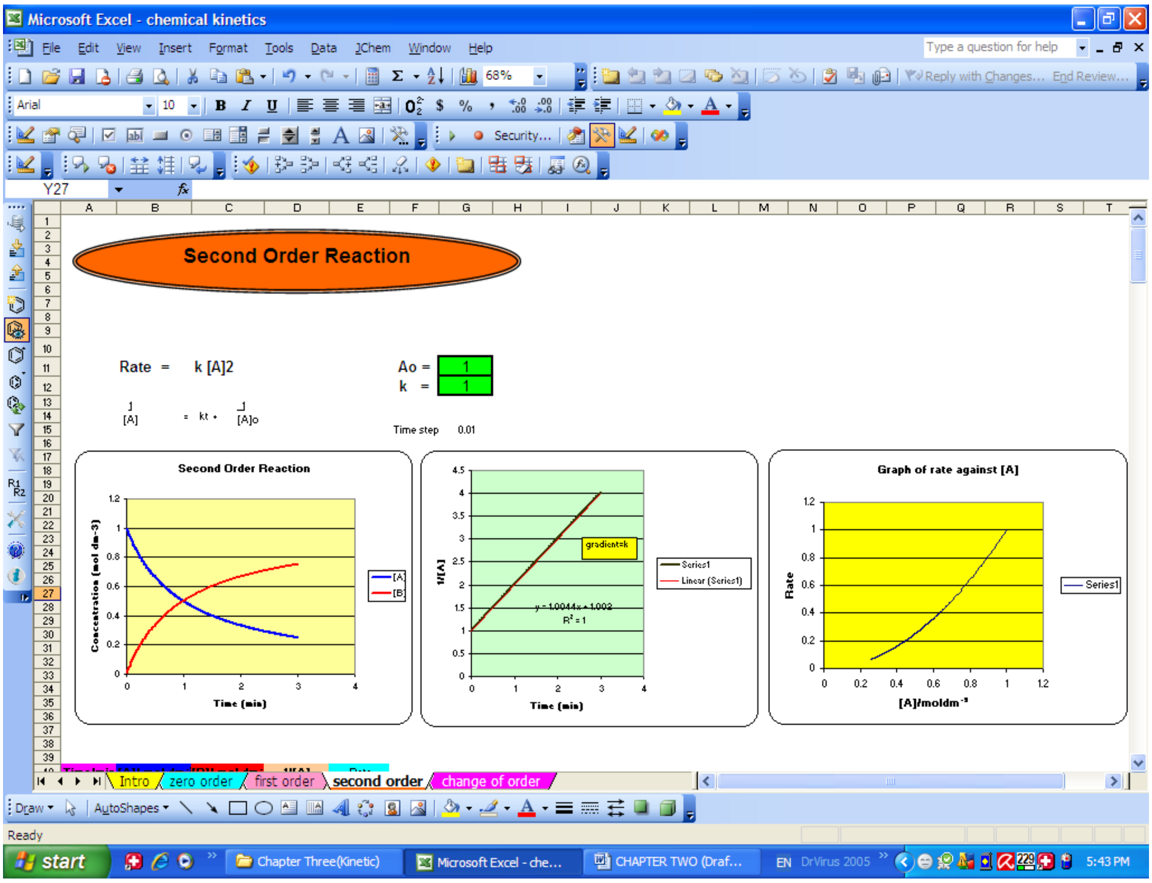

Figure 3.14: Second order worksheet

In the "second order" worksheet, the graph of concentration against time, graph of rate against [A] and graph of 1/[A] against time (Figure 3.14) are created using the formulae below:

Cell B41 = G11

Cell B42 = B41-$G$12*B41*B41*$G$15

Cell C41 = $B$41-B41

Cell D41 = 1/B41

Cell E41 = (C42-C41)/(A42-A41)

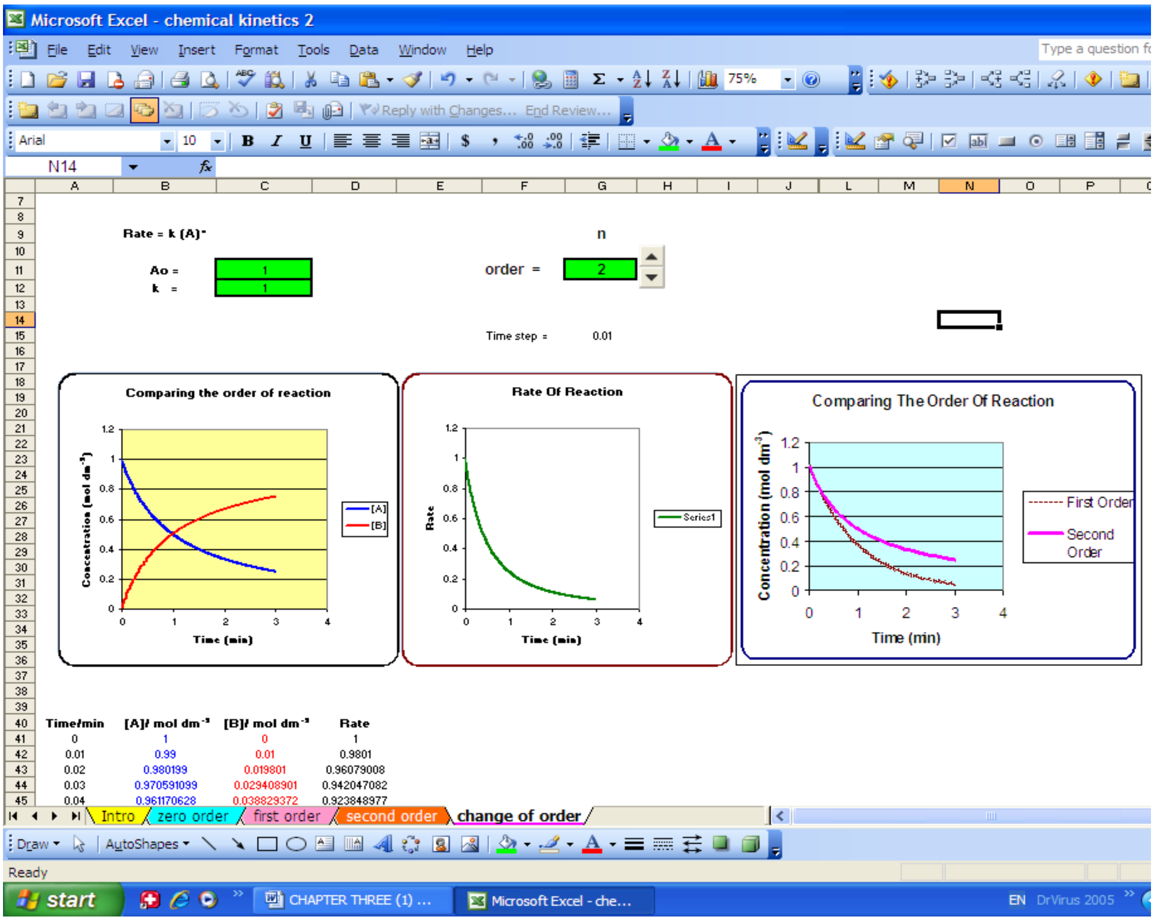

Figure 3.15: Change of order worksheet

In the "change of order" worksheet (Figure 3.15), a spinner button was created using "Active X" control in MS Excel beside the green colored cells, demoting order of reaction. Teachers/students can just click at the terminal arrow to choose the order of reaction from the button and observe the changes to the graphs. Besides the order of reaction, teacher/students can also alter the value of A_o or k by typing the value in the green box provided to observe the changes to the graphs. Formulae used to compute the graphs in this worksheet are:

Cell B41 = IF(K41<0,0,K41)

Cell C41 = $K$41-K41

Cell D41 = (C42-C41)/(A42-A41)

Teacher/students can browse any of these sheets by clicking the tab at the bottom of each corresponding sheets.

(b) Chemical Kinetics 2 Workbook

In this section, how MS Excel is used to display the experimental data and help to determine the order of reaction, value of k and $t_{½}$ is presented. As mentioned earlier, a rate law tells us that the rate of reaction depends on the reactant's concentrations at a particular moment. However, chemists often would like to have a mathematical relationship showing how the reactant concentration changes over a period of time. Such an equation would be directly comparable to the experimental data, which are usually obtained as concentrations at various times. In this case, hydrolysis of methyl ethanoate is used as an example to investigate the first order reaction and decomposition of nitrogen dioxide as the second order reaction.

The equation for the hydrolysis of methyl ethanoate is

$$CH_3COOCH_3 \longrightarrow CH_3COOH + CH_3OH$$

This relationship can be easily explored using MS Excel. A spreadsheet that involves the first order kinetics is shown in the "methyl ethanoate" worksheet (Figure 3.16). From the experimental data, students are required to prepare a graph of concentration, [methyl ethanoate] as a function of time and a graph of natural logarithm of concentration, LN[methyl ethanoate] against time. This task can be easily accomplished using MS Excel chart wizard in a very short time. From the graphs obtained, students can determine the order of reaction and the value of k. The spreadsheet will calculate the value of $t_{½}$ automatically once students type in the value of k (Figure 3.16). Detailed instructions to carry out the experiment and to prepare the graphs are provided in the supplementary material (Appendix A and B).

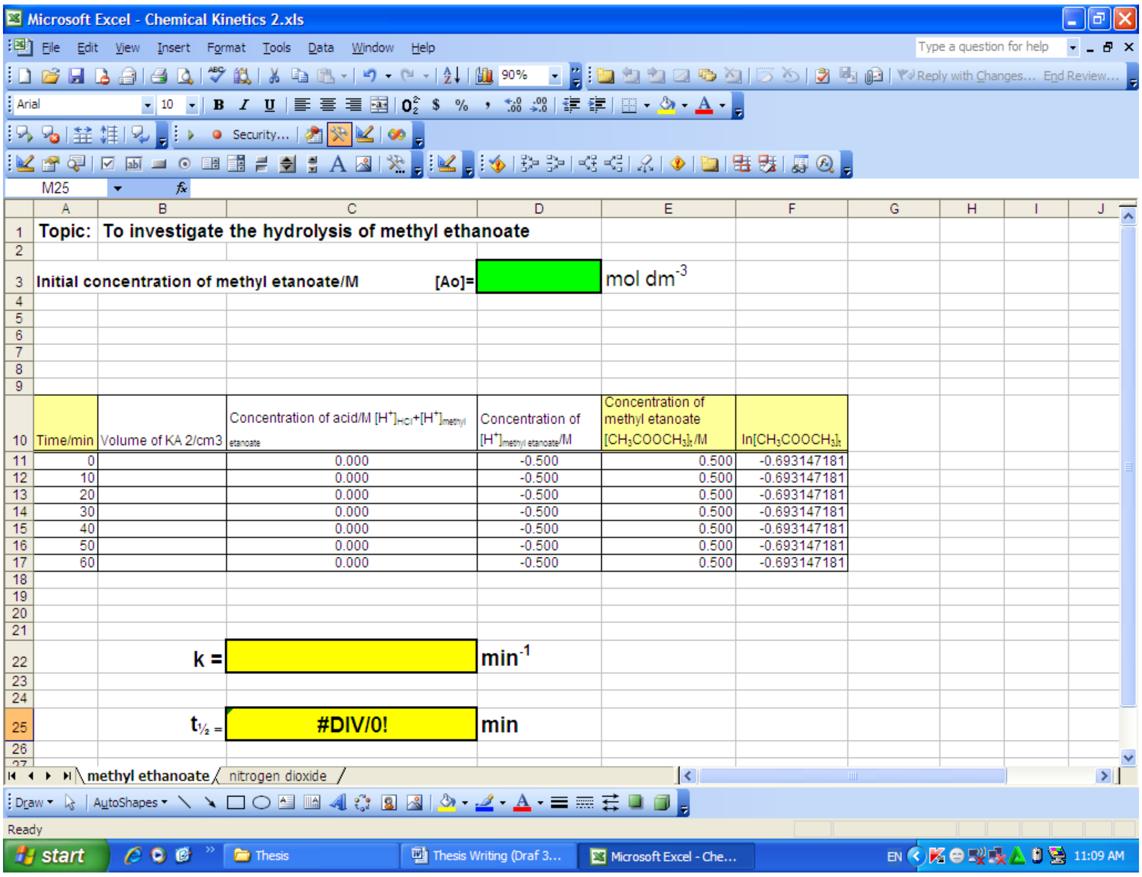

Figure 3.16: Methyl ethanoate worksheet

The formulae used to compute concentration of methyl ethanoate and other related variables in "methyl ethanoate" worksheet are presented below. A_o is a named cell corresponding to cell D3.

Cell C11= $\quad$ *0.1*B11/5*

Cell D11= $\quad$ *C11 – 0.5*

Cell E11= $\quad$ A_o *- D11*

Cell F11= $\quad$ *LN(E11)*

Cell C25= $\quad$ *0.693/C22*

Referring to Figure 3.16, the initial concentration is defined as the named variable, A_o, and the value is assigned to cell D3. The time scale is defined from cell A11 to A17 to cover the time range of 0 – 100 minutes. The formula used to calculate the concentration of methyl ethanoate (cell E11) is A_o (cell D3) minus the concentration of hydrogen ion, $[H^+]$ from methyl ethanoate (cell D11). In order to cover the time range in column A, the content of cell E11 is copied into cell E12 through E17. Similarly, the content of cell C11 is copied into cells C12 through C17 and the content of cell D11 is copied into cell D12 through D17. The natural logarithm, LN of concentration of methyl ethanoate (column F) are calculated using the built in "LN" function in MS Excel program. The content of cell F11 is then copied into cell F12 through F17 for the time range in column A.

As an illustration in using MS Excel in plotting graphs for the determination of a second order reaction, the following data for the decomposition of NO_2 is used.

Time/s	0	60	120	180	240	300	360
$[NO_2]$/M	0.01	0.00683	0.00518	0.00418	0.00350	0.00301	0.00264

The equation for decomposition of nitrogen dioxide is:

$$2\,NO_2 \longrightarrow 2\,NO + O_2$$

A spreadsheet for determining the second order kinetics, k value and the value of $t_{½}$ is shown in the "nitrogen dioxide" worksheet (Figure 3.17).

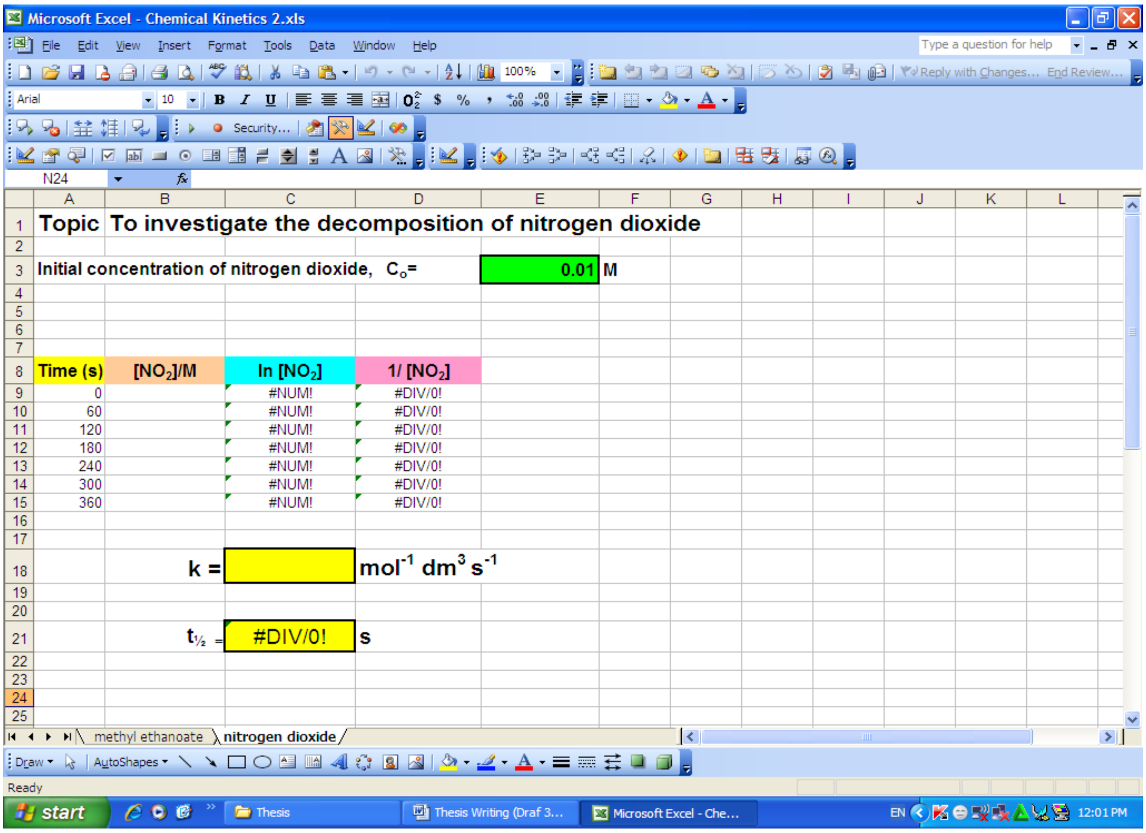

Figure 3.17: Nitrogen dioxide worksheet

The initial concentration of NO_2 is defined as C_o and the value ranging from 0 – 360 seconds, is assigned into cell A9 to A15. The formulae used to compute natural logarithm of [NO_2], ln [NO_2], 1/[NO_2] and $t_{½}$ are listed below:

Cell C9= *LN(B9)*

Cell D9= *1/B9*

Cell C21= *1/(C18*E3)*

The contents of cell C9 are then copied into cells C10 through C15 whilst the contents of cell D9 are copied into cell D10 through D15 for the same time range in column A. As with first order reactions, detailed instructions for preparing these graphs are provided in the supplementary material (Appendix B). In this case, students are required to prepare the graph of [NO_2] vs time, graph of natural logarithm of [NO_2] against time and graph of 1/[NO_2] as a function of time using the MS Excel chart wizard. From the graphs, students could determine the order of reaction, obtain the k value and the spreadsheet will calculate the half-life of the reaction automatically. The need for graphing and computer skills is directly addressed through this activity.

3.3.2 States Of Matter

Gases are distinguished from liquids and solids by their ability to be compressed into smaller and smaller volumes. Gases are also the simplest physical state of matter. All gases under moderate conditions behave accordingly with respect to pressure, temperature, volume and molar amount. In this section, application of MS Excel to explore the compressibility factor and distribution of molecular speeds of gas will be discussed.

3.3.2.1 The Ideal Gas Equation

The ideal gas equation, $pV = nRT$ at low pressure was established by combining a series of empirical laws. This expression is consistent with Boyle's law (pV=constant) when n and T are constant, Charles's law (V/T=constant) when n and p are constant and with Avogadro's principle (n/V= constant) when p and T are constant. Any gas which obeys the ideal gas equation perfectly under all conditions is known as an ideal gas (perfect gas), a gas which exists only in theory. For an ideal gas, the compressibility factor,

$$z = \frac{pV}{nRT} = 1$$

A plot of z against p will give a straight line parallel to the p axis (Figure 3.18)

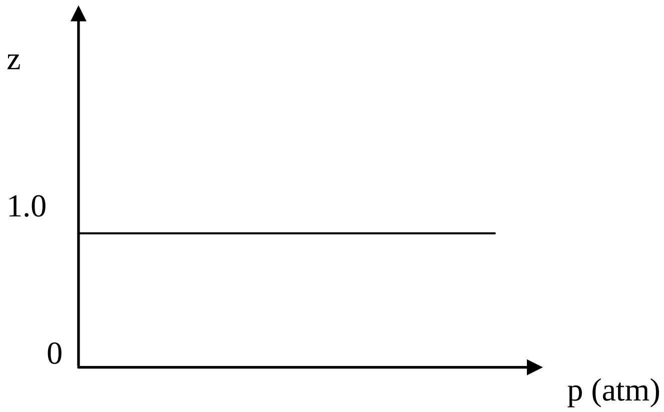

Figure 3.18: Graph of compressibility vs pressure

However, in reality, all gases are real gases and show a deviation from ideal gas equation. Real gases do not obey the ideal gas equation especially at high pressure and low temperature, specifically when a gas is at the point of condensing to liquid. Real gases show deviation from the perfect gas law because molecules interact with each other and have a finite volume. At high pressure, the volume occupied by the gas is small but cannot be ignored. The molecules of gas are pushed so close together that repulsive forces operate between them making the gas less compressible. At low temperature, the kinetic energy of the molecules is low and the intermolecular forces between the molecules become more apparent.

All real gases behave almost ideally under very low pressure and very high temperature. At low pressure, the volume occupied by the gas is very large. The volume of the gas molecules by comparison is extremely small and can be ignored. At high temperature, the kinetic energy of the molecules is so high that the intermolecular forces operating between them can be ignored. Furthermore, the volume of a gas at higher temperature is larger and the volume occupied by molecules is very small and can be ignored. The small differences suggest that the perfect gas law (in this case $pV = nRT$) is in fact the first term in a series of powers of a variable, p, and is in the form of the expression $pV_m = RT(1+B'p+C'p^2)$ or $z = 1+B'p+C'p^2$ where B and C are the virial coefficients which depend on the temperature. There are two types of deviation:

(a) Negative Deviation (Compressibility factor, z <1)

At low pressure, this deviation is mainly due to attractive forces between the gas molecules which cause the molecules to be nearer to each other and the measured volume to be smaller than the expected value. In addition, the speed of molecules colliding with the walls of the vessel is retarded resulting in the measured pressure of the gas being lower than the expected pressure. Hence, the value of z is less than 1.

(b) Positive Deviation (Compressibility factor, z >1)

Positive deviation occurs at high pressure. This is mainly due to repulsive forces between the gas molecules which cause the molecules colliding with the walls of the vessel to increase and the measured pressure of the gas is higher than the expected pressure causing the value of z to be greater than 1. Furthermore, the volume of gas molecules which cannot be neglected at high pressure results in the volume of real gas at high pressure being larger than that predicted by the ideal gas law.

The compressibility factor of ideal gas and non ideal gases could be easily computed using MS Excel program. Some examples of non ideal gases such as H_2, He, N_2, O_2, Ar, and CO are used in this section to demonstrate and explain the compressibility of gas compared to the ideal gas using MS Excel program.

3.3.2.2 Distribution Of Molecular Speeds

The kinetic theory of gases can be used to explain the behavior of gases. The main principle of the theory is that molecules are in constant random motion (Ebbing & Wrighton 1993). In this section, the kinetic theory of molecules will be discussed.

According to kinetic theory, the speeds of molecules in a gas vary over a range of values. This distribution of speeds depends on the temperature. According to Maxwell Boltzmann's distribution curve, at any temperature, the molecular speeds vary widely but most are close to the average speed which is close to the speed corresponding to the maximum in the distribution curve (Figure 3.19)

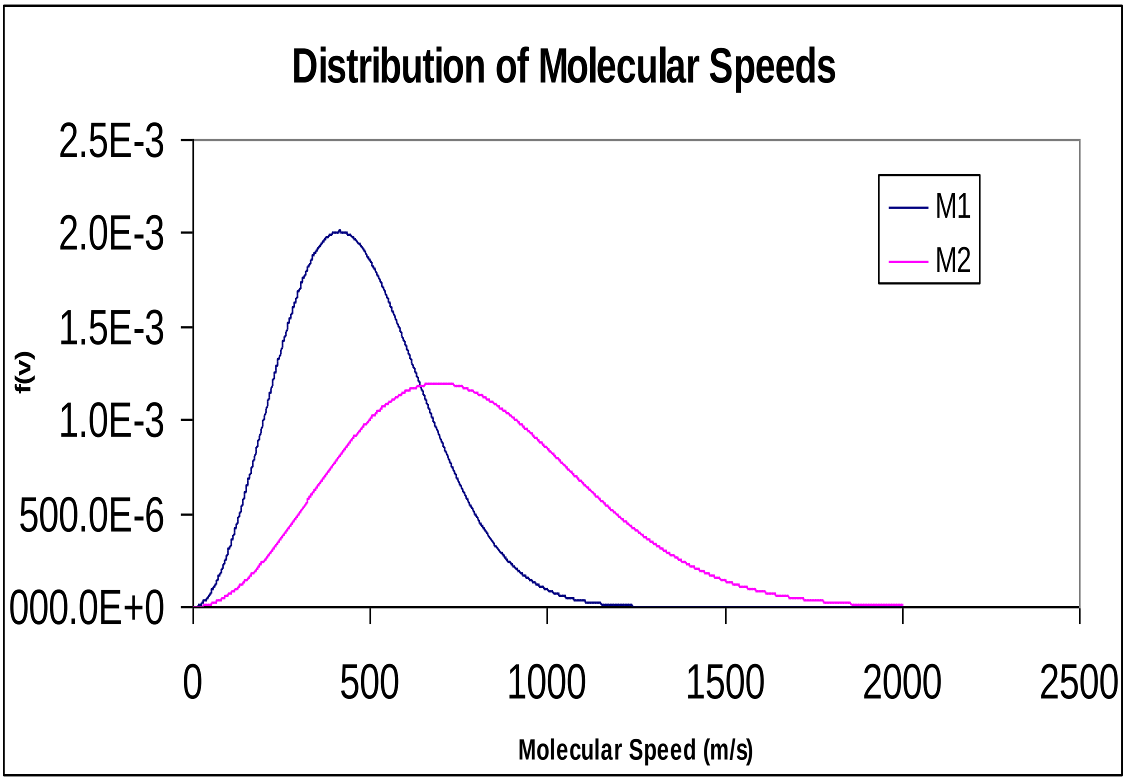

Figure 3.19: Distribution of molecular speeds curve

The root mean square (rms) molecular speed, u, is equal to the speed of molecules having the average molecular kinetic energy. It is given by the formula

$$u = \sqrt{\frac{3RT}{M_m}}$$

where R is the molar gas constant, T is the absolute temperature and M_m is the molar mass for the gas. Note that for two different gases, the one with the higher molar mass will have the lower rms speed. The fraction of molecules that have speeds in the range ν to ν + dν is proportional to the width of the range and written as f(ν)dν, where f(ν) is called the distribution of speeds. The equation corresponding to the molecular speed distribution is

$$f(\nu) = 4\pi \left(\frac{M}{2\,\pi RT} \right)^{\frac{3}{2}} \nu^{2}\, e^{-M\,\nu^{2} / 2RT}$$

From the distribution curve shown in Figure 3.19, the area under the curve represents the total number of molecules in a sample of gas. It shows that at a higher temperature, the number of molecules with higher speeds increases whereas the number of molecules with average speed decreases. Thus, the number of molecules with energy that equals or is more than the activation energy, increases. Hence, the number of effective collisions resulting in a reaction increases at a higher temperature. This causes the reaction rate to increase.

3.3.2.3 Gas Compressibility Workbook

From established data, the graph of compressibility factor (z) against pressure for ideal and non-ideal gases are presented in this workbook (refer to CD). The graph will respond interactively when the parameter set is being changed. A combo box and a scroll bar are created using “Active X” controls of MS Excel (Figure 3.20).

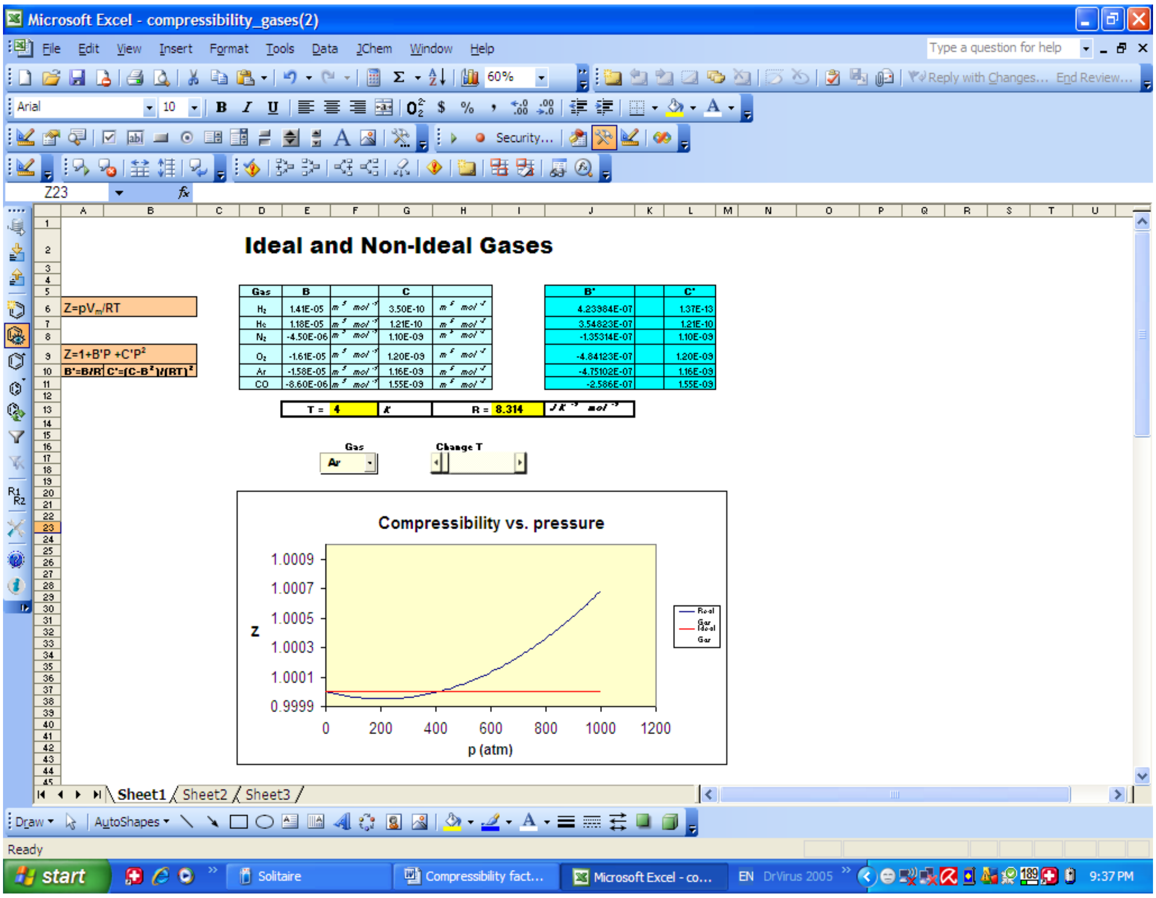

Figure 3.20: Gas compressibility workbook

Non ideal gases included in this combo box are H_2, He, N_2, O_2, Ar, and CO. Teachers and students can click at the drop down menu to choose any non ideal gases from the list and observe changes to the graph. To see the effect of temperature on the deviation of non ideal gas from ideal gas, teachers and students can drag the scroll bar to change the temperature from 1 to 300 K and observe how the graph of compressibility of gas against pressure changes with temperature. From the observation of various graphs shown, it is noticed that the heavier the non ideal gas is, the greater is the deviation of its compressibility from ideal gas (z=1). MS Excel has provided a very easy and convenient way to compute the graphs. Formulae used to compute the graph in this workbook are:

Cell J6 = E6/($I$13*$F$13)

Cell L6 = G6-E6^2 /($I$13*$F$13)^2

Cell O21 = IF(O17= “H_2”,J6,IF(O17= “He”,J7,IF(O17= “N_2”,J8,IF(O17= “O_2”,J9, IF(O17= “Ar”,J10,IF(O17= “CO”,J11,0))))))

Cell O22 = IF(O17= “H_2”,L6,IF(O17= “He”,L7,IF(O17= “N_2”,L8,IF(O17= “O_2”,L9, IF(O17= “Ar”,L10,IF(O17= “CO”,L11,0))))))

Cell N25 = 1 + $O$21*O25 + $O$22*O25^2

In order to cover non ideal gases used in column D, the content of cell J6 is copied into cell J7 through J11 and the content of cell L6 is copied into cell L7 through L11 whilst the content of cell N25 is copied into cell N26 through N125.

It is believed that presentation of interactive graphs showing the deviation of compressibility for various non ideal gases from ideal gas using MS Excel would bring about a better understanding of the relationship between compressibility factor, pressure and temperature for students.

3.3.2.4 Molecular Speed Workbook

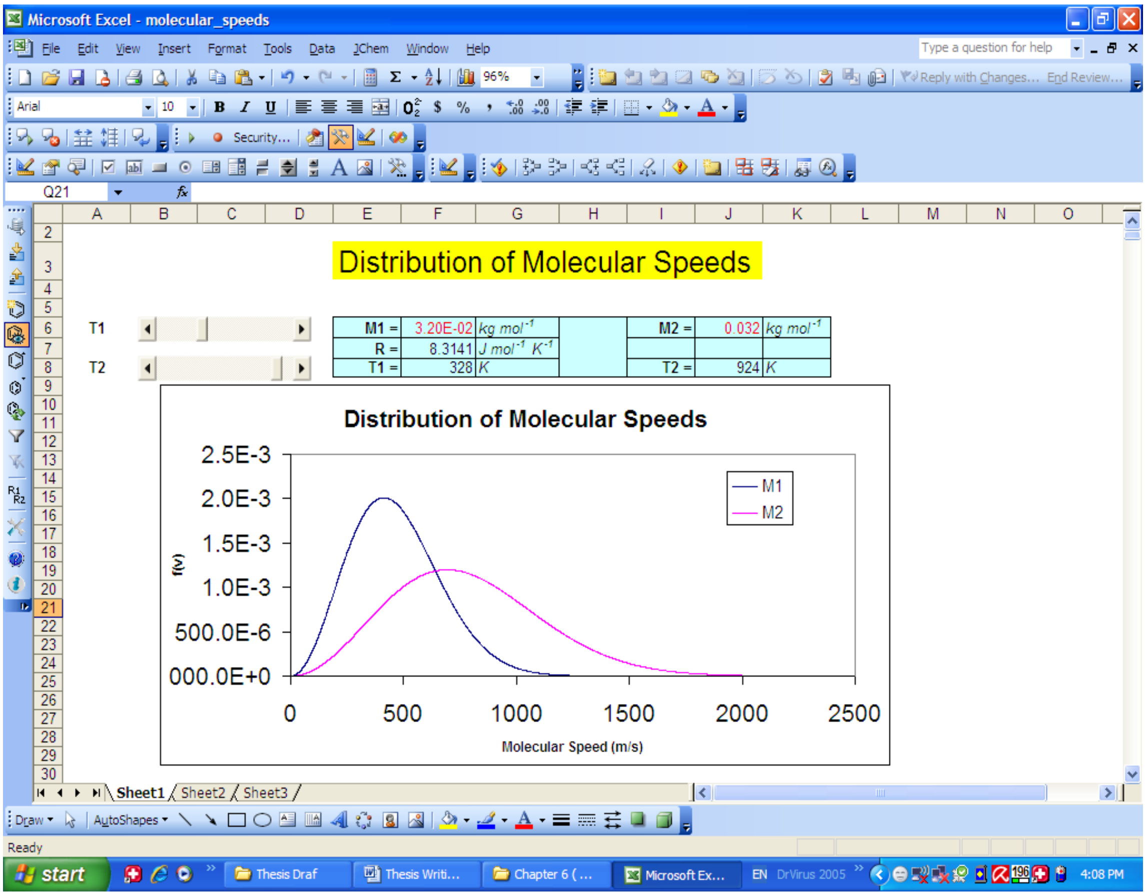

Figure 3.21: Molecular speeds workbook

In this workbook (refer to CD), two curves are created representing two different gases, M1 and M2 using the MS Excel chart wizard. Two scroll bars, T1 and T2 are created using 'Active X' control button where teachers or students can change the temperature by dragging the scroll bar for temperature ranging from 0K to 1000K (Figure 3.21). The curve will respond interactively once the temperature is being changed. For example, when the temperature, T1, is being changed, curve M1 will respond immediately. Similarly if T2 being changed, M2 will be changed interactively. Beside these, teachers or students can also change the molar mass of gas, M1 or M2 to see the differences between the curves shown. Students can better understand how temperature or molar mass of gas affect distribution of molecular speeds by observing the changing curves. Formulae used to plot the curves are:

*Cell B12 = 4*PI()*((M/(2*PI()*R_R*T))^(3/2))*D12*EXP(-((M*D12)/ (2*R_R*T)))*

Cell D12 = C12^2

*Cell F12 = 4*PI()*((M_2/(2*PI()*R_R*T_2))^(3/2))*H12*EXP(- ((M_2*H12)/(2* R_R*T_2)))*

Cell H12 = G12^2

The symbols used in formulae above are name of cells which are defined earlier. Named cells could be used directly in a formula to refer to the values contained in the cells. For example, to name cell F6 as M, from the insert menu, ‘name’ was chosen and then ‘define’ is clicked. The name of the cell, M, is then typed. Students will get a clearer picture and understand the formula better if name are defined instead of just using the standard cell reference. Below are the defined names that have been used in the formulae:

Cell	Name of cell	
F6	M	(for molar mass of gas M1)
J6	M_2	(for molar mass of gas M2)
F7	R_R	
F8	T	(for temperature T1)
J8	T_2	(for temperature T2)

In the compressibility gas workbook, students can observe and compare the compressibility of non ideal gases in comparison to ideal gases within a range of temperature (from 1K to 300 K). In the molecular speeds workbook, students observe the changes of distribution of molecular speeds when the temperature or molar mass of gases are changed. Interesting learning environments with visualization will allow students to develop a deeper understanding of physical concepts such as those demonstrated in this section.

3.3.3 Period Three Elements

The periodic table is one of the most important icons in science. It lies at the core of chemistry and embodies the most fundamental principles of the field. It examines the manner in which the term "element" has been interpreted by chemists. The modern periodic table was first introduced by Mendeleev in the year 1869 by arranging the elements in order of increasing relative atomic mass. However, the present periodic table is arranged according to increasing proton number. The study of inorganic chemistry embraces the structures, properties and reactivity's of the elements and their compounds. However, students always find study of the elements' properties in the periodic table very dull and boring. In this section, application of MS Excel in exploring the reactions and selected properties of all elements in Period three (sodium to argon) will be discussed. It is hoped that through this approach the factual content of periodic table could be made more lively, thus boosting the students' interest in learning the periodic table.

3.3.3.1 Periodic Trends Across Period Three

The third period of the Periodic Table consists of eight elements, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine and argon. Elements in the periodic table show periodic variations in their physical properties with increasing proton number and electron configuration. The elements also display periodic variations in their chemical properties. In this study, the variation in physical properties of the elements across period three, such as atomic radii, electronegativity, ionization energy, melting points and boiling point is discussed using MS Excel as follows:

(a) Decrease In Atomic Radii

Generally, the size of an atom is dependent on the number of electronic shells, the nuclear charge and the shielding effect. Going across the period three in the periodic table, the atomic radii decreases from sodium (Na) to argon (Ar). The number of proton in the nucleus increases by one each time causing the nuclear charge to increase from sodium to argon but the added electron goes into the same quantum shell. The screening effect remains constant. The force of attraction between the electron charge cloud and the increasing nuclear charge increases. The outermost electrons are thus pulled towards the nucleus resulting in radius contraction. Therefore, the size of atom decreases across the period from sodium to chlorine (Figure 3.22).

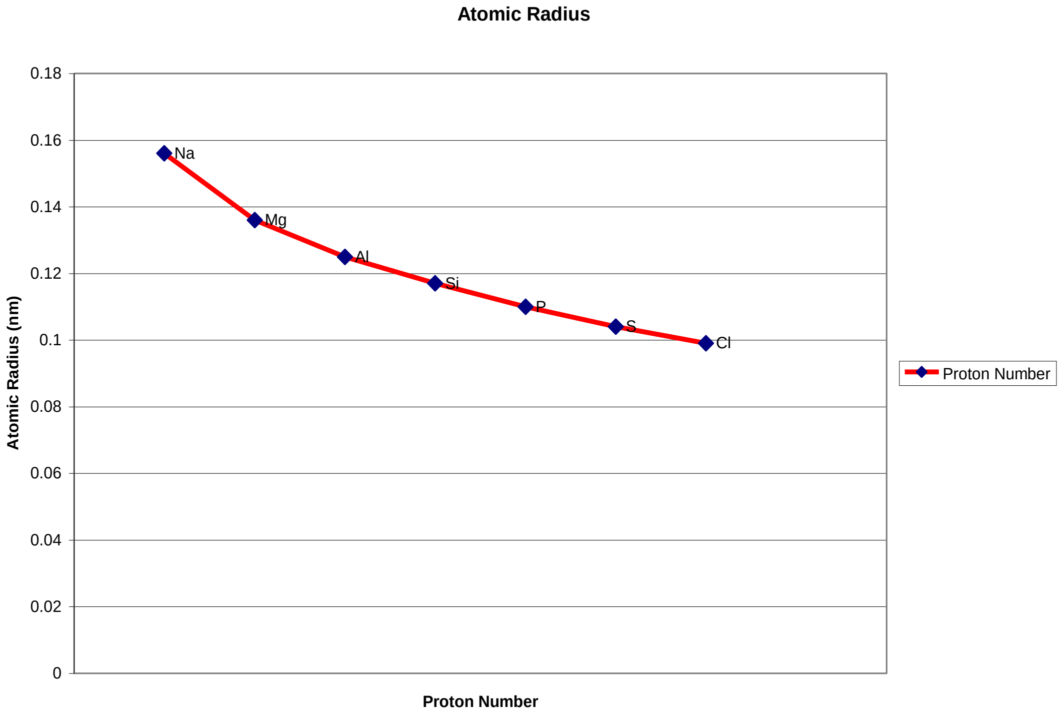

Figure 3.22: The variation of atomic radius across period 3

(b) Increase In Electronegativities

Electronegativity is the measure of a bonded atom's ability to pull electrons in a bond towards itself, from other atoms to which it is bonded. An element with a high electronegativity pulls electrons towards it away from an atom which is less electronegative. A highly electronegative element has a small atomic radius and a higher effective nuclear charge. Going across the period from sodium to argon, the size of atom decreases but the nuclear charge increases as mentioned above. Thus, the effective nuclear charge increases. The bonded electrons in a covalent bond will thus be attracted more strongly towards the nucleus of the atom, causing the electronegativity to increase from Na to Cl (Figure 3.23).

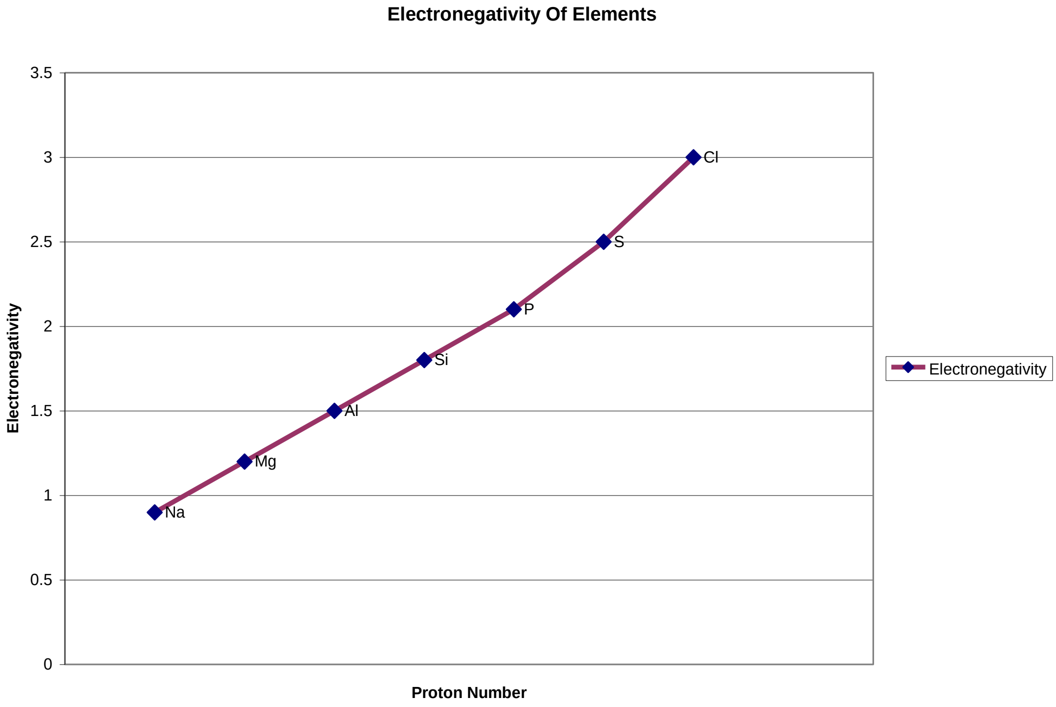

Figure 3.23: The variation of electronegativity across period 3

(c) Increase In Ionization Energies

The ionization energy of an element is defined as "the minimum energy required to remove one mole of electrons from one mole of single, isolated gas-phase atoms". For example,

$Na(g) \rightarrow Na^{+}(g) + e^{-}$

Ionization energies depend on the effective nuclear charge, the distance between the electron and nucleus and the shielding effect of inner electrons. Across the period three from sodium to argon, the successive ionization energy increases because of the decrease in atomic radius whilst the charge of the nucleus increases. This means that the distance between the valence electrons and the nucleus is getting shorter. In addition, the screening effect of the orbitals is insignificant across the period and the force of attraction between the nucleus and the outer electrons keeps increasing. All these factors contribute to an increase in ionization energy across the period as valence electrons become more difficult to be removed (Figure 2.24).

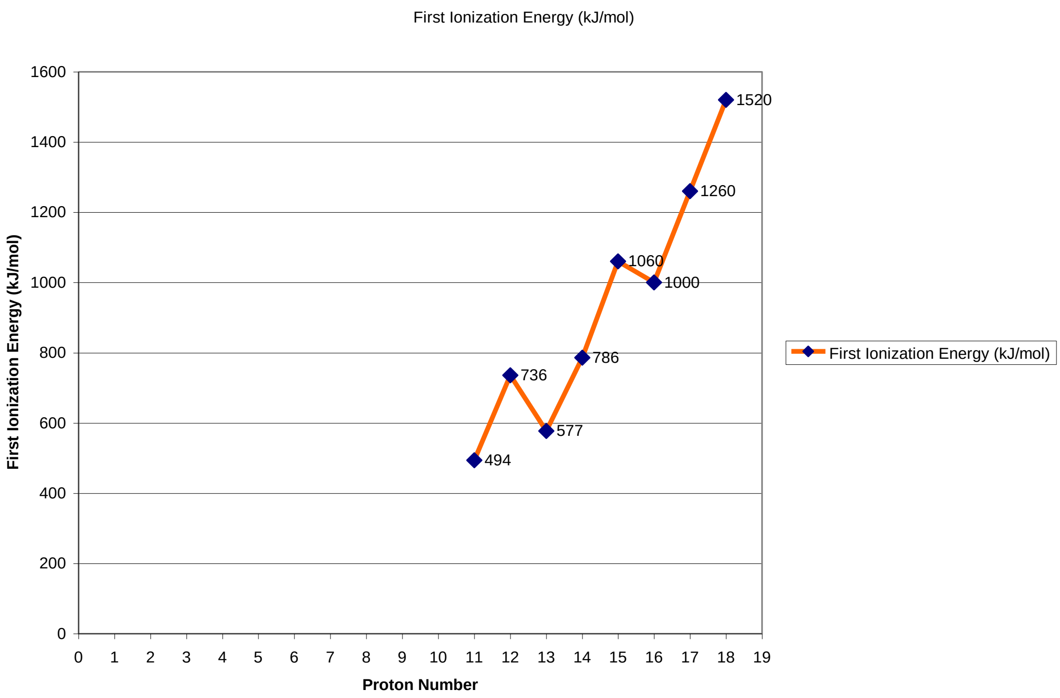

Figure 3.24: The variation of first ionization energy across period 3

(d) Increase In Melting Point/Boiling Point

The melting point and boiling point of a substance depends on the structure and type of bonding in the substances. On going across period three from Na to Ar, the melting and boiling points of the first three elements, which are sodium, magnesium and aluminium increase because of their metallic structure. The metal atoms are held together by strong metallic bonds. The strength of these metallic bonds increase as the number of electrons available for metallic bonding increases. Hence, the melting point and boiling point for the metals increase from sodium to aluminium because more valence electrons can be delocalized for metallic bonding.

Silicon has the highest melting and boiling point because it exists as macromolecules. This element has a giant covalent molecular structure where the atoms are held together by strong covalent bonds in an infinite arrangement. Micro molecules like phosphorus, sulphur, chlorine and argon have low melting and boiling points. These elements exist as discrete molecules (P_4, S_8, Cl_2 and Ar) because of the weak intermolecular forces, i.e. van der Waals between the molecules (Figure 3.25 & 3.26).

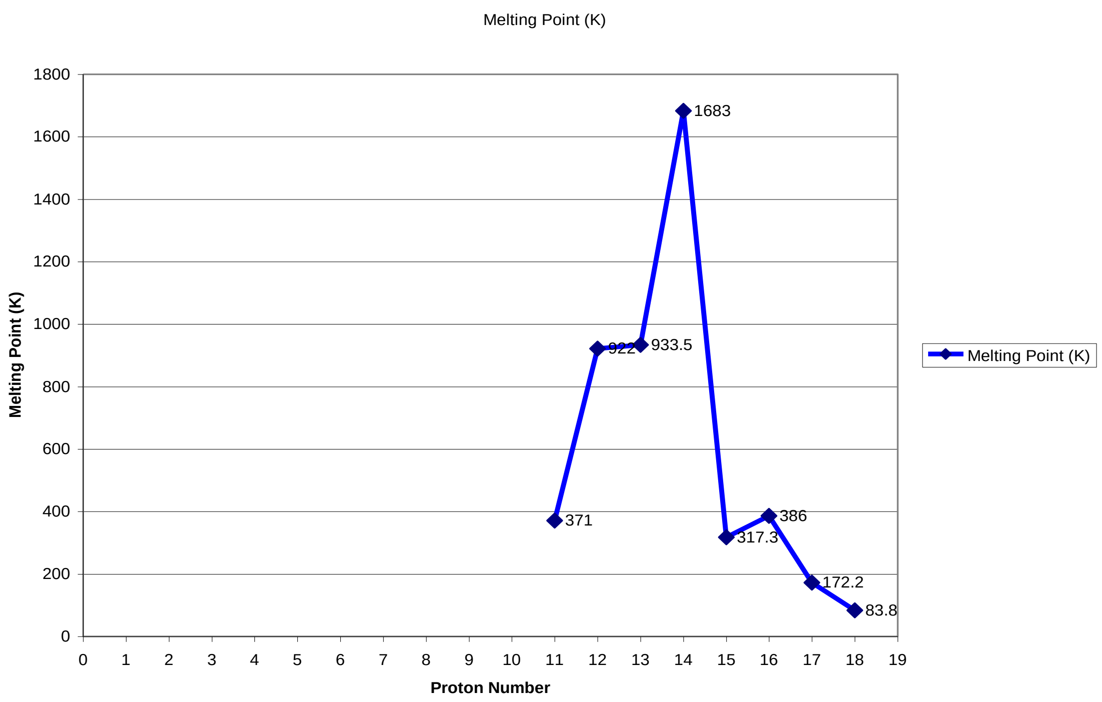

Figure 3.25: The variation of melting point across period 3

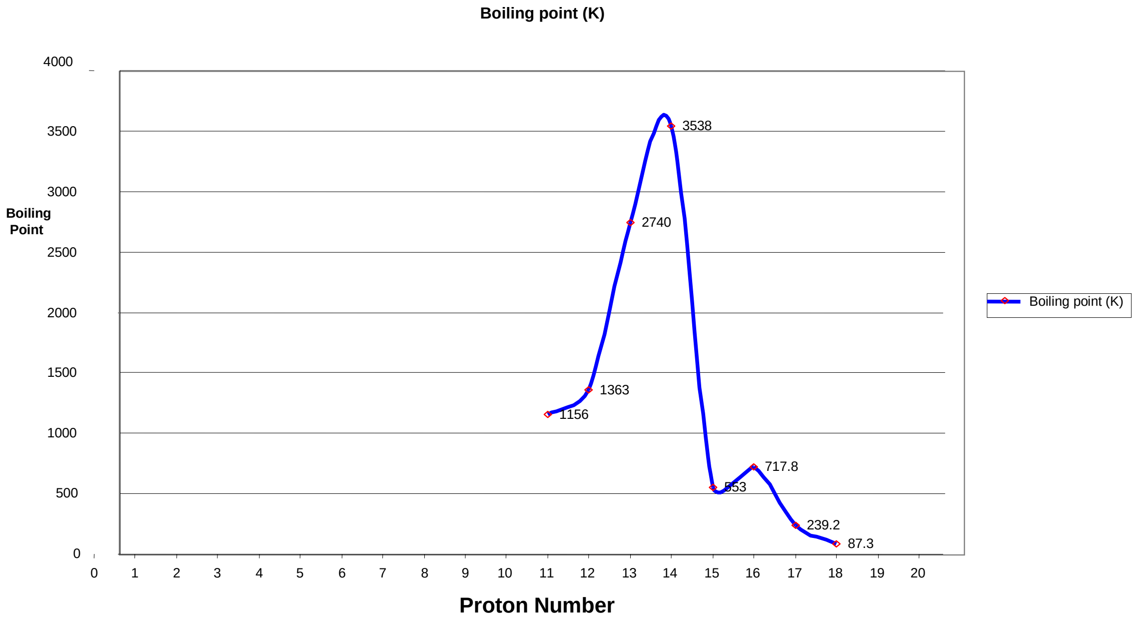

Figure 3.26: The variation of boiling point across period 3

The tables below show the selected physical properties of the elements:

TABLE 3.2: Period three elements

Proton no.	Element	Symbol	Atomic radius (nm)	Electronic Configuration	First Ionization Energy (kJ/mol)	Melting Point (K)	Boiling Point (K)	Electronegativity
11	Sodium	Na	0.156	2.8.1	494	371	1156	0.9
12	Magnesium	Mg	0.136	2.8.2	736	922	1363	1.2
13	Aluminium	Al	0.125	2.8.3	577	933.5	2740	1.5
14	Silicon	Si	0.117	2.8.4	786	1683	3538	1.8
15	Phosphorus	P	0.110	2.8.5	1060	317.3	553	2.1
16	Sulphur	S	0.104	2.8.6	1000	386	717.8	2.5
17	Chlorine	Cl	0.099	2.8.7	1260	172.2	239.2	3.0
18	Argon	Ar	-	2.8.8	1520	83.8	87.3	-

3.3.3.2 Reaction Of Elements In Period Three With Water

(a) Sodium With Water

Sodium reacts vigorously with cold water to form an alkaline solution. Hydrogen gas is evolved.

$$2Na(s) + 2\,H_2O(l) \longrightarrow 2\,NaOH(aq)\ [\text{alkaline}] + H_2(g)$$

(b) Magnesium With Steam

Magnesium is less reactive than sodium. Magnesium does not react with water at room temperature. When magnesium is heated with steam, magnesium is oxidized to magnesium oxide as shown in the equation below. Hydrogen gas is evolved.

$$Mg(s) + H_2O(g) \longrightarrow MgO(s) + H_2(g)$$

(c) Aluminium With Water

Aluminium does not react with water due to the presence of the protective oxide layer on its surface. If the oxide layer is removed, aluminium will react vigorously with water to form aluminium oxide. Hydrogen gas is evolved.

$$2Al(s) + 3\,H_2O(l) \longrightarrow Al_2O_3(s) + 3\,H_2(g)$$

(d) Silicon, Phosphorus, Sulphur And Argon With Water

Silicon, phosphorus, sulphur and argon do not react with water under any circumstances.

(e) Chlorine With Water

Chlorine is slightly soluble in water at room temperature to form 'chlorine water' which is a mixture of hydrochloric acid and chloric(I) acid.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HCl(aq) + HOCl(aq)\ \text{[acidic]}$$

3.3.3.3 Reaction Of Elements In Period Three With Oxygen

(a) Sodium With Oxygen

Sodium is the most reactive element in Period 3. It burns vigorously in oxygen with a bright yellow flame to produce sodium oxide, a white solid. Sodium is so reactive that it is usually kept under paraffin oil.

$$4Na(s) + O_2(g) \longrightarrow 2\ Na_2O(s)$$

(b) Magnesium With Oxygen

Magnesium burns in oxygen with a brilliant white flame to produce magnesium oxide, a white solid.

$$2Mg(s) + O_2(g) \longrightarrow 2\ MgO(s)$$

(c) Aluminium With Oxygen

Aluminium burns in oxygen with a brilliant white light to produce aluminium oxide, a white solid.

$$4Al(s) + 3\ O_2(g) \longrightarrow 2\ Al_2O_3(s)$$

(d) Silicon With Oxygen

Silicon burns in oxygen at red heat to produce silicon(IV) oxide, a white solid.

$$Si(s) + O_2(g) \longrightarrow SiO_2(s)$$

(e) Phosphorus With Oxygen

Phosphorus exists as two allotropes: white and red phosphorus. White phosphorus burns in oxygen at about 40 ^{0}C to form phosphorus(V) oxide, a white solid. In limited supply of oxygen, a liquid phosphorus(III) oxide is formed.

$P_4(s) + 5\,O_2(g) \longrightarrow P_4O_{10}(s);$

$P_4(s) + 3\,O_2(g) \longrightarrow P_4O_6(l)$

Red phosphorus burns in oxygen at about 300 ^{0}C to form phosphorus (V) oxide.

(f) Sulphur With Oxygen

When heated in oxygen, sulphur first melts, then burns with a blue flame to form mainly sulphur (IV) oxide or sulphur dioxide. The sulphur dioxide can further combine with oxygen in the presence of vanadium (V) oxide as catalyst at 450 ^{0}C to form sulphur (VI) oxide or sulphur trioxide.

$S(s) + O_2(g) \longrightarrow SO_2(g);$

$2\,SO_2(g) + O_2(g) \rightleftharpoons 3\,SO_3(g)$

(g) Chlorine And Argon With Oxygen

Chlorine does not react directly with oxygen. However, there are two main oxide of chlorine, which are chlorine (I) oxide, Cl_2O and chlorine (VII) oxide, Cl_2O_7.Argon being chemically inert and does not react with oxygen.

3.3.3.4 Period Three Elements Workbook

Based on the established data of period three elements (Lim & Yip, 2005; Tan, 2006; Lee, 2006; Kwan, 2009; Winter, 1993-2011; Ryan, 2008; Ottawa, 2007), 30 worksheets were created in this workbook (refer to CD). The name and contents of all the worksheets are listed below (Table 3.3). Extensive use of simple functions in MS Excel such as combo box, command button, charting, hyperlink and simple macro are demonstrated in creating these worksheets.

TABLE 3.3: Contents of workbook

Worksheet's Name	Contents
Sheet 1	Contains the complete periodic table where students can click on any of the elements in the periodic table.
Sheet 2	Contains a combobox where students can choose any of the sub titles from the drop down menu.
Atomic Radius	Contains a chart of atomic radius of period 3 elements versus proton number with the symbol of the period 3 elements shown in the chart, two command buttons and a problem solving question based on the chart.
1^{st} Ionization Energy	Contains a chart of first ionization energy of period 3 elements versus proton number with the figure of 1^{st} ionization energy shown in the chart, two command buttons and a problem solving question.

Melting point	Contains a chart of melting point of period 3 elements versus proton number with the melting point of each element shown and two command buttons.
Boiling point	Contains a chart of boiling point of period 3 elements versus proton number with the boiling point of each element shown, two command buttons and a problem solving question.
Eletronegativity	Contains a chart of electronegativity of period 3 elements versus proton number with the symbol of period 3 elements shown in the chart, two command buttons and a problem solving question.
Atomic radius and Melting point	Contains a chart with both the atomic radius and melting point of period 3 elements exist together in the same chart using same x axis and two command buttons.
Atomic radius and 1st I.E	Contains a chart with both the atomic radius and 1st ionization energy of period 3 elements exist together in the same chart using same x axis and two command buttons.
Sodium	Contains the picture and detailed information of sodium and three command buttons.
Magnesium	Contains the picture and detailed information of magnesium and three command buttons.
Aluminium	Contains the picture and detailed information of aluminium and three command buttons.
Silicon	Contains the picture and detailed information of silicon and three command buttons.
Phosphorus	Contains the picture and detailed information of phosphorus and three command buttons.
Sulphur	Contains the picture and detailed information of sulphur and three command buttons.
Chlorine	Contains the picture and detailed information of chlorine and three command buttons.
Argon	Contains the picture and detailed information of argon and three command buttons.
Reaction with water	Contains simple explanation of reactions of period 3 elements when react with water and eight command buttons.
Reaction with oxygen	Contains the equations/explanations of reactions of period 3 elements when react with oxygen and two command buttons.

Equation for Na with water	Contains the equation for reaction between sodium and water and three command buttons.
Equation for Mg with steam	Contains the equation for reaction between magnesium and steam and three command buttons.
Equation for Al with water	Contains the equation for reaction between aluminium and water and three command buttons.
Equation Cl with water	Contains the equation for reaction between chlorine and water and three command buttons.
sodiumatomic	Contains images of electron configuration and atomic diagram for sodium and three command buttons.
mgatomic	Contains images of electron configuration and atomic diagram for magnesium and three command buttons.
alatomic	Contains images of electron configuration and atomic diagram for aluminium and three command buttons.
siliconatomic	Contains images of electron configuration and atomic diagram for silicon and three command buttons.
patomic	Contains images of electron configuration and atomic diagram for phosphorus and three command buttons.
sulphuratomic	Contains images of electron configuration and atomic diagram for sulphur and three command buttons.
chlorineatomic	Contains images of electron configuration and atomic diagram for chlorine and three command buttons.
argonatomic	Contains images of electron configuration and atomic diagram for argon and three command buttons.

In this learning module, students can flexibly view any of the worksheets by clicking at the worksheet bar at the bottom of the worksheet. Students can also choose any sub title from the combo box available in “Sheet 2” worksheet. In “Sheet 1” worksheet, a complete periodic table is displayed in the worksheet. The elements in period three are linked to their corresponding worksheets using the hyperlink function. For example, when sodium (Na) in period three (Figure 3.27) is clicked, it is linked to sheet “Sodium” where the picture of sodium and detailed information on sodium are shown (Figure 3.28).

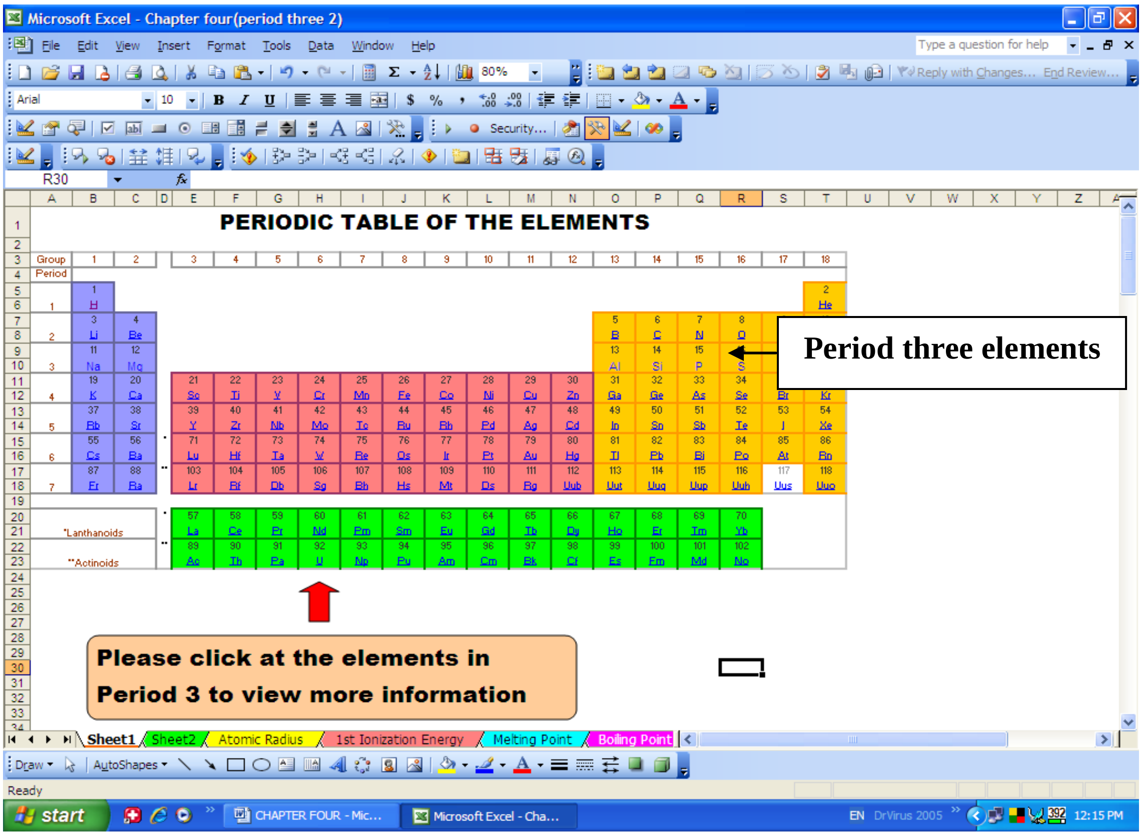

Figure 3.27: “Sheet 1” worksheet

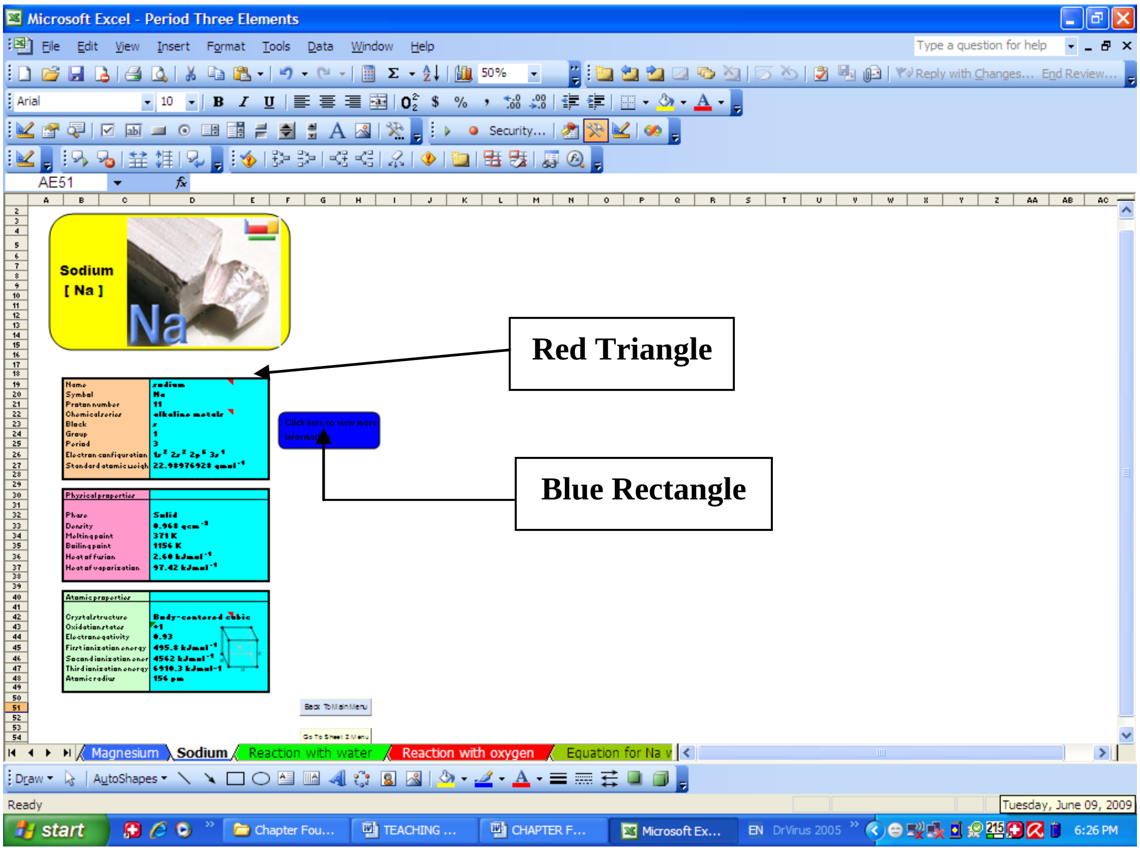

Figure 3.28: “Sodium” worksheet

From worksheet “Sodium”, students can click at the small blue rectangle which is linked to worksheet “Sodiumatomic” where students can further view the images of electron configuration and atomic diagram of sodium. From the picture of sodium, a link is made to its website if the computer is on line. Students can also click at the cell with a red triangle on the top right corner for further explanation. Another advantage of this module is that students can always go back to “Sheet 1” worksheet or “Sheet 2” worksheet by just clicking at the command buttons available within the worksheet. A simple macro is used to run the task for the command button. The visual basic application (VBA) code connected to run this task is

Private Sub Commandbutton2_Click()

Worksheets (“sheet 1”). Select

End Sub

Private Sub Commandbutton1_Click()

Worksheets ("sheet 2"). Select

End Sub

The same operations were created for other elements in period three from magnesium to argon. If other elements in the periodic table beside period three elements are clicked, for example Lithium (Li), a message box "Element not applicable" will appear as shown (Figure 3.29).

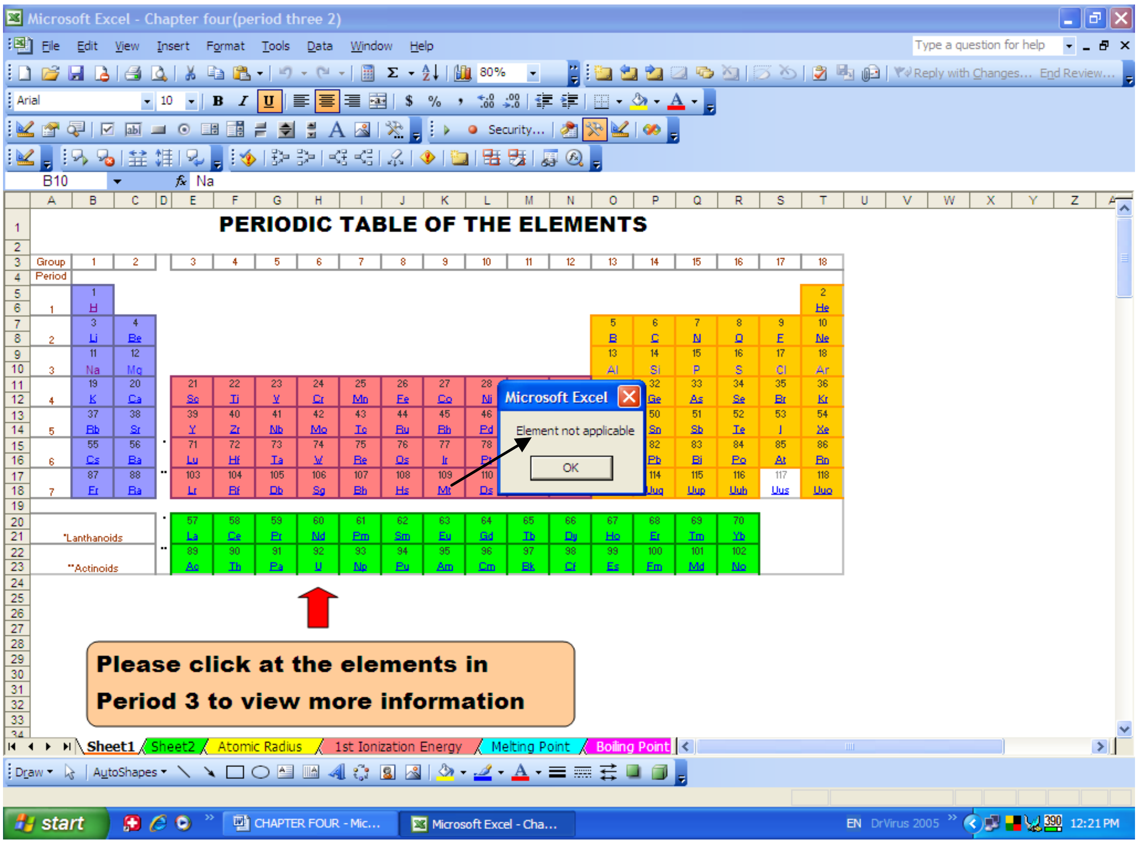

Figure 3.29: Message box appears in "Sheet 1" worksheet

The VBA code to run this macro is

Sub Rectangle34_Click

Msgbox ("Element not applicable")

End sub

In “Sheet 2” worksheet, a combo box is created using “Active X” controls. When any of the title in the combo box is clicked, the correspondent worksheet will be displayed. For example, if atomic radius in the combo box is clicked, the worksheet “Atomic Radius” will be displayed. VBA snippet to run this task is

Private Sub ComBox1_Click()

Select Case ComboBox1.Value

Case “Atomic Radius”

Sheets(“Atomic Radius”). Select

End Select

(To view the full VBA code, refer to Appendix C)

The charting function in MS Excel are used to present some trend of physical properties of the period three elements such as atomic radius, first ionization energy, melting point, boiling point, electronegativity, comparison of atomic radius with melting point and comparison of atomic radius with first ionization energy. Creating a chart can be easily done by MS Excel. From the chart, for example chart of atomic radius (Figure 3.30), students can observe the trend of atomic radius across period three from sodium to argon.

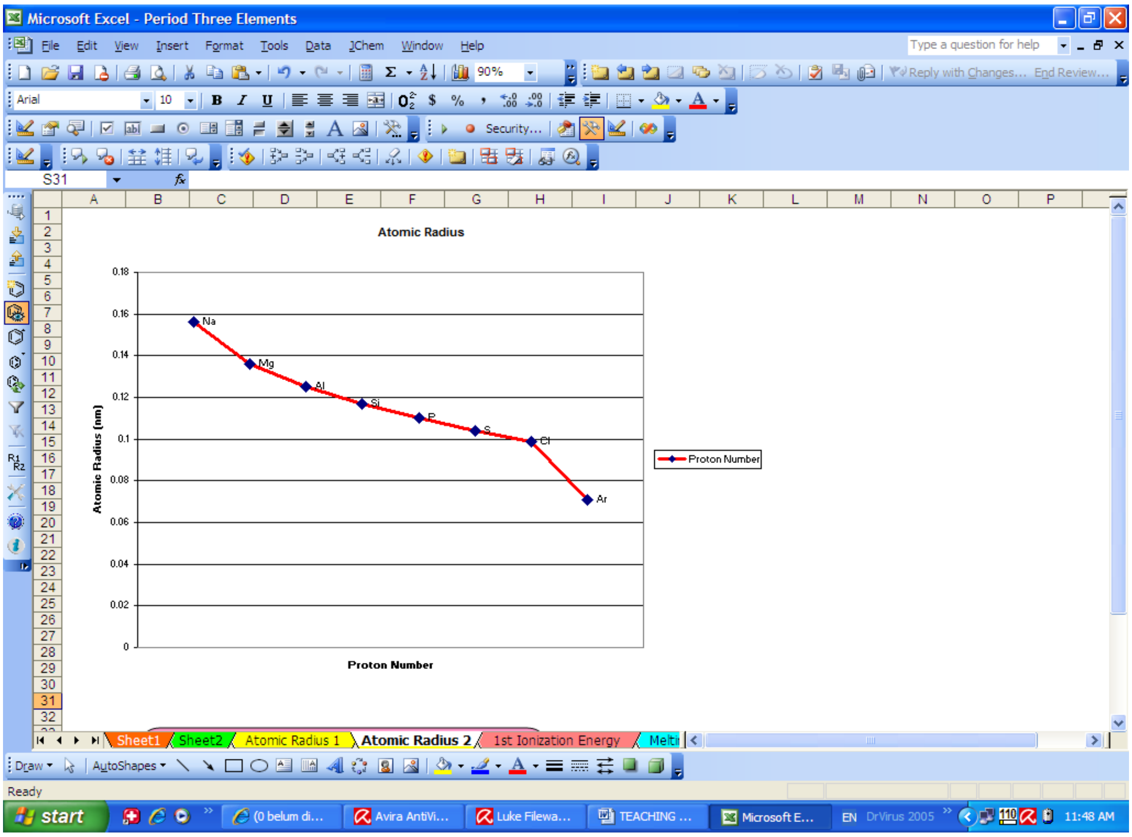

Figure 3.30: “Atomic radius” worksheet

In addition, comparison of two physical properties in the same chart across period three, for example comparison between atomic radius and melting point (Figure 3.31) can be displayed to give a clearer picture to students about the relationship.

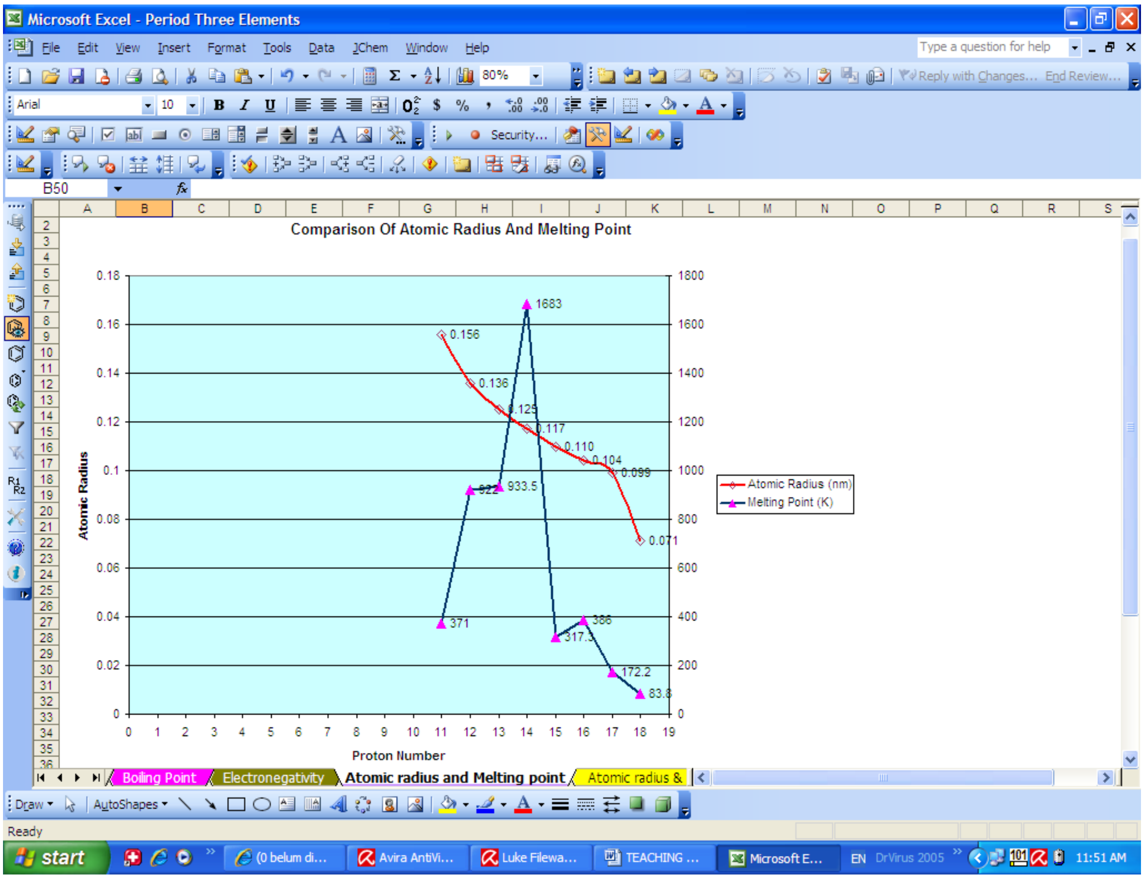

Figure 3.31: “Atomic radius and melting point” worksheet

Questions prepared in the worksheets are to stimulate students’ thinking while they are looking at the chart. Students can always check the solution to the question (as shown in Figure 3.32) by clicking at the question box. A message box will appear to show the explanation.

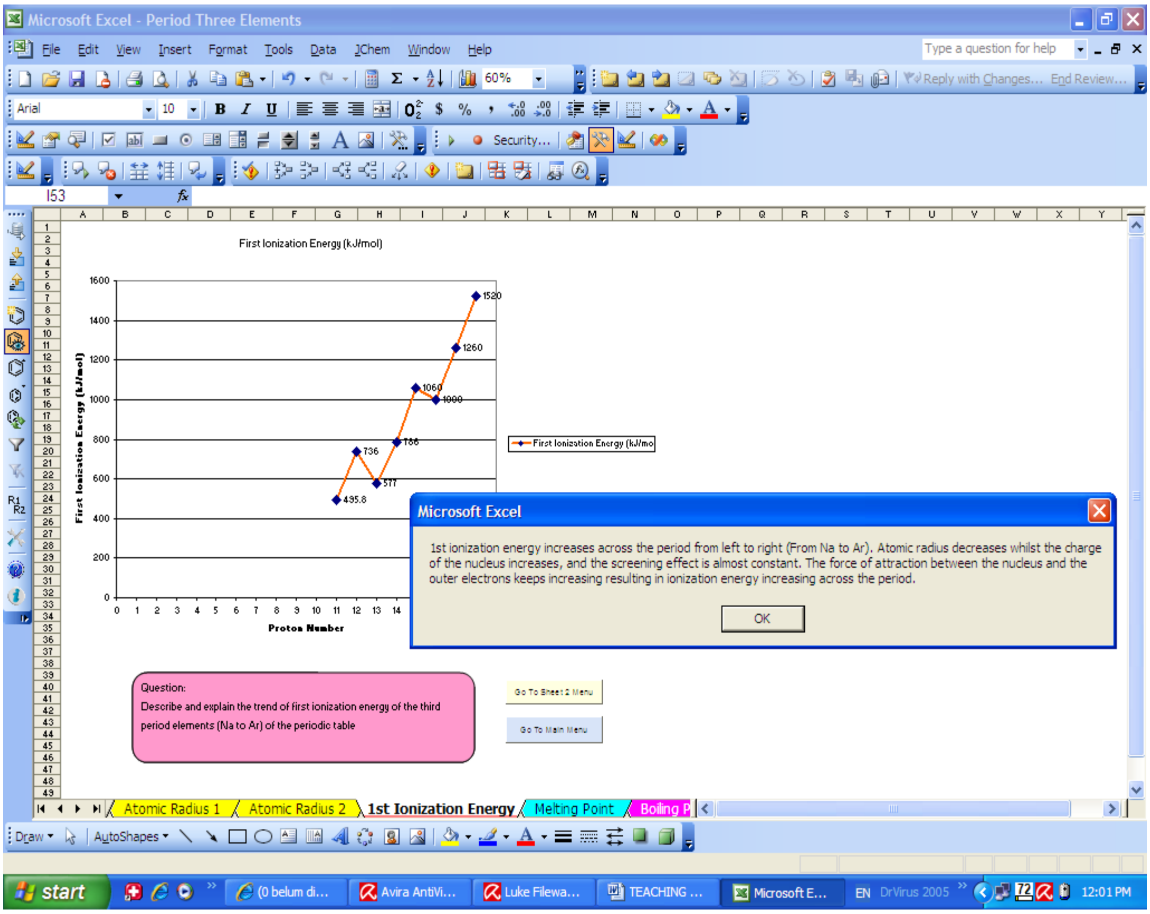

Figure 3.32: Solution shown in “1st ionization energy” worksheet

The example of the VBA code to run this task is

Sub First_ionization_energy_Click()

MsgBox ("1st ionization energy increases across the period from left to right (From Na to Ar). Atomic radius decreases whilst the charge of the nucleus increases, and the screening effect is almost constant. The force of attraction between the nucleus and the outer electrons keeps increasing resulting in ionization energy increasing across the period.")

End Sub

(Refer to Appendix D to view the complete VBA code for all solutions to the question set)

To view some of the animation of reaction between an element with water, students can click at the "Animation" button available in "Reaction with water" worksheet which is linked to the animation website. For example, students can watch the animation of reaction between sodium and water which is a violent reaction. Watching the animation of reaction could give a better understanding to students compared to reading from the textbook. Equation for reaction between period three elements with water could be obtained by clicking at the "Equation" button which is linked to the respective worksheets using the hyperlink function in MS Excel. In worksheet "Reaction with oxygen", the explanation of each reaction between the elements with oxygen could be obtained by clicking at the equation box. For example, when the first equation box in the "Reaction with oxygen" worksheet is clicked, a message box will appear as shown below (Figure 3.33).

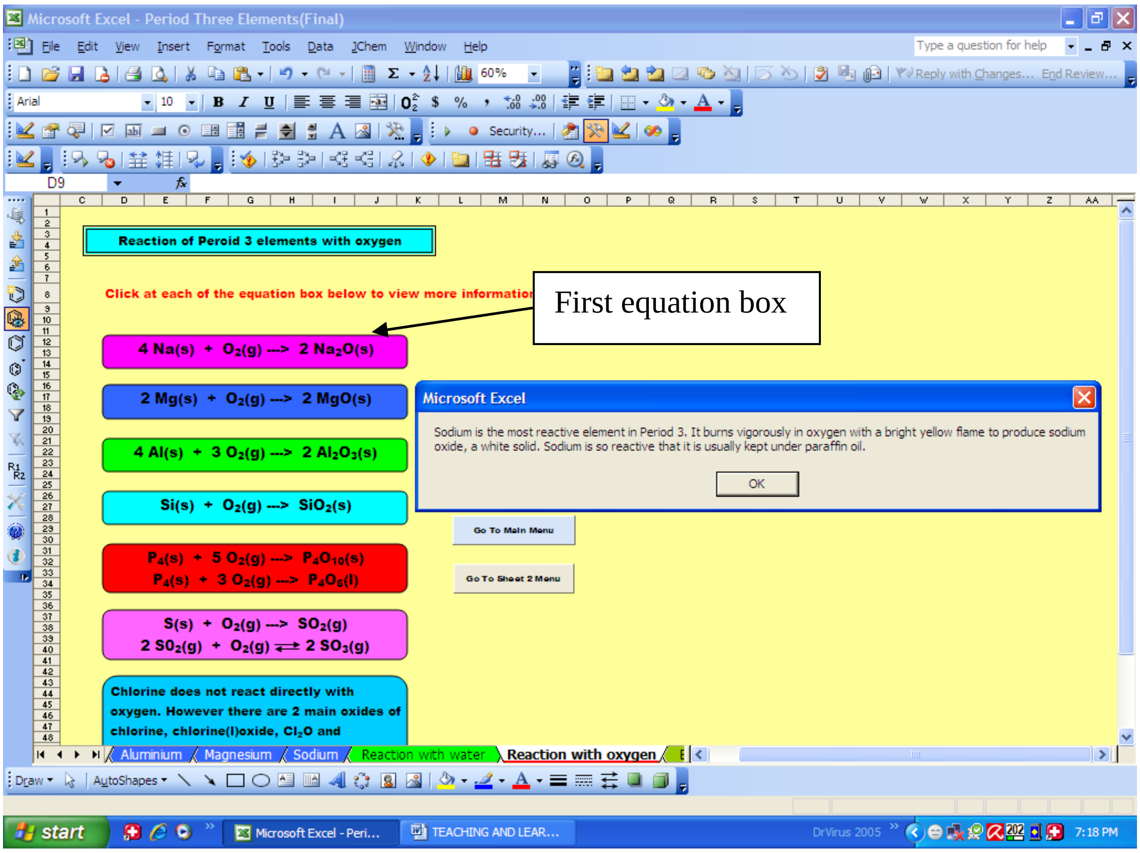

Figure 3.33: "Reaction with oxygen" worksheet

The VBA code to run this task is:

```
Sub sodiumoxygen()
MsgBox "Sodium is the most reactive element in Period 3. It burns vigorously in oxygen with a bright yellow flame to produce sodium oxide, a white solid. Sodium is so reactive that it is usually kept under paraffin oil."
End Sub
```

(Refer to Appendix E to view the full VBA code to run this task)

Thus, MS Excel provides a very stimulative and interesting learning environment where students can view the physical properties of period three elements by clicking at the buttons available on the worksheets. In addition, the picture of each period three element, detailed explanation of some chemical terms as well as some chemical reaction animation could motivate students' learning. Furthermore, questions available in the worksheets can help stimulate students to think and understand the properties of period three elements better.

In inorganic chemistry students study the structures, properties and reactivity of the elements and their compounds. However, students often find inorganic chemistry less interesting due to its descriptive features in which students feel that they have to read and memorize the facts related to the elements' properties. By creating these interesting worksheets, MS Excel could help in the teaching and learning of inorganic chemistry by providing an interactive learning medium for the students. Such an approach can strongly enhance the quality of teaching and learning.

3.3.4 Qualitative Analysis

Qualitative analysis is concerned with the identification of a chemical substance, a mixture of substances or a solution present in a sample (Holtzclaw & Robinson, 1988). Two basic methods can be used to establish the identity of substances in a sample, which are instrumental methods and chemical methods. Instrumental method often require specialized equipment which will not be discussed in this study whilst chemical methods are generally applicable in ordinary laboratory setting in school which often use only test tubes and common reagents. Chemical methods expose students to understand the details of various chemical reactions via interesting interation. Students are challenged to practice their manipulative and observational skills in identifying a substance, a mixture of substances or a solution.

3.3.4.1 The Strategy Of Qualitative Analysis

In general, chemical substances fall into two classes, electrolytes (inorganic acids, bases and salts) and non-electrolytes (most organic compounds) (Kwan, 2009). Most electrolytes dissociate into positive ions (cations) and negative ions (anions) in water. Thus, most of the operations of qualitative analysis are carried out in a solution in which water is the principal solvent (Durward,1961). In solution, each of these ions undergoes chemical reactions independently. Hence, ions can be detected by performing simple reactions with suitable reagents.

This study focuses on inorganic qualitative analysis which concerns the determination of cations and anions in substances or in a mixture of substances. The basis for identification of substances lies in their chemical and physical properties. The simplest properties used for identification are those that can be directly observed by the experimenter. The colour of a substance and the results of its reaction with various reagents are commonly used for identification purposes. Reagents that produce observable effects must form coloured substances (in solution or as a precipitate), form gaseous products that can be visually seen to leave the solution, produce a characteristic odor, or cause a previously insoluble substance to dissolve.

3.3.4.2 Cations Analysis

In the qualitative analysis of a solution that may contain any or all of the common metal ions, the first step is to separate the ions into several groups by the addition of specific group reagents, each of which contains ions exhibiting a common chemical property. The term "group" as it is used here has nothing to do with the location of the species in the periodic table. A series of steps for the separation of common metal ions into groups is described briefly below:

(a) The Metals Of Analytical Group I

Dilute hydrochloric acid is the group reagent. When dilute hydrochloric acid is added to a solution of the common metal ions (and ammonium ion), mercury(I) chloride, silver chloride, and lead chloride precipitate. The chlorides of the other entire common metal ion are soluble in this acid solution and can be separated from those of group 1 by filtration or centrifugation.

(b) The Metals Of Analytical Group II

The group reagent for the second group is hydrogen sulfide (H_2S). After the group I chlorides have been separated, the solution is made acidic and the group II metal ions are precipitated as sulfides by the addition of H_2S. The precipitate formed consists of the sulfides of lead, bismuth, copper, cadmium, mercury(II), arsenic, antimony and tin. Mercury occurs in both group I and II because mercury(I) chloride is insoluble, whereas mercury(II) chloride is soluble in dilute hydrochloric acid.

(c) The Metals Of Analytical Group III

The group reagent for the third group is a mixture of NH_4OH and $(NH_4)_2S$, which precipitates a mixture of hydroxides and sulfides that are insoluble in alkaline solution. After the group II sulfides have been separated, the solution is saturated with hydrogen sulfide and then an excess of aqueous ammonia is added. Under these basic conditions the sulfides of cobalt, nikel, manganese, iron and zinc precipitate and the insoluble hydroxides of aluminium and chromium precipitate. The sulfides of group III do not precipitate with the sulfides of group II because the high acidity used during the precipitation of the group II ions reduces the concentration of sulfide ion to such an extent that the solubility products of the group III sulfides are not exceeded.

(d) The Metals Of Analytical Group IV

Ions of the group IV metals (barium, strontium and calcium) are precipitated as their carbonates by ammonium carbonate in a buffer of aqueous ammonia and ammonium chloride.

(e) The Metals Of Analytical Group V

The filtrate from the group IV separation contains sodium, potassium, magnesium and ammonium ions. These ions constitute group V.

3.3.4.3 Anion Analysis

Although several schemes for anion analysis involving the separation of the ions into groups have been developed, the procedures are in general more complicated and unreliable compared to cations analysis. It is easier and more satisfactory to identify the various anions in separate tests rather than systematic analysis. The number of anions is limited in this study to suit the Form six syllabus in Malaysian secondary schools. The following are the preliminary elimination tests for the anions. When all the elimination tests have been made, it will be apparent which anions may be present. Tests can then be made for the anions that have not been eliminated.

(a) Elimination Of Anions That Form Volatile Acid Anhydrides

The anions CO_3^{2-}, SO_3^{2-}, S^{2-}, and NO_2^- are derived from the weak acids H_2CO_3, H_2SO_3, H_2S, and HNO_2 respectively. As acids in solution, H_2CO_3, H_2SO_3, H_2S, and HNO_2 are unstable and decompose, producing gases. H_2S does not decompose but has a limited solubility in water. When salts of these anions are treated with strong acids, the anions, being strong Bronsted bases, readily combine with the hydrogen ions from the strong acids. The high concentration of hydrogen ions furnished by the sulfuric acid used in this elimination test serves to shift the equilibrium to the right in each case. When the solubility of each gas is exceeded, it will escape from the solution in the form of bubbles. Gentle heating decreases the solubility of the gases and aids in the test.

If no gas is evolved during acidification and gentle heating of an unknown sample, CO_3^{2-}, SO_3^{2-}, S^{2-}, and NO_2^- are absent. If a gas is evolved, then one or more of these anions is present and it is necessary to carry out tests for the presence of each of these ions unless they are proven absent by other elimination tests.

(b) Elimination Of Oxidizing Anions

The nitrate ion in acid solution is an oxidizing agent in the presence of strong reducing agents and a reducing agent in the presence of strong oxidizing agents. Thus, nitric ion is included in the elimination tests for both oxidizing anions and reducing anions. The prepared solution is tested for the oxidizing anions NO_2^- and NO_3^- with a saturated solution of manganese (II) chloride in concentrated hydrochloric acid. The development of dark brown or black color is the result of the oxidation. In strong acidic solution, manganese (II) ion, Mn^{2+} will turn to manganese (III) ion. The manganese (III) ion then unites with chloride ions and forms the dark coloured complex $[MnCl_4]^-$.

(c) Elimination Of Reducing Anions

A sample of the prepared solution is acidified with hydrochloric acid and then added with iron (III) chloride and potassium hexacyanoferrate (III). The prompt appearance of a blue to blue-green colour of precipitate proves the presence of one or more of the reducing anions S^{2-}, SO_3^{2-}, NO_2^- and I^-. Iron (III), Fe^{3+}, form a brown solution when fresh and a green solution when old. In the presence of a strong reducing agent, the Fe^{3+} may be reduced to Fe^{2+} , or the $[Fe(CN)_6]^{3-}$ reduced to $[Fe(CN)_6]^{4-}$, with the formation of $KFe[Fe(CN)_6] \cdot H_2O$, a blue pigment.

(d) Elimination Of Fluoride And Oxalate

Fluoride and oxalate ($C_2O_4^{2-}$) form calcium salts that are insoluble in 4 M acetic acid. If no precipitate forms when calcium chloride is added to an acetic acid solution of the unknown, then fluoride and oxalate are absent.

(e) Elimination Of Sulfate

After the separation of fluoride and oxalate as insoluble calcium salts, barium chloride is added to precipitate the sulfate ion as white crystalline barium sulfate from the solution that is still acidic with acetic acid. If the sulfite is present in relatively large amounts, barium sulfite may precipitate. $BaSO_4$ is insoluble in dilute hydrochloric acid while $BaSO_3$ will dissolve and evolve SO_2 when treated with hydrochloric acid.

(f) Elimination Of Phosphate And Metaborate

The solution from the barium sulfate separation is acidified with hydrochloric acid and heated to expel CO_2 form CO_3^{2-} and SO_2 from SO_3^{2-} if these ions are present. If they were not first removed, these ions would be precipitated as barium salts in the ammoniacal solution used to precipitate barium phosphate and barium metaborate.

(g) Elimination Of Sulfide

The addition of dilute sulphuric acid to a sample of the prepared solution causes hydrogen sulfide gas to be evolved if the sulfide ion is present. Hydrogen sulfide reacts with lead acetate and forms a black precipitate of lead sulfide.

(h) Elimination Of Chloride, Bromide And Iodide

If the sulfide ion is present, it is first removed as the insoluble CoS before attempting to eliminate chloride, bromide and iodide. Silver nitrate is then added to precipitate the halides as AgCl (white), AgBr (pale yellow) and AgI (yellow). Silver chloride is completely soluble in the mixture of aqueous ammonia and silver nitrate solutions. Silver bromide is partially soluble and silver iodide is insoluble in this reagent. If a white precipitate forms when the aqueous ammonia extract of the silver halide precipitate is acidified, then the presence of chloride ion is confirmed. After the process of elimination test, confirmatory tests for the anions can be carried out to confirm the existence of anions.

A complete system of qualitative inorganic analysis would include methods for detecting all cations and anions of the elements. However, since we are interested in presenting an understanding of the methods of qualitative analysis and principle that underlie these methods, a systematic analysis and knowledge of traditional methods of separation of ions will not be required. Students are expected to be familiar with simple reactions of a few common and representative cations and anions which are chosen to be demonstrated in this study according to the Form Six syllabus in Malaysian secondary schools to help in teaching and learning of qualitative analysis.

The cations and anions considered in this study are Pb^{2+}, Cu^{2+}, Ni^{2+}, Mn^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Ba^{2+}, Ca^{2+}, Mg^{2+}, NH_4^+ , Cl^-, Br^-, I^-, S^{2-}, OH^-, CO_3^{2-}, $[Fe(CN)_6]^{3-}$, $[Fe(CN)_6]^{4-}$, HPO_4^{2-}, CrO_4^{2-}, SO_4^{2-}, CH_3COO^-, $C_2O_4^{2-}$, and SCN^-. Based on established results (Kwan, 2010) (Table 3.4) through pairing of the cations and anions, qualitative analysis workbook were created using MS Excel. Qualitative analysis workbook consists of three worksheets namely QA simulation 1 worksheet, QA simulation 2 worksheet and QA simulation 3 worksheets (refer to CD).

TABLE 3.4: Partial matrix of reactions

Cations Anions	Pb^{2+}	Cu^{2+}	Ni^{2+}
Cl^{-}	White precipitate soluble when heated; recrystallises on cooling	No observable result	No observable result
Br^{-}	No observable result	No observable result	No observable result
I^{-}	Yellow ppt soluble when heated; recrystallises on cooling	White precipitate in brown solution	No observable result
S^{2-} (in HCl)	Black precipitate forms	Black precipitate form	No observable result
OH^{-}	White precipitate soluble in excess of NaOH(aq)	Blue precipitate insoluble in excess of NaOH(aq), becomes black on heating	Green precipitate insoluble in excess of NaOH(aq)
CO_3^{2-}	White precipitate forms	Blue precipitate becomes black on heating	Green precipitate forms
$[Fe(CN)_6]^{3-}$	No observable result	No observable result	No observable result
$[Fe(CN)_6]^{4-}$	White precipitate forms	Reddish brown precipitate soluble in excess NH_3(aq) to form blue solution	Green precipitate forms
HPO_4^{2-}	White precipitate forms	Blue precipitate forms	Green precipitate forms

3.3.4.4 QA Simulation 1 Worksheet

In the QA simulation 1 worksheet (Figure 3.34), there are three command buttons, two list boxes and one label box.

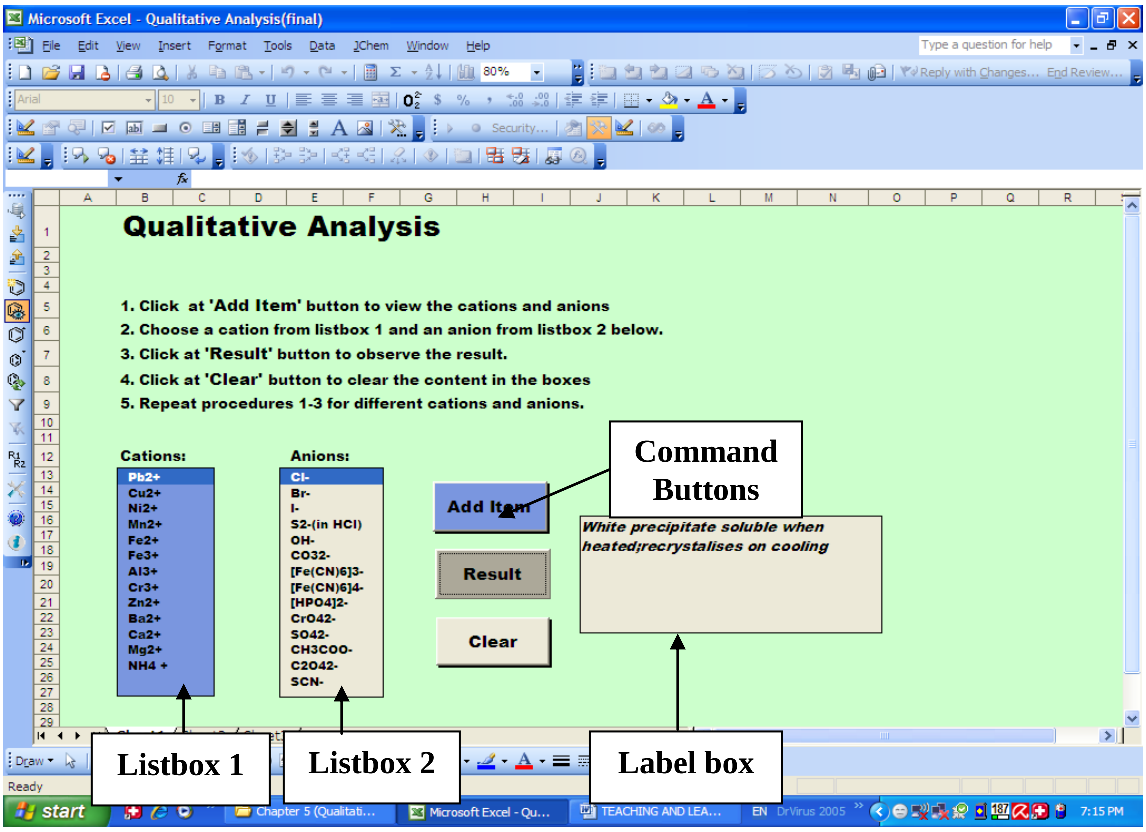

Figure 3.34: QA simulation 1 worksheet

Students are given a list of cations and anions to choose from the system and view the results in the label box. These command buttons, list boxes and label box were created using 'Active X' controls in MS Excel. By clicking at the "Add Item" button, the list of cations and anions will appear in list boxes 1 and 2 (Figure 3.34). Simple VBA was used to run the task for "Add Item" button. The snippet code for "Add Item" button is shown below:

```
Private Sub CommandButton2_Click()
Me.ListBox1.AddItem "Pb2+", 0
Me.ListBox1.AddItem "Cu2+", 1
Me.ListBox2.AddItem "Cl-", 0
Me.ListBox2.AddItem "Br-", 1
End Sub
```

(Refer full VBA code at Appendix F)

Students can choose any combination of cations (from list box 1) and anions (from list box 2) and view the result of the reaction by clicking the “Result” button. For example, as shown in Figure 3.34, if students choose Pb2+ from list box 1 and Cl- from list box 2 and then click the “Result” button, “White precipitate soluble when heated; recrystalises on cooling” will appear in the label box (Figure 3.34). The snippet code to run the command for the “Result” button is shown below:

```
Private Sub CommandButton1_Click()
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 0 Then
Me.Label1.Caption = "White precipitate soluble when heated;recrystalises on cooling"
End If
End Sub
```

(Refer to full VBA code at Appendix G)

Students are given the opportunity to choose any combination of cations and anions from the list and view the result of the reaction by clicking the “Result” button. The function of the “Clear” button is to clear the contents of list box 1, list box 2 and label box. The VBA code to run the task for this command button is:

```
Private Sub CommandButton3_Click()

Me.ListBox1.Clear

Me.ListBox2.Clear

Me.Label1.Caption = " "

End Sub
```

When students click the “Clear” button, the list of cations (list box 1), anions (list box 2) and contents of the label box will be deleted.

3.3.4.5 QA Simulation 2 Worksheet

This worksheet contains three command buttons and three text boxes (Figure 3.35). In cell B9 and C9, RANDBETWEEN function in MS Excel is used to return a random integer within the range specified by its two arguments as shown:

Cell B 9 =RANDBETWEEN(1,13) [13 cations]

Cell C 9 =RANDBETWEEN(1,14) [14 anions]

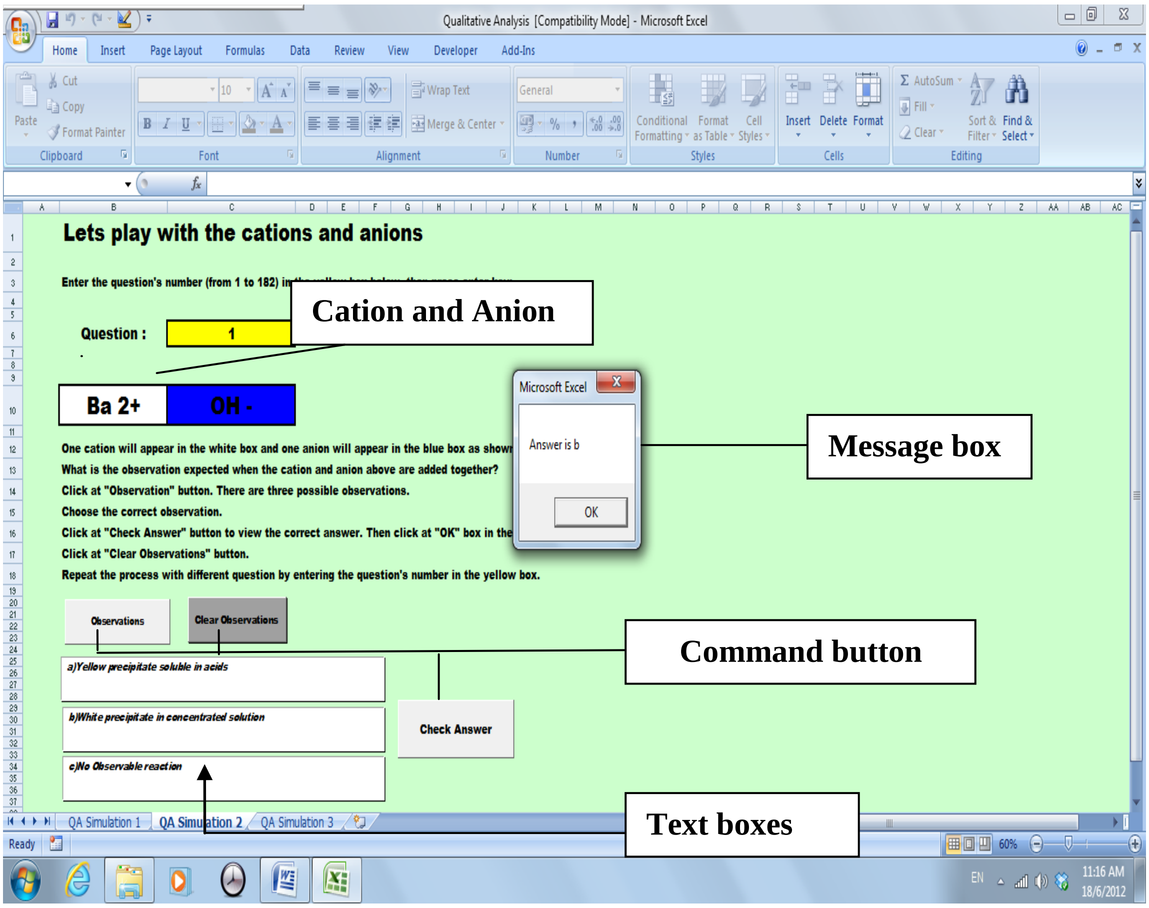

Figure 3.35: QA simulation 2 worksheet

There are 182 different combinations of cations and anions which were designed to appear randomly in cell B10 and cell C10 respectively using the formula shown below based on the random number appearing in cells B9 and C9.

Cell B 10 =INDEX(M7:M19,B9,1)

Cell C 10 =INDEX(N7:N20,C9,1)

Students can start with any question from 1 to 182 by typing in the number of questions in the yellow box in cell “C 6” and pressing the “Enter” key. One cation and one anion will appear on the screen at once. When students click the “Observation” button, three multiple choice answers will appear in the text boxes. Students are expected to choose the correct observation for the reaction between cation and anion shown on the screen.

Students can always check their answers if they have any doubt on their choice by clicking the “Check Answer” button. A message box will appear showing the correct answer. To remove the message box, click at the “OK” box in the message box. To go on to the next question, students must click at the “Clear Observation” button to delete the contents of the text boxes. The “Observations”, “Check Answer” and “Clear Observations” buttons were created using ‘Active X’ controls which are connected to the VBA code written to run the task. For example, as shown in Figure 3.35, when students enter the question number in cell C6 and press “Enter” key. A cation “Ba^{2+}” will appear in cell B10 while an anion “OH^{-}” will appear in cell C10. Then the student can click at the “Observation” button and the multiple choice answer will appear in the text boxes. The snippet VBA code to run the “Observation” button is

```
Private Sub CommandButton1_Click()
If Range("B9").Value = 10 And Range("C9").Value = 5 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate in concentrated solution"
TextBox3 = "c)No Observable reaction"
End If
End Sub
```

If students want to check the answer, they can click the “Check Answer” button, then a message box will appear showing an answer “Answer is b”. The snippet code to run this button is

```
Private Sub CommandButton3_Click()

If Range("B9").Value = 10 And Range("C9").Value = 5 Then

MsgBox "Answer is b"

End If

End Sub
```

(Refer full VBA code at Appendix H and Appendix I)

whilst the VBA code to run the "Clear Observations" command is

```
Private Sub CommandButton2_Click()

TextBox1 = " "

TextBox2 = " "

TextBox3 = " "

End Sub
```

This worksheet provides students with a wide range of practice and extra learning opportunities which we believe will enhance and improve students' intuitive learning of qualitative analysis.

3.3.4.6 QA Simulation 3 Worksheet

Qualitative analysis simulation 3 worksheet was created to test basic chemical intuition of students in identifying unknown cations X, Y and Z. In this worksheet, there are three list boxes and three command buttons which were created using 'Active X' controls. A simple macro is used to run the task of the related command buttons. The VBA code to run the task of command buttons is as shown below:

```
Private Sub CommandButton1_Click()
MsgBox "X is Ba2+"
End Sub
Private Sub CommandButton2_Click()
MsgBox "Y is Fe2+"
End Sub
Private Sub CommandButton3_Click()
MsgBox "Z is Zn2+"
End Sub
```

As shown in Figure 3.36, students will have to make intelligent choices of reagents (anions) from the list box provided to react with unknown X and view the results. Based on a series of results, students can then eliminate irrelevant cations and make a smart guess to predict the unknown X. Students can then type the result in the yellow box provided.

Students can check their answer by clicking the "Check Answer" button. For example, by click at the "Check Answer" button, a message box will appear showing "X is Ba^{2+}". This process can be repeated to determine unknowns Y and unknowns Z. HLOOKUP function is used in cell E20, cell E24 and cell E30 to retrieve the result of reaction from a hidden matrix table (Appendix J). The formulae used are:

Cell E20 *=HLOOKUP(C20,AB20:AO21,2,FALSE)*

Cell E24 *=HLOOKUP(C24,AB22:AO23,2,FALSE)*

Cell E30 *=HLOOKUP(C30,AB24:AO25,2,FALSE)*

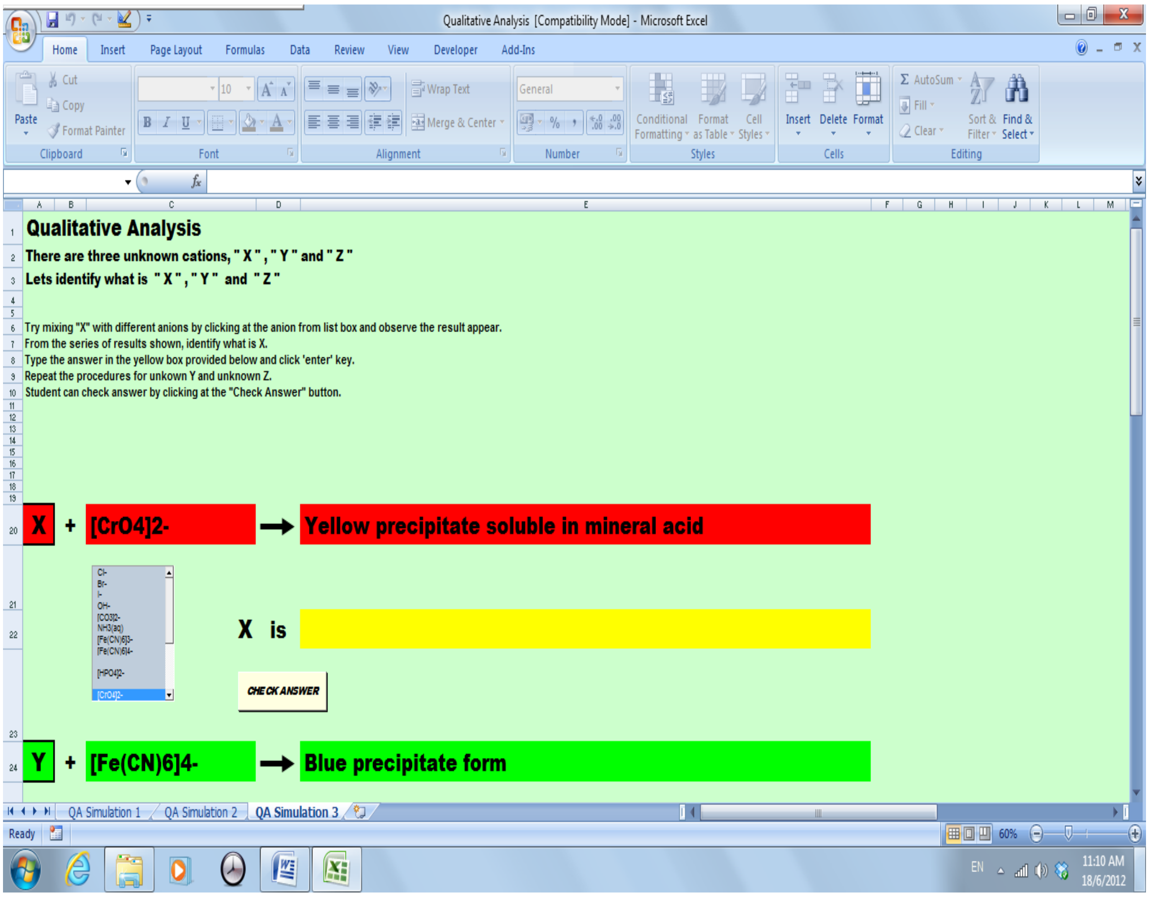

Figure 3.36: QA simulation 3 worksheet

Although practical experiments cannot be replaced by pen and paper exercise, students may not have the liberty to carry out exhaustive experimental work due to time, cost and safety constraints. In order to reduce students' difficulty in making connections between theoretical concepts and observations, especially when both the concepts and observations are unfamiliar to the students, simulation can be used to increase familiarity with some observations in order to bridge the gap with theory. MS Excel can be used to create stimulative and interesting worksheets to convey greater intuition about chemical processes and to communicate more clearly the abstractions that are not immediately obvious from either manipulating chemicals in a physical laboratory or solving mathematical equations. Worksheets created provide students with a flexible environment where they can interact freely with "chemicals" and see directly the results of reactions. Students can grasp the concept of chemical reactions more effectively with the wide range of practice and extra learning opportunities. Furthermore, in order to provide students with a more intuitive feel of an experiment, video clips of each reaction simulated in the worksheet have been prepared. Students can refer to the video clips to view the result of each reaction (Appendix K).

3.3.5 Spectroscopy

Spectroscopy was originally the study of the interaction between radiation and matter as a function of wave length (λ). The concept was then expanded to comprise frequency (ν) and energy (E) as a variable once the relationship $E=h\nu$ for photon was realized (h is the Planck constant). Spectroscopy is often used in physical and analytical chemistry for the identification of substances through the spectrum emitted from or absorbed by them. The study of spectroscopy particularly molecular spectroscopy is also very useful to astrophysicists and environmental scientists for detecting molecules in the Earth's stratosphere, planetary atmospheres and even interstellar space from their rotational, vibrational and electronic spectra. This section discusses how a MS Excel spreadsheet simulation of linear-molecule spectra can be used to explore the dependence of rotational band spacing on average bond lengths in the initial and final quantum states.

3.3.5.1 Rotational Spectroscopy

Rotational spectroscopy studies the absorption and emission of electromagnetic radiation (typically in the microwave region of the electromagnetic spectrum) by molecules associated with a corresponding change in the rotational quantum number of the molecule. It deals with the response (spectrum) of molecules interaction with probing signals of known energy (or frequency according to Planck's formula). The origin of spectral lines in molecular spectroscopy is the absorption, emission or scattering of a photon when the energy of a molecule changes (Atkins & Paula, 2002). Molecular spectra contain information relating to bond length and bond angles. They also provide a way of determining a variety of molecular properties, particularly molecular dimension, shapes and dipole moments. Pure rotational spectra can be observed in the gas phase in which only the rotational state of a molecule changes.

In quantum mechanics the free rotation of a molecule is quantized, that is the rotational energy and the angular momentum can take only certain fixed values. These values are related simply to the moment inertia, I. The rotational energy level of a rigid rotor can be expressed in terms of angular momentum and the importing the quantum mechanical properties of angular momentum into the equation. The classical expression of the energy for a body rotating about as axis a is

$$E_a = ½\, I_a\omega_a^2$$

Where ω_a is the angular velocity (rads^{-1}) about that axis and I_a is the corresponding moment of inertia. A body free to rotate about three axes has energy

$$E = ½\, I_a\omega_a^2 + ½\, I_b\omega_b^2 + ½\, I_c\omega_c^2$$

where I_a is the moment of inertia of the A axis, I_b is the moment of inertia of the B axis and I_c is the moment of inertia of the C axis.

The classical angular momentum about the axis a is $J_a = I_a\omega_a$, hence with similar expression for other axis

$$E = \frac{J_a^2}{2I_a} + \frac{J_b^2}{2I_b} + \frac{J_c^2}{2I_c}$$

When all three moments of inertia are equal to some value I, the classical expression for the energy is

$$E = \frac{J^2}{2I}$$,where J is the magnitude of the angular momentum.

Based on the Born-oppenheimer approximation, changes in molecular energies, $\Delta E_{molecule}$ are conveniently partitioned into electronic, vibrational and rotational contributions:

$$\Delta E_{molecule} = \Delta E_{el} + \Delta E_{vib} + \Delta E_{rot}$$

where ΔE_{el} is the change in electronic energy, ΔE_{vib} is the change in vibration energy and ΔE_{rot} is the change in rotational energy

For linear molecules, the rotational energies are quantized and normally expressed in terms of the rotational constant, B, of the molecule. The rotational energy levels F(J) of a linear molecule based on rigid rotor model can be expressed as

$$F(J) = BJ(J+1)\ \text{cm}^{-1} \qquad J=0,1,2, \ldots$$

where B is the rotational constant of the molecule and is related to the moment of inertia of the molecule where $I_b = I_c$; $I_a = 0$

$$B = \frac{h}{8\pi^2 c I_c} \quad \text{(in wave number scale, cm}^{-1}\text{)}$$

Selection rules state that during absorption, the rotational quantum number has to change by unity, i.e. $\Delta J = J' - J'' = \pm 1$. thus, the locations of the lines in a rotational spectrum will be given by

$$F(J') - F(J'') = 2B(J'' + 1) \text{ cm}^{-1} \qquad J'' = 0, 1, 2, \ldots$$

where J" denotes the lower energy level and J' denotes higher energy level involved in the transition. Because the rotational constant decreases as I increase, we see that large molecules have closely spaced rotational energy levels. The intensity of the lines is determined by the distribution of the molecules at different energy levels and the probability of transition between two energy levels. It is observed that, for a rigid rotor, the transition lines are equally spaced. However, this is not always the case, except for the rigid rotor model. For non-rigid rotor model, we need to consider changes in the moment of inertia of the molecule. Two primary reasons for this are:

(a) Centrifugal Distortion

The atoms of rotating molecules are subject to centrifugal forces that tend to distort the molecule geometry and change the moments of inertia. When a molecule rotates, the centrifugal force pulls the atoms apart. As a result, the moment of inertia of the molecule increases, thus decreasing B. To account for this, a centrifugal distortion correction term is added to the rotational energy levels of the molecule.

$$F(J) = BJ(J + 1) – DJ^2(J + 1)^2 \qquad J = 0, 1, 2, \ldots$$

where D is the centrifugal distortion constant. Therefore, the line spacing for the rotational mode changes to

$$F(J') – F(J'') = 2B(J'' + 1) – 4D (J'' + 1)^3 \qquad J'' = 0, 1, 2, \ldots$$

(b) Vibration-Rotation Coupling

A molecule is always in vibration. For a diatomic, as the molecule vibrates more, the bond stretches. Hence, its moment of inertia changes. As B is dependent on v, therefore

$$B = B – \alpha (v + ½)$$

where α is the vibrational-rotational coupling constant

However, as long as the vibrational quantum number does not change (i.e. the molecule is in only one state of vibration), the effect of vibration on rotation is not important because the time for vibration is much shorter than the time required for rotation. The vibration-rotation coupling is often negligible too.

3.3.5.2 Rotational Worksheet

Based on the equations discussed, simulation of pure rotational spectrum for several diatomic molecules are demonstrated using MS Excel (refer to CD). The molecules are B-N, Cl-Cl, C-O, F-F, H-Br, H-Cl, H-F, H-H, N-N, N-O, O-O, PbO and PbS. In this worksheet, there are one combo box, two option buttons (rigid rotator or non-rigid rotator) and one command button (Execute) created using the 'Active X' control tool box in MS Excel (Figure 3.37).

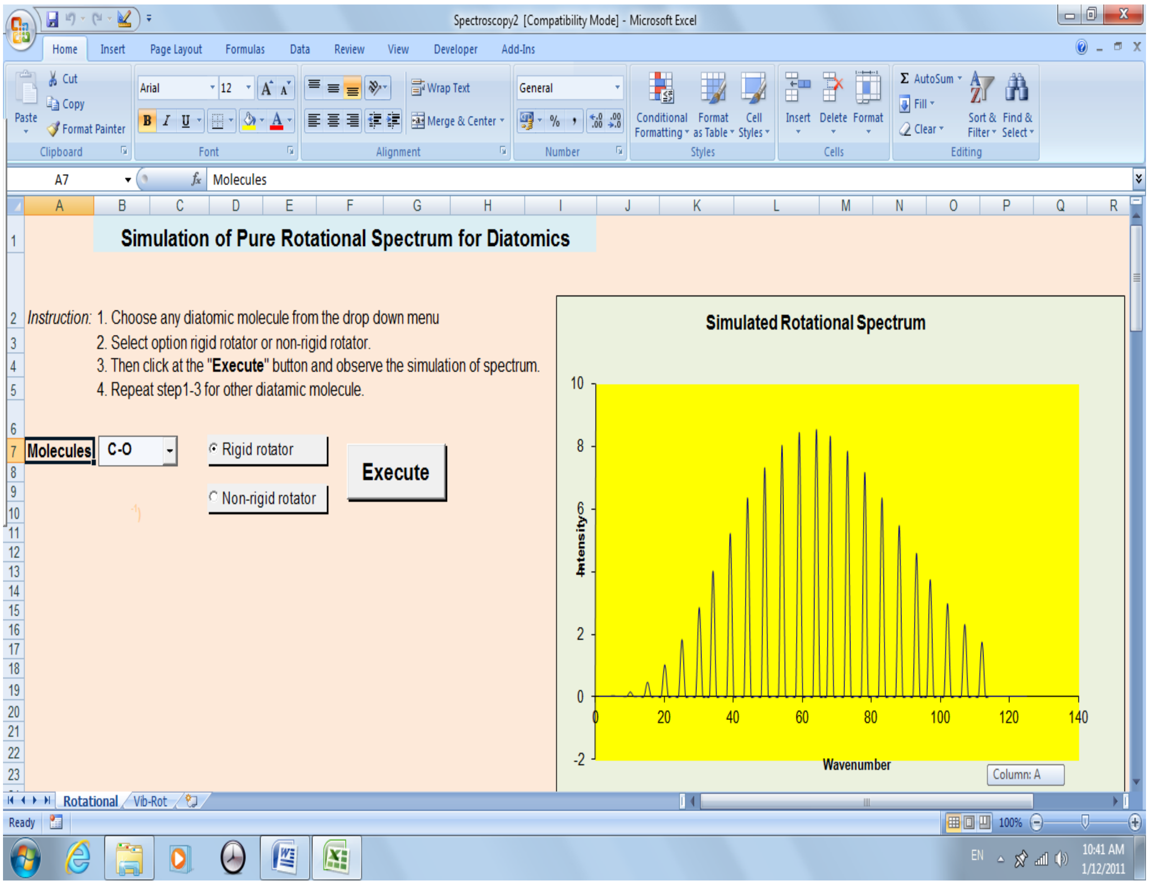

Figure 3.37: Rotational worksheet

Teachers/students can choose any of the preset molecules as mentioned above in the combo box by clicking at the molecule formula. The next step is to choose either the rigid rotator or non-rigid rotator model by clicking the option buttons provided. Teachers/students then click the "Execute" button and observe the simulation of the spectrum. Figure 3.37 shows the spectrum of C-O molecule as a rigid rotator. Teachers/students can simulate the rigid rotator or non-rigid rotator model for each molecule chosen and observe the difference in the spectrum. A simple macro is used to run the task for the option and "Execute" button. (Appendix L). The formula used to process the spectroscopic data needed in this worksheet are as follow:

v	=IF($N$4=TRUE,2*$G$8*(A8+1),2*$G$8*(A8+1)-4*$J$8*(A8+1)^3)
I	=EXP(-($G$8*$G$4*$G$5*A8*(A8+1))/($J$4*$J$5))*(A8+1)^2*(1-EXP(-(2*$G$8*$G$4*$G$5*(A8+1))/($J$4*$J$5)))
2B	=B9-B8
µ	=((1/6.023E+23)*($G$9*$J$9)/($G$9+$J$9))*0.001
B	=$G$4/(8*PI()^2*$G$6*$G$7^2*$G$5)
r	=VLOOKUP($Q$3,$O$4:$R$16,2)
m_1	=VLOOKUP($Q$3,$O$4:$R$16,3)
m_2	=VLOOKUP($Q$3,$O$4:$R$16,4)

The fill down series function in MS Excel was used to copy the formula down the column for v, I and 2B.

3.3.5.3 Vibrational-Rotational Spectroscopy

Each line of the high resolution vibrational spectrum of a gas phase heteronuclear diatomic molecule is found to consist of a large number of closely spaced fine lines. Hence, molecular spectrum are often called band spectrum. The separation between the fine lines is of the order of 10 cm^{-1} which suggest that the structure is due to rotational transitions accompanying the vibrational transition. A molecular vibration occurs when atoms in a molecule are in periodic motion while the molecule as a whole has constant translational and rotational motion. The frequency of the periodic motion is known as the vibration of frequency. A molecular vibration is excited when the molecule absorbs a quantum of energy, E, corresponding to the vibration's frequency, v, according to the relation E=hv, where h is Planck's constant. In some cases, a single vibration transition appears as a triplet containing P, Q, R branches, as a result of vibration-rotation interaction. A rotational change should be expected because classically vibration alters the length and angular momentum of a rotating bond periodically and we can think of the transition as leading to a sudden increase or decrease in the instantaneous bond length. Thus, the molecular rotation is either accelerated or retarded by a vibrational transition. This interaction can be described by the sum of vibrational and rotational energies.

In the rotational spectroscopy discussed in the earlier part, we considered transitions between rotational energy levels associated with the same vibrational level (usually v=0). In vibrational-rotational spectroscopy, we consider transitions between the sets of rotational energy levels associated with two different vibrational levels. Thus, a vibrational "band", that is a transition v'$\leftrightarrow$v", is composed of a number of "lines" v'J'$\leftrightarrow$v"J". the energy levels are given by the sum of the rotational term values, $F_v(J)$ and the vibrational term values, G(v),

$E^{vJ} = G(v) + F_v(J)$

Thus, the energy of transition is given by

$\Delta E^{v'J' \rightarrow v''J''} = [G(v'') + F_{v''}(J'')] - [G(v') + F_{v'}(J')]$

A detailed analysis of the quantum mechanics of simultaneous vibrational and rotational changes shows that the rotational quantum number J changes by ± 1 during the vibrational transition of a diatomic molecule, and selection rules also allow Δ J=0. Transitions with Δ J=0 can occur when the electronic angular momentum of the molecule is non zero. The vibrational band is composed of a number of 'branches', which in the simplest case are:

R-branch $\Delta J = J' - J'' = +1$

Q-branch $\Delta J = 0$

P-branch $\Delta J = J' - J'' = - 1$

Note that the Q branch transitions do not occur for Σ states (diatomic molecules). The frequencies of each of the lines are (ignoring the distortion)

$$\tilde{v}_P(J) = \tilde{v}_o + B'J'(J' + 1) - B''J''(J'' + 1)$$
$$= \tilde{v}_o + B'(J - 1)J - B''J(J + 1)$$
$$= \tilde{v}_o - (B' + B'')J + (B' - B'')J^2$$

Similarly

$$\tilde{v}_R(J) = \tilde{v}_o + (B' + B'')(J + 1) + (B' - B'')(J + 1)^2$$

where B" is the rotational constant of ν" vibrational state and B' is the rotational constant of the ν' vibrational state. The band appears fairly symmetrical about the band center, v_o and there is approximately equal spacing between adjacent R-branch lines and between adjacent P-branch lines.

3.3.5.4 Vibrational-Rotational (Vib-Rot) Worksheet

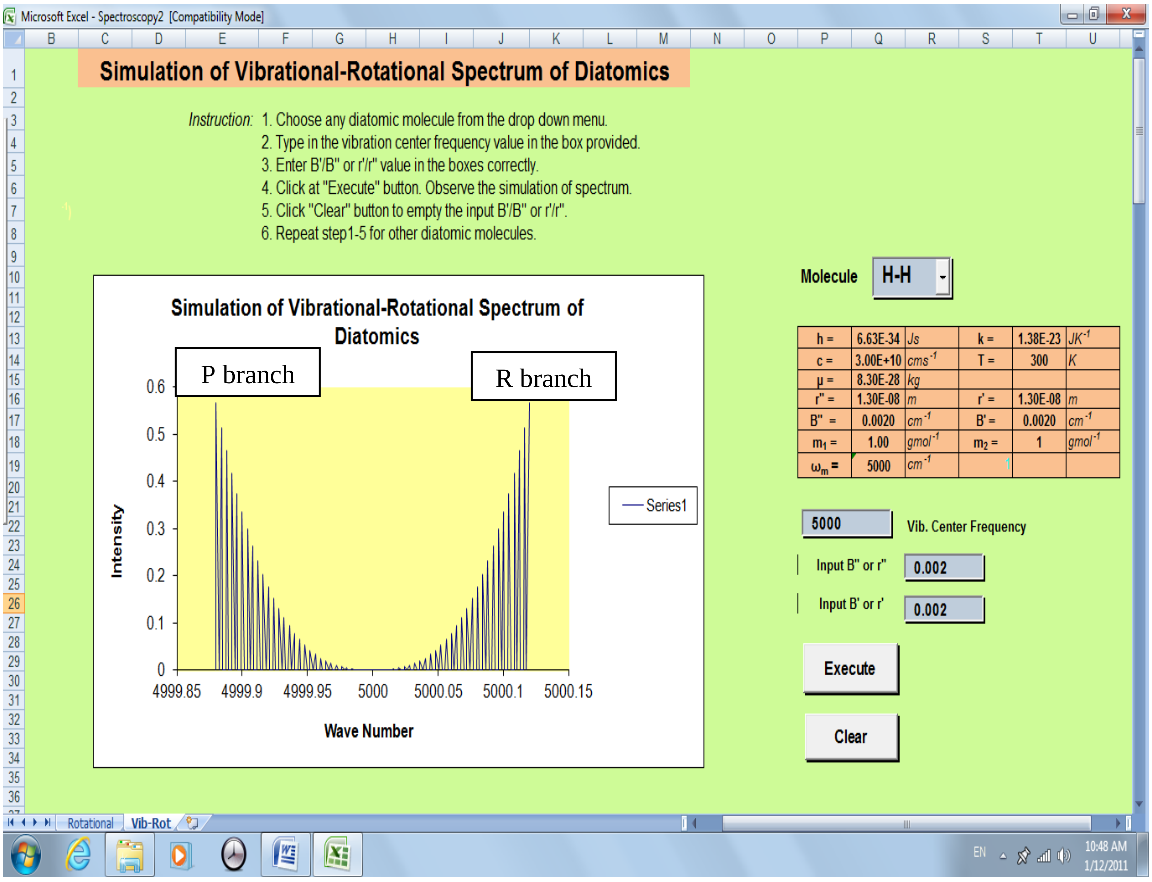

Figure 3.38: Vib-Rot worksheet

The simulation of the vibrational-rotational spectrum of diatomics is created in the Vib-Rot worksheet (Figure 3.38). In this worksheet (refer to CD), teachers/students could view the simulation of diatomic molecules spectrum, namely HCl, HF, H-H, N-N, NO, O-O, PbO and PbS. Two command buttons, one "Execute" button, one "Clear" button and a combo box were created using Active X control. Teachers/students first choose any diatomic molecules from the list in the combo box. In order to view the simulation of the spectrum, teachers/students have to type in the values of band center frequency, ν_o, B'/r' and B"/r" in the text boxes provided. The simulation of respective spectrum will appear once the "Execute" button is clicked. This button is connected to the VBA code (Appendix M) to run the task. The "Clear" button is to clear the values of

B’/r’ and B”/r” in the text box. This process could be repeated using different values of B’/r’, B”/r” or band center frequency.

Formulae used in this worksheet to manipulate the data are as follow:

```
v =     $B$38+($Q$17+$T$17)*A8+($T$17-$Q$17)*A8^2
I =     EXP(-($Q$17*$Q$13*$Q$14*ABS(A8)*(ABS(A8)+1))/($T$13*$T$14))
        *(ABS(A8)+1)^2*(1-EXP(-(2*$Q$17*$Q$13*$Q$14*(ABS(A8)+1))/
        ($T$13*$T$14)))
2B =    B9-B8
μ =     ((1/6.023E+23)*($Q$18*$T$18)/($Q$18+$T$18))*0.001
r”=     IF($N$8="",IF($N$6="",VLOOKUP($Q$3,Rotational!$O$4:$R$16,2),
        SQRT($Q$13/(8*PI()^2*$Q$15*$Q$17*$Q$14))),VALUE($N$8))
B”=     IF($N$6="",$Q$13/(8*PI()^2*$Q$15*$Q$16^2*$Q$14),VALUE($N$6))
m1=     VLOOKUP($Q$3,Rotational!$O$4:$R$16,3)
r’=     IF($N$9="",IF($N$7="",VLOOKUP($Q$3,Rotational!$O$4:$S$16,2),
        SQRT($Q$13/(8*PI()^2*$Q$15*$T$17*$Q$14))),VALUE($N$9))
B’=     IF($N$7="",$Q$13/(8*PI()^2*$Q$15*$T$16^2*$Q$14),VALUE($N$7))
m2=     VLOOKUP($Q$3,Rotational!$O$4:$R$16,4)
```

Undergraduate students often have the misconception that molecules have fixed, unchanging bond lengths. The concept that a molecule can have vibrational state-dependent bond lengths is not introduced until more advanced courses at the universities in Malaysia. This can lead to learning difficulties since students’ conceptions are resistant to change. Hence, awareness of this misconception is required for acceptance of the correct concept. Since many introductory organic and general chemistry courses do introduce IR and UV-vis spectroscopy, Excel spreadsheet simulations offer quick, simple, visual demonstrations that bond lengths can increase or decrease on vibrational or electronic excitation without a detailed mathematical analysis of the spectrum and with minimal time imposition on the curriculum. A simple visual explorative exercise that demonstrates the relationship between the spectrum of a molecule and its bond length would minimize the dependence on mathematical analysis. This spreadsheet can be used as a classroom demonstration or as a laboratory exercise and caters for those learners who do not favour symbolic or mathematical representation in their learning.

3.3.6 Chemical Equilibrium

Many reactions do not proceed to completion. For example, in the reaction between hydrogen gas and iodine vapour to form hydrogen iodide,

$$H_2\,(g) + I_2\,(g) \rightleftharpoons 2HI\,(g)$$

The reactants (hydrogen and iodine) do not change completely to form the product because the product (hydrogen iodide) can dissociate to form hydrogen and iodine. All processes that occur in a closed system at a uniform temperature eventually reach a state of equilibrium. Equilibrium in a chemical system is a state in which no macroscopic changes are occurring (Parker & Breneman, 1991; Ebbing & Wrighton, 1993; Lim & Yip, 2005, Lee, 2006; Tan et al., 2010). At this point, the reaction mixture contains both products and reactants and no further changes in the concentrations are observed although at molecular level, there are processes occurring but they balance one another. This means that the forward and reverse reactions are still occurring but at equal rates. Therefore, the equilibrium achieved is dynamic equilibrium.

At equilibrium, there is a relationship between the concentrations of the reactants and products. The conditions under which the reaction is carried out determine what the reactant and product concentrations are when the system has reached equilibrium. However, the position of equilibrium can be altered after the reaction has appeared to cease by varying one or more of the parameters that affect the equilibrium position.

According to mass action law which is also known as the law of chemical equilibrium (Praba, 2006), at a fixed temperature in a closed system under equilibrium, the ratio of the concentration of the products (raised to the respective power of their stoichiometric coefficients) to the concentrations of the reactants (raised to the respective power of their stoichiometric coefficients) is a constant. The constant is given the symbol K_c and is known as the equilibrium constant. Thus, for the reaction below,

$$aA + bB \rightleftharpoons cC + dD$$

the equilibrium constant K_c is given by

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

The symbol 'c' indicates that the units for the reactants and the products are moles per cubic decimeter (mol/dm^3). The units of the equilibrium constant vary from one equilibrium to another. In some equilibrium reactions, the equilibrium constant has no unit. For reactions involving gases, the equilibrium constant is often expressed in terms of the partial pressures of the gases rather than their concentrations. The equilibrium constant is given by K_p. The equilibrium constant can be used to determine the resulting equilibrium concentrations when the initial concentration is known.

3.3.6.1 Equilibrium Concentration

In this section, a simple reaction such as the equilibrium between a dimer, dinitrogen tetraoxide and monomer, nitrogen dioxide will be used as an example to illustrate the concept of equilibrium using MS Excel. The reaction is

$$N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g)$$

Initial/moldm^{-3}	R	P
Change	-x	2x
Equilibrium	R-x	P+2x

The data are expressed in concentration although pressure units are more usual for a reaction involving gases. Hence, the concentration of the gases in the above reaction is found to have a simple relationship;

$$K_{eq} = \frac{[NO_2]^2}{[N_2O_4]}$$

$$K_{eq} = \frac{(P + 2x)^2}{(R - x)}$$

where K_{eq} is the equilibrium constant

Therefore, $4x^2 + (4P + K_{eq})x + P^2 - K_{eq}R = 0$

and

$$x = \frac{-(4P + K_{eq}) \pm \sqrt{(4P + K_{eq})^2 - 16(P^2 - K_{eq}R)}}{8}$$

There are two possible solutions to the equation shown above but only the one with the positive discriminant produces positive concentrations of dinitrogen tetraoxide and mononitrogen dioxide. This is because only concentrations that are positive have a physical meaning. This is true because x must be positive when P = 0 in order to have a positive concentration of [NO_2]. For this mathematical relationship, there exists an infinite number equilibrium concentration that will satisfy this equilibrium. When non equilibrium concentration is substituted into the equilibrium expression, it will produce a value that does not equal to K_{eq}. For non equilibrium condition, it is customary to use Q, called the reaction quotient. The value of Q is calculated in a manner that is completely analogous to the calculation of the equilibrium constant. By comparing the value of initial concentrations, Q and K_{eq} , the direction of equilibrium could be predicted. Based on the Le Chatelier principle, if the value of $Q = K_{eq}$ in the system, the system is said to be at equilibrium. If the value of $Q < K_{eq}$, the system contains concentration of reactants that are too high and concentration of products that are too low. The system is said not to be at equilibrium and reaction position will shift to the right and more product (NO_2) will form in order to achieve the equilibrium. If the value of $Q > K_{eq}$, the ratio of product to reactant is too large and the reaction position will shift to the left to achieve equilibrium where more nitrogen dioxide will form dinitrogen tetraoxide.

The equilibrium constant can be used to determine the resulting equilibrium concentrations when the initial concentrations are known. The value of x and the new equilibrium concentrations could be easily computed by MS Excel with the given Q and K_{eq} value at a fixed temperature.

3.3.6.2 Chemical Equilibrium Workbook

In this workbook, the dinitrogen tetraoxide and nitrogen dioxide equilibrium is used as an example (refer to CD). The experimentally measured equilibrium constant at 100 ^{0}C is 0.212 (cell H8). This value is used in the formula to obtain the x value as shown in the worksheet (Figure 3.39)

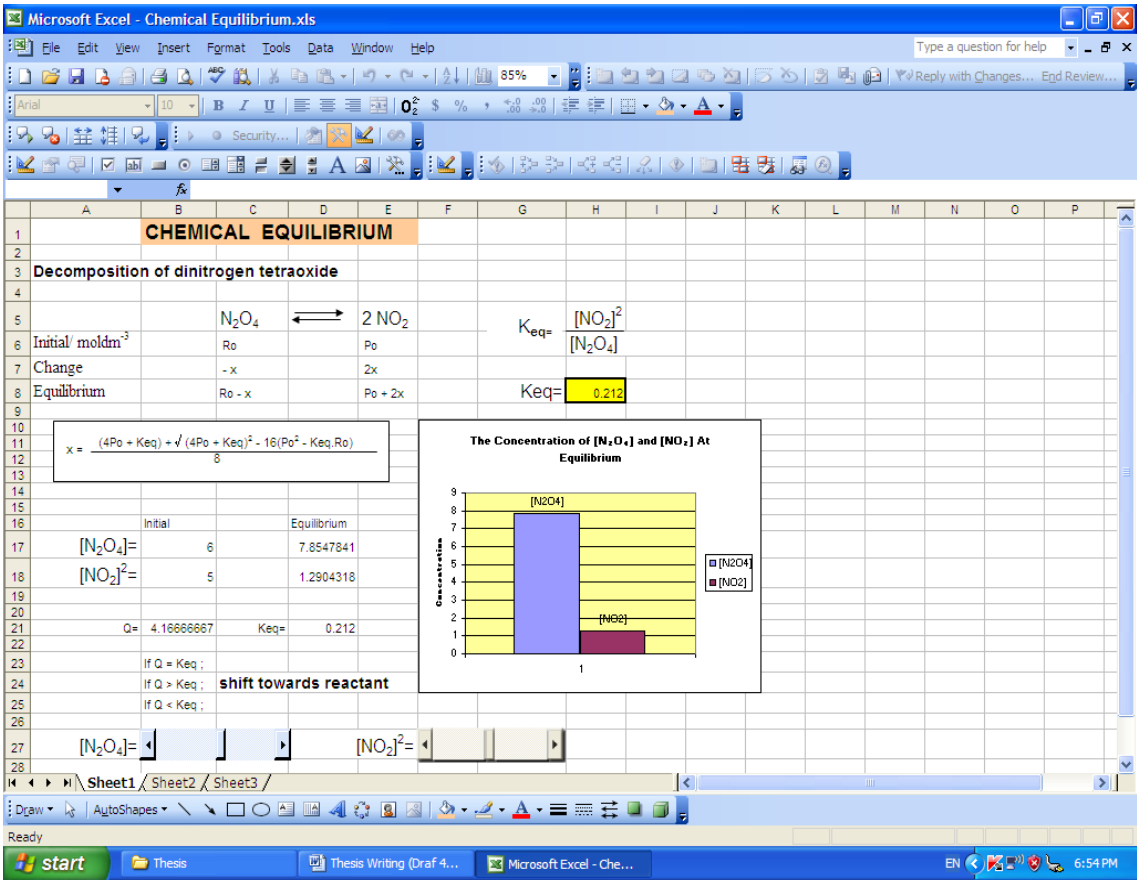

Figure 3.39: Chemical equilibrium workbook

If the initial concentrations of $[N_2O_4]$ and $[NO_2]^2$ are changed by dragging the scroll bars created using ‘Active X’ control in the worksheet, the equilibrium system is disturbed and the value of Q is changed. If the system is not at equilibrium, it will proceed in the direction necessary to achieve equilibrium again. New equilibrium concentrations will be obtained in order to achieve equilibrium. To show changes of the new equilibrium concentrations interactively, a bar chart is created using the chart wizard function in MS Excel. At the same time, the position of the equilibrium will be shown in the worksheet as well. For example, if the value of Q is greater than K_{eq} as shown in Figure 3.39, a statement “shift towards reactant” will appear in the worksheet. The value in cell B17, B18 and H8 are defined as Ro, Po and K_{eq} respectively in order to give a clearer picture to students when these values are substituted in the formula. The main formulae used in this worksheet are as follow:

Cell B21 = Po^2/Ro

Cell D21 = D18^2/D17

Cell C23 = IF(B21=D21,"equilibrium","")

Cell C24 = IF(B21>D21,"shift toward reactant","")

Cell C25 = IF(B21<D21,"shift toward product","")

Cell D17 = Ro-(-(4*Po+Keq)+((4*Po+Keq)^2-16*(Po^2-Keq*Ro))^0.5)/8

Cell D18 = Po+(-(4*Po+Keq)+((4*Po+Keq)^2-16*(Po^2-Keq*Ro))^0.5)/4

Using MS Excel to illustrate the effect on the equilibrium position when one or more of the parameters is varied is very easy and convenient. Students can observe the changes of concentration of reactant and product simultaneously and the equilibrium position will be shown in the worksheet.

CHAPTER FOUR

THE FIELD STUDY

4.1 INTRODUCTION

As a ‘worldware’ tool (Siti et al., 2007), MS Excel is a spreadsheet program that have been used and proven to be a useful teaching and learning tool especially for mathematics and science based subjects (Abramovich & Eun, 2008; Lau & Kuruganty, 2008; Wischniewsky, 2008; Benacka, 2008a; Benacka, 2008b; Thin & Wee, 2008; King, 2005; Arganbright, 2005; Lim, 2005b; Lim, 2003; Baker & Sugden, 2003; Troutt et al., 2001; Grossman, 1999; Hawk, 1999). In order to gauge student’s and teacher’s views towards the use of MS Excel worksheet in teaching and learning of chemistry, three questionnaires were distributed to Form Six students, Form Six chemistry teachers and universities chemistry students.

4.2 CONCEPT MAP

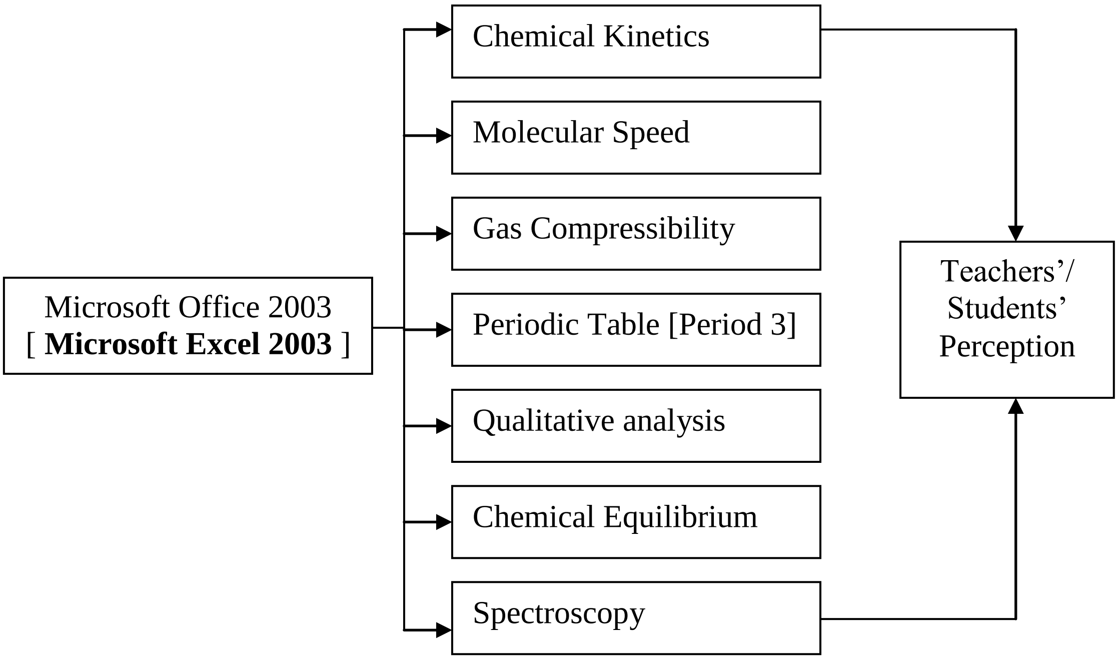

Figure 4.1: Concept Map

Workbooks were created as shown in the concept map above (Figure 4.1) and the topics chosen for the creation of MS Excel worksheets in this study are chemical kinetics, molecular speed, gas compressibility, periodic table, qualitative analysis, chemical equilibrium and spectroscopy. From all the workbooks created, the chemical kinetics workbooks were given to secondary school students while the spectroscopy workbooks were given to university students as field studies. These workbooks were chosen as the field studies in order to fit into the research time frame. The design of the field study, sample of field study, limitation of field study, data collection and analysis of data will be further discussed in the following sections.

4.3 THE DESIGN OF FIELD STUDY

The survey method was used to obtain the perceptions of lower six science students and chemistry teachers towards the use of MS Excel in their teaching and learning of chemistry, in particular their perceptions on the effectiveness of this approach in teaching and learning of chemistry. The perceptions of students and teachers were collected with a set of tested questionnaires whilst the perception of undergraduate students (second year) studying molecular spectroscopy towards the spectroscopy workbooks was collected using another set of questionnaire.

4.4 SAMPLE OF FIELD STUDY

The target samples of this field study are the lower six science students in secondary school studying chemistry, chemistry teachers for Form Six students and undergraduate students studying molecular spectroscopy. Twelve government secondary schools from three different states (Negeri Sembilan, Malacca and Johor) in Malaysia took part in this field study. They are SMK King George V, SMK St Paul, SMK Seri Ampangan, SMK Tunku Ampuan Durah, SMK Dato Mohd Said Nilai, SMK Tuanku Muhammad Kuala Pilah, SMK Datuk Mansur Bahau, SMK Tuanku Besar Tampin, SMK Tinggi Port Dickson, SMK Dato Sri Amar Muar, SMK Tinggi Muar and SMK Gajah Behrang Melaka. The lower six students (612 students) and 24 chemistry teachers involved in this field study are multiracial. Undergraduate students (68 students) who took part in this field study are from University of Malaya (UM), University of Science Malaysia (USM), University Teknology Mara (UiTM) and University Malaysia Terengganu (UMT).

4.5 LIMITATIONS OF THE STUDY

The limitations of this study include:

(a) Only twelve schools from three different states with 612 Lower Six students and 24 chemistry teachers were involved in this field study. This sample size is rather small when compared to the vast number of Lower Six students and chemistry teachers throughout the country.

(b) Only 68 undergraduate students (second year) from a few universities as named in the sample of field study were involved in this field study.

(c) Only the chemical kinetics workbook were used in the field study due to time constraints since only Lower Six students were allowed to be involved in this field study due to restriction by the Education Planning, Research and Development Department (EPRD) and the State Education Department. Lower Six students only begin their schooling in the middle of May and the term ends in the middle of November. In addition, teachers in each school may teach the topics at different times. A longer period of survey study was needed.

(d) Only the spectroscopy workbook were used as field study in a few local university due to time constraints and poor response.

(e) Respondents' perceptions were collected through a set of questionnaire with set questions only.

4.6 INSTRUMENT AND DATA COLLECTION

In this field study, the instrument used to gather the students' perceptions towards the use of MS Excel in teaching and learning chemistry is a set of validated questionnaire (Appendix N) which was used by Nor Liya (2003) for physics with relevant modification according to this study's need. The questionnaire was divided into two parts, part A and part B. The objective of part A is to collect biodata of students such as gender, race, education background and level of computer knowledge whilst part B consists of 15 questions to gauge students' perceptions towards the effectiveness and suitability of MS Excel in teaching and learning chemical kinetics. Students have to answer either "Yes" or "No" to each question.

Teachers' perceptions on the effectiveness and suitability of using MS Excel were collected using another set of validated questionnaire (Appendix O) (Nor Liya, 2003) which is also divided into two parts, part A and part B. Part A collects the biodata of the teachers and part B gathers the teachers' perceptions or comments on using MS Excel in teaching and learning chemical kinetics. Similarly, teachers are asked to choose either "Yes" or "No" to each question.

Undergraduate students' perceptions on the spectroscopy worksheets were collected using another set of questionnaire (Appendix P) which consists of part A and part B. Part A collects the students' biodata and part B comprising ten questions, collects data on the students' perceptions on the effectiveness of the worksheets. These worksheets were given to second year undergraduate students from the faculty of science who registered for the molecular spectroscopy course. Students were asked to explore and use the worksheets and then fill the questionnaire. Students have to answer either "Yes" or "No" to each question.

Before the field work was carried out in schools, approval for research from the Education Planning, Research and Development (EPRD) in the Ministry of Education, State Education Department (Appendix Q), and all the headmasters from the twelve schools were obtained. The field study for secondary school students and teachers were carried out within the time frame of July 2009 to May 2010 depending on the school's planning schedule in teaching this topic.

All the questionnaires for secondary school students and teachers were brought to each school personally and briefing was given to all the chemistry teachers involved in this field study on how to use the workbooks in the classroom. Teachers and students were asked to fill the questionnaire after the lesson and experiment. Teachers and students were requested to answer the questionnaire honestly.

The questionnaires were collected personally from all the schools involved from the middle of March 2010 until the middle of May 2010 whilst questionnaires for undergraduate students were collected through email or by post from the middle of October 2011 until the end of December 2011.

Appreciation was delivered to all headmasters who allow their schools to be involved in this field work and also to all the teachers and students who were willing to help and complete the questionnaires. Appreciation was also delivered to all lectures and undergraduate students who were willing to be involved in this field study.

4.7 ANALYSIS OF DATA

Both descriptive and inferential analysis of the survey response were carried out using SPSS 12.0 to describe, summarize and present the outcome in a more meaningful way.

Based on the data collected from participating secondary schools, students' perceptions on this new approach in teaching and learning chemical kinetics were analysed and presented in the form of percentages. Inferential analysis, ie the Chi-Square test was used to observe the difference in the perceptions of this approach between the two genders and among different races. The profiles of the respondents are shown in Table 4.1 below:

TABLE 4.1: Sample Profile

	Gender	Frequency	Percentage
Teacher	Male	8	33.3
	Female	16	66.7
Student	Male	253	41.3
	Female	359	58.7
	Race		
Teacher	Malay	14	58.3
	Chinese	10	41.7
	India	-	-
Student	Malay	56	9.2
	Chinese	450	73.5
	India	103	16.8
	Others	3	0.5

The demographic breakdown of the survey respondents manifests the typical Form Six (science) classrooms in a Malaysian government secondary school. There are 359 (58.7%) female students and 253 (41.3%) male students. From the 24 teachers involved in this field study, 16 (66.7%) are female teachers and 8 (33.3%) are male teachers. From the sample profile, it can be seen that there is a predominance of female teachers in participating schools. This is not a surprising since majority of the teachers in Malaysian schools are female. Based on the statistics reported by MOE in 2010 (MOE Malaysia, 2011), from the total of 177,382 teachers in government and government-aided secondary schools, 121,927 (68.8%) are female while 55,455 (31.2%) are male. Out of 24 teachers involved, 14 (58.3%) are Malay and 10 (41.7%) are Chinese.

There are 450 (73.5%) Chinese students, 103 (16.8%) Indian students, 56 (9.2%) Malay students and 3 (0.5%) other race students. The breakdown according to race shows less Malay students compared to other races.

TABLE 4.2: Students' Response

Question (N = 612 students)	Frequency Of "Yes"	Percentage (%)
I like to use Excel worksheets during my learning process.	492	80.4
I don't have difficulty in using the Excel worksheets.	483	78.9
I become more hard working and put in more effort after using the computer during my chemistry lessons.	436	71.2
Using the Excel worksheets can save a lot of time in solving chemistry problems.	528	86.3
It is easier to evaluate interactive graphs using the Excel worksheets.	573	93.6
Through Excel worksheets, charts can be presented accurately in a short time.	582	95.1
It is more convenient and easier to plot graph of concentration over time using the Excel worksheets.	577	94.3

I feel very interested and enjoy my chemistry lessons with the Excel worksheets.	507	82.8
I remember lessons better after using the Excel worksheets.	422	69.0
Excel worksheets has many advantages which can help in the teaching and learning of chemistry.	546	89.2
The use of Excel worksheets should be encouraged to a wider area of chemistry.	566	92.5
Using Excel worksheets in the teaching and learning can encourage discussion among the students and with the teacher.	529	86.4
I think Excel worksheets are not suitable to use in chemistry learning.	190	31.0
The language and menu in Excel worksheets are easy to understand and user friendly.	571	93.3
I have no experience in using Excel worksheets, I am afraid to use it in learning chemistry.	218	35.6

From the descriptive analysis shown in table 4.2 (Appendix R), it is found that students (>90%) strongly agreed that Excel worksheets provided a more convenient and easier platform to evaluate and plot various graphs accurately in a shorter time. Excel worksheets also helped them to solve chemistry problems such as determination of k and $t_{½}$ value faster. Hence, they would have more time to discuss the problems or spend most of the time on chemistry activities within the spreadsheet rather than spending time to calculate all the parameters needed and to plot the graphs manually. This result infers that students may have difficulty in plotting graphs, especially a curve or they dislike to plot graphs. Hence, this approach would be useful for students who are weak in plotting graphs, those who may find plotting graphs a tedious job and those who has weak mathematical background. Lim (2008) had used spreadsheets to support the teaching of chemical equilibrium and reported that students with weak mathematical backgrounds have benefitted from using the computational approach.

Besides that, data collected indicates that students involved in the field study shows very positive attitude towards this new teaching approach in their lesson. Majority of the students (>80%) like using the Excel worksheets and felt that the program is interesting and they enjoyed their chemistry lesson. Most of them agreed that the language and menu in the Excel worksheets is easy to understand and user friendly. They do not have much difficulty in using the Excel worksheet and many of them feel that they are more hard working and that they put in more efforts following this approach. These results are congruent with many other researches' findings which have been mentioned in the literature review, particularly regarding the user friendly features of the Excel worksheet. For example, Thin and Wee (2008) reported that they witnessed students showing greater enthusiasm in applying Monte-Carlo simulation to help them solving problems using Excel worksheets. They concluded that the use of spreadsheets is simple yet powerful.

The feedback from field study also showed most students (89.2%) agreed that Excel worksheet has many advantages which could help in the process of teaching and learning kinetics and it should be encouraged and exploited for wider area of teaching and learning chemistry.

TABLE 4.3: Teachers' Response

Question (N = 24 teachers)	Frequency of "Yes"	Percentage (%)
Students use the worksheets actively.	23	95.8
Excel worksheets are attractive.	24	100.0
Excel worksheets motivates students towards the lesson.	23	95.8
Learning through Excel worksheets stimulates students to think.	21	87.5
Learning through Excel worksheets encourages collaborative discussion among students and also between teacher and students.	21	87.5
These worksheets can be used as reference for revision.	19	79.2
Content of worksheets fulfill the objective of lesson.	23	95.8
Language used in Excel worksheets easy to understand.	23	95.8
Facts presented with interactive features can deliver the lesson effectively.	22	91.7

All the teachers (100%) involved in the field study also gave very positive comments about this new approach. They found the MS Excel program to be attractive. As seen from the data shown in Table 4.3 (Appendix S), more than 90.0% of the teachers agreed that interactive features in the Excel worksheets provided have helped them deliver the lesson more effectively and that it motivates students towards lesson. They feel that the program helped to fulfill the objective of lesson. The Excel spreadsheets were able to allow students to construct the trends observed in kinetic behavior in a more effective manner. Hence, they are drawn to the lesson and used the designed worksheets actively. Another important finding from this field study is that about 87.5% teachers involved in the survey reported that learning via the Excel worksheets have encouraged team work and more discussion among students as well as between teachers and students. They agreed that the Excel worksheets stimulated students to think. Similar findings have been reported where, in an example, Arganbright (2005) reported that one of the additional cultural benefits from the use of Excel spreadsheet in teaching mathematics is that it has made it easier for some students to discuss mathematics not only with their friends but also with their parents via a tool that is familiar to them. Wood and D'Souza (2001) studied the benefits of spreadsheets in a collaborative learning environment at the secondary school level and found that spreadsheets were able to allow students to concentrate on thinking about the subject matter rather than on the software. Sinex (2008) reported that students engage in numerous higher-order thinking and science process skills as they work through the Excel spreadsheets simulation.

On top of that, for the use as reference for revision, 79.2% of teachers agreed that the worksheets can fulfill such functions which can provide great help to students. In addition, as reported in many other studies mentioned in the literature review, majority of the teachers in this study also said that language used in Excel worksheets is easy to understand and user friendly. All the teachers involved in this study reported that they would use the MS Excel spreadsheet if available. This finding is very encouraging and fulfilled the objective of this study.

TABLE 4.4: Chi-Square Test to observe the students' perception towards using MS Excel in teaching and learning chemical kinetics between different gender.

	Value	df	Asymp. Significant value (2-sided)
Pearson Chi-Square	25.976	15	0.038*
Likelihood Ratio	27.975	15	0.022
Linear-by-Linear Association	12.374	1	0.000
N of Valid Cases	612		

*Significant P<0.05

Based on SPSS analysis (Appendix T), the summary results of Chi-Square test (Pearson Chi-Square) is presented in Table 4.4 above (x^2=25.976, df=15, p<0.05). Results show that there is a significant difference of opinion towards the new teaching approach in chemistry lesson using MS Excel between male and female students where more males prefer to use this method. This could be due to the natural behaviour of male students who are more drawn to ICT. This finding supports the common view that males are technically more competent than females (Kubiatko et al., 2010). The similar assertions were also made elsewhere (Cooper, 2006; Cathrine, 2008; Kubiatko, 2010). Cooper indicated that the public in general believes that males are more interested in using computers, and hence they are more competent in using computers. Cathrine said that boys use computers and the internet more than girls, have wider computer experience, spend more time online, report greater interest in and perceive more positive attitudes to computer-related activities. Milan's study revealed that males have more positive attitudes towards ICT as compared to females. However, both male and female students in this study show positive response towards this new approach.

TABLE 4.5: Chi-Square Test to observe the students' perception towards using MS Excel in teaching and learning chemical kinetics between different races.

	Value	df	Asymp. Significant value (2-sided)
Pearson Chi-Square	36.275	45	0.820
Likelihood Ratio	42.073	45	0.597
Linear-by-Linear Association	0.051	1	0.821
N of Valid Cases	612		

*Significant P<0.05

Another summary result of Chi-Square test (Pearson Chi-Square) using SPSS analysis (Appendix T) in Table 4.5 above (x^2=36.275, df=45, p>0.05) shows that there is no significant difference of students' opinion towards the new teaching approach in chemistry lesson using MS Excel among different races. The results of the study showed that all students were exhilarated by the MS Excel's provision of a very convenient platform to assist students conceptualise experimental kinetics data. They were very satisfied with the innovative method of teaching and learning chemical kinetics and of the opinion that the use of MS Excel should be encouraged to include a wider area of chemistry.

Similarly, undergraduate students' perception towards the spectroscopy worksheet created were analysed and presented in the form of percentage. Inferential analysis using Chi-Square test was carried out to observe the difference in perception towards this worksheet between two different genders. The profiles of the respondents are shown in Table 4.6 below:

TABLE 4.6: Sample Profile

	Gender	Frequency	Percentage
Undergraduate Student	Male	11	16.2
	Female	57	83.8
	Race		
	Malay	64	94.1
	Chinese	3	4.4
	India	1	1.5

Of the 68 students involved in this field study, 57 (83.8%) were female students and only 11 (16.2%) were male students (Table 4.6). It was observed that there is a predominance of female students in the survey. This may be due to the lower enrolment of male students compared to female students in the system in Malaysia. As reported in the statistics of higher education of Malaysia 2010 (MOE Malaysia, 2010), there are 39.8% of male students compared to female students (60.2%) enrolled in local public universities. The breakdown according to race shows predominance of Malay students compared to other races. There are 64 (94.1%) Malay, 3 (4.4%) Chinese and 1 (1.5%) Indian students. This is the typical population of undergraduate students in national public universities where more Malay rather than Chinese or Indian students are enrolled, while Chinese and Indian students are predominantly enrolled in private institution of higher learning.

TABLE 4.7: Students' Response

Question (N = 68 students)	Frequency Of "Yes"	Percentage (%)
I am surprised to see that EXCEL can be used to learn/teach spectroscopy.	58	85.3
The simulation worksheet is well designed and user friendly	63	92.6
The simulation worksheet renders visualization of vibration-rotation spectroscopy concept more concretely.	60	88.2
The worksheet is flexible enough to allow me to explore the important ideas behind rotational and vibrational spectroscopy.	55	80.9
Simulation of pure rotational spectra for various diatomic molecules in the worksheet allows me to better understand how the different parameters in the rotational equation effect the appearance of the spectrum	59	86.8
Spreadsheet simulation of the vibrational-rotational spectrum allows me to understand clearly that vibrational transitions of a molecule are accompanied by fine rotational transition.	49	72.1
The idea of rigid and non-rigid rotor is made clear via this simulation worksheet.	57	83.8
I can understand better the idea behind rotational and vibrational spectroscopy via the interactive graph animation in the worksheet compared to traditional learning methods.	51	75.0
Use of EXCEL in learning vibrational and rotational spectroscopy is more convenient and fun compared to learning the concepts from books.	58	85.3
The use of MS Excel in learning/teaching chemistry should be widely encouraged in school and universities.	65	95.6

Data collected (Table 4.7; Appendix U) showed most undergraduate students from various universities (>80%) give very positive response to the spectroscopy worksheet created. Similar to the responses of secondary school students, most of the undergraduate students agreed that the simulation worksheet is user friendly (92.6%) and should be widely encouraged (95.6%) in the teaching and learning of chemistry. Based on the result of finding, 85.3% of students said that learning spectroscopy via Excel simulation worksheet is more convenient and fun since the worksheet is flexible enough for them (80.9%) to explore important ideas behind rotational and vibrational spectroscopy. Many (85.3%) expressed their surprise that Excel can be used in teaching and learning of spectroscopy.

In addition, most students (>83%) agreed that the simulation worksheet could render visualization of vibration-rotation spectroscopy concept more concretely and helped them to understand better how the different parameters in the rotational equation effect the appearance of the spectrum and the idea of rigid/non rigid rotor is made clear via this simulation worksheet. Besides, 72.1% of the respondents said that the simulation of the vibrational-rotational spectrum allow them to understand clearly that vibrational transitions of a molecule is accompanied by fine rotational transition. 75.0% of the respondents said that this worksheet also helped them to better understand the idea behind rotational and vibrational spectroscopy via the interactive graph animation in the worksheet compared to traditional learning methods. As a conclusion, students involved in the field study found that the spectroscopy worksheet could help them to understand the concepts of vibrational and rotational spectrum better and has also made their study easier.

This result is congruent to the study done by Lim (2005a). Lim discussed how a spreadsheet simulation of linear-molecule spectra can be used to explore the dependence of rotational band spacing and contours on average bond lengths in the initial and final quantum states, especially to those learners who do not favour a symbolic or mathematical representation in their learning. He also reported that spreadsheet simulations offer quick, simple, visual demonstrations that bond lengths can increase or decrease on vibration or electronic excitation which can overcome the misconception that molecules have fixed, unchanging bond length by most of the students.

TABLE 4.8: Chi-Square Test to observe the undergraduate students' perception towards the spectroscopy worksheet created between different gender.

	Value	df	Asymp. Significant value (2-sided)
Pearson Chi-Square	4.871	6	0.560
Likelihood Ratio	4.846	6	0.564
Linear-by-Linear Association	1.022	1	0.312
N of Valid Cases	68		

*Significant P<0.05

Unlike for the secondary school, the summary result of Chi-Square test (Pearson Chi-Square) (Appendix V) in Table 4.8 above (x^2=4.871, df=6, p>0.05) shows there to be no significant difference of undergraduate students' perception between male and female students towards the spectroscopy worksheet. All the respondents involved in this field study have their own computer/laptop and have been exposed to computer. Most (75%) know how to use the MS Excel. However, they were still exhilarated by the MS Excel's provision of a very convenient platform for the evaluation of spectroscopy spectrum.

From the result of both studies discussed above, it can be conclude that most respondents involved in the field study (secondary school's students, secondary school's chemistry teachers and undergraduate students) gave very positive feedback to the program which is very encouraging.

CHAPTER FIVE

GENERAL DISCUSSION

Chemistry is often regarded as an abstract subject. Teachers find it difficult to bridge the gap between theory and real chemical process. Hence, one of the goals of chemistry education research is to provide information as to how chemistry can be meaningfully introduced to students, to identify the causes of impediments to learning chemistry, how teaching and learning chemistry occurs in classroom setting and how teachers can improve their instructional techniques in an attempt to promote better chemistry education.

The development in the ICT has accelerated the dissemination of information and knowledge in every field of studies. Therefore, development of new powerful chemistry teaching software is essential for the success of 21st century chemistry education. Effective software with interactive features should improve students' conceptual understanding and better facilitate their exploration of relationship between abstract theoretical concepts and observable chemical processes. This study reports several MS Excel worksheets program of chemistry concepts and the effectiveness and efficiency of these programs in improving students' understanding and problem solving skills in chemistry learning. The implication of the study will be further discussed in later part of the chapter.

The main objective of this study is to develop MS Excel spreadsheets which could help to solve the difficulties in teaching and learning of chemistry. A few topics were chosen from Form Six and first/second year university syllabi, namely chemical kinetics, distribution of molecular speed of gas, gas compressibility, periodic table, qualitative analysis. chemical equilibrium and spectroscopy for demonstration as explained in the previous chapter.

The interactive graphical approach by the use of Excel worksheets to study chemical kinetics, compressibility of gas, distribution of molecular speed of gas and spectroscopy could provide a stimulative and interesting learning environment to students. The simulation of graphs by changing the parameters set could give a clearer picture to students. Hence, students can understand better the concepts of chemical kinetics, compressibility of gas and molecular speed of gas rather than just memorizing the equation.

Chemical reactions form the backbone of chemistry. On this topic, teachers usually concentrate on the rate laws and students are expected to figure out the order of reaction and rate constant in the study of chemical kinetics (Chung & Newman, 2000). Simulation of graphs using random rate constant and order of reaction could give better image to students. In addition, evaluation of the rate constant, order of reaction and calculation of $t_{½}$ become easy and fast. The result of the field study is congruent with studies carried out by Bruist (1998), Denton (2000) and Moreira et al. (2006) which have been discussed in chapter 2 in that the use of Excel worksheets was found to contribute positively to the teaching and learning of chemical kinetics. Although the spreadsheet created in this study is much simpler as compared to the studies on reaction kinetics mentioned, the excellent agreement from both the teachers and students that is observed confirms the reliability of this approach. It is noteworthy to observe that male students showed more interest towards ICT. Nevertheless, this approach could enhance students' interest in learning and at the same time could also motivate female students towards using ICT (MS Excel) in learning chemistry, as shown in the results of the field study.

In the compressibility of gas worksheet, students can observe the changes of curve and compare the compressibility value, z, of different non ideal gases (as shown in compressibility of gas worksheet) which deviate from ideal gas in the range of temperature from 1 K to 300 K. In the distribution of molecular speed of gas worksheet, students can observe the simulation of distribution curve for gases with different molar mass when they drag at the temperature bar menu to change the temperature within the range from 1 K to 1000 K. MS Excel worksheets have provided a platform for students to explore and understand better the behaviour of gases. Consequently, they can learn qualitatively, about the relationship between the temperature and with the z value for ideal and non-ideal gases as well as the relationship between the temperature and distribution of molecular speed of different gases.

Beside chemical kinetics, compressibility of gas and distribution of molecular speed, Excel worksheets could be used to demonstrate some descriptive chemistry such as the study of periodic table and qualitative analysis in chemistry. Performing descriptive chemistry such as learning properties of period three elements using MS Excel could offer great benefits to students as well as the teachers for its explicitness, flexibility and accessibility. In period three elements worksheets, Excel worksheets has provided a very stimulative and interesting learning environment where students can view the physical properties of period three elements by just a click at the buttons available in the worksheets. Extensive use of simple functions such as control toolbox, charting wizard, hyperlink function, internet link to website and simple macro were demonstrated in creating these worksheets. In addition, the picture of each period three elements, detailed explanation of some chemical terms as well as some chemical reaction animation would also motivate students' interest in learning. Furthermore, questions available in the worksheets could help stimulate students to think and understand the properties of period three elements better where the study of periodic table is always consider as a dull topic. This interactive feature could bring the study of period three elements 'alive'.

Using MS Excel worksheets in teaching and learning qualitative analysis, randomly matched features in different worksheets that contain 182 different combinations of cations and anions together with various simulation activities, a lively and interesting platform in learning qualitative analysis is produced. Based on established experimental data, the result of reactions between cations and anions could be obtained by just the click of a button, offering a more flexible learning environment. Worksheets created allow students freedom to explore at anytime or anywhere with just a standard computer with MS Office program running on Windows XP version. Interactive features give students more intuitive feel for the reaction. The simulation exercise allows a substantial number of experiments to be undertaken in a time frame that is a fraction required for the real experiments. Hence, performing qualitative analysis using the worksheets created through MS Excel could offer great benefits to students and teachers for its flexibility and easy accessibility. In addition, it is believed that this approach could improve intuitive learning of qualitative analysis in students by providing them a wide range of practice and extra learning opportunities.

As mentioned earlier, chemistry is abstract and often seems distant from students' experiences. Thus, instructors find it difficult to bridge the gap between theory and real chemical processes in a way that promotes interest in the subject. Particularly during these times, paper and pencil homework is simply not well suited to this goal and hands-on laboratory activities are important. However, they are typically limited in number and flexibility due to time, cost and safety constraints. Furthermore, chemistry is often viewed as essential subject to the schools or university and therefore not to be taken lightly. In this study, the author outlines the strategy for designing simulations and integrating them smoothly into currently existing chemistry curriculum in order to gradually improve student learning.

Lecturing well on how a chemical topic relates to an interesting real-world phenomenon can excite student's learning. Currently there exists some computer-based instructional support for teaching in chemistry to address some of the teaching/learning difficulties by relating concepts to chemical phenomena. In this context, MS Excel spreadsheet provides an alternative representation that complements what is usually presented on the board. It does not approach or solve the problem as it would be done with paper and pencil. Rather it serves as a supplement to such calculations with the goal of providing students deeper insight into the qualitative nature of the system and the calculation. The goal is to simulate the system in a manner that can accommodate any correct approach.

The advantage of Excel worksheets is that it is a platform that enables students to make connections between theoretical concepts about the molecular level and observations at the macroscopic level especially when both the concepts are unfamiliar to the students. For example, providing practice with a simulation in chemical kinetics workbook can increase familiarity with some observations and begin to bridge the gap to theory.

Of all the worksheets created from the few topics chosen from Form Six syllabi in higher secondary school and introductory chemistry course in first year /second year of university, chemical kinetics workbook were brought to test in 12 schools in 3 different states and spectroscopy workbook were tested in a few local universities. Teachers in high schools were provided with the workbook created to teach kinetics in class and students used the provided workbooks to solve some kinetics problems whilst second year universities' students were required to explore and use the spectroscopy workbook to help them in learning. The field studies have proved the contention that MS Excel do stimulate and improve the teaching and learning of chemistry.

5.1 IMPLICATIONS AND CHALLENGES AHEAD

The basic paradigm of an array of row and column with automatic update and display of results has been extended with libraries of mathematical and statistical functions, versatile graphing and charting facilities, powerful add-ins such as Microsoft Excel's Solver, attractive and highly functional graphical user interfaces and the ability to write custom code in languages such as Microsoft's Visual Basic for application has made MS Excel a very powerful tool to be used. However, creation of well designed spreadsheets for this purpose is still considered to be the domain of computer expert or 'Excel gurus' leaving the teachers as merely users of these excellent tool (Siti et al. 2007). Another reason to the draw back to implement this approach is the lack of knowledge or experience among chemistry teachers that simple application software like MS Excel can produce astounding materials to help in teaching and learning of chemistry and creating simple worksheets is just within the grasp of every teacher.

As part of Microsoft Office suite of software, it shares many of the same menus and toolbars as Microsoft Word and Microsoft PowerPoint, which are more common classroom applications. Once you learn how to use a toolbar in one program, you can use it with other programs. This will decrease the learning curve. Moreover, expressive power has been combined with a friendly user-interface in MS Excel, making it light, adaptive and inspiring platform for creating visualizations or various needs in chemistry. It provides us with a natural, interactive medium for doing calculation and mathematics modeling. It is this, the modeling side of using MS Excel that can make them really useful in teaching and learning of chemistry. Of course, before we employ a new approach, we should first examine the reason for doing so. In particular, it would seem that a computer program should meet at least three criteria:

(a) It should fit the chemistry that we teach and enhance the learning process.

(b) Teachers and students should need to devote only a limited amount of time to learning to use the software effectively.

(c) The software should be usable in the later topics, other subjects and through out a student's career.

The finding of the study showed that a spreadsheet, such as MS Excel meet these criteria quite well unlike some programs which need special browser 'plug in' such as quick time shock wave and chime plug-ins to view the animation and simulation.

This study illustrates how we can implement some of the primary spreadsheets visualization techniques using MS Excel in creating effective, interactive and animated graphic educational models for the topics mentioned above. All the worksheets were created using only standard MS Excel functions and simple macro were used to run the task of some buttons created in the worksheets without using difficult programming language or add-ins. It is believed that with very elementary knowledge of MS Excel, a chemistry teacher could be able to create effective and entertaining teaching aids using this widely available spreadsheet package according to their needs in school for the benefit of the students. With MS Excel spreadsheets, scientific calculations or modeling is especially advantages since no major computer programming language is necessary. The result of this study will also provide other researchers, as well as leaders of educational system of Malaysia with a clearer understanding of the state of teaching chemistry through MS Excel and a starting point for further research, debates and discussions.

The challenge ahead now is shifting from predominantly teacher-centered pedagogies to more learner-centered pedagogies in class because majority teachers in the country are still not comfortable with using ICT as a connection and reconstruction tool to expand the learning opportunities of their students. Ministry of Education and teacher training department should conduct professional development programs for chemistry teachers in the country. They should be introduced and trained to use MS Excel spreadsheet to help them in their teaching. As said by Abramovich and Eun (2009), the use of spreadsheet in problem posing can be characterized as a cultural support of the teachings' ability to develop new curriculum materials for a mathematics classroom. It is true also for a chemistry classroom. Therefore, chemistry teachers are strongly recommended and encouraged to exploit this teaching and learning approach by creating more effective worksheets that meet their needs rather than depending on pre-prepared computer softwares or softwares available in the market which often do not fit textbook and the curriculum pattern to attract students' interest in learning chemistry since chemistry is often described as a difficult subject and the young generation is afraid of chemistry in general (Chen 2002). Furthermore, Ministry Of Education should also explore how these innovations can be cascaded to all schools in the country. Strategies may include:

(a) Creating platforms for face-to-face sharing of good worksheets created and networking amongst chemistry teachers.

(b) Showcasing good worksheets using the internet.

An appreciation of the physical world, promoted by interaction simulations can lay the basis for a deeper knowledge of the concepts because simulation can generate image of considerable power. However, it would be unreasonable to replace totally the primary teaching materials with software although simulation allow students to see concepts in meaningful context because students need to be able to understand and use equations for example and carry out experiments in the laboratory. Experiments using real systems are the best way to explore chemistry and simulation offer students alternative ways to discover when real systems are not available or impossible to setup. Hence, variety is always beneficial in learning. A mixed diet of simulation, lecture, experiments and discussions will do best to stimulate students' appetite for chemistry.

A goal for future research is to make this approach easier for the users. Incorporation into MS Excel of features such as extended libraries of auxiliary criteria and appropriate graphical user interfaces appears promising for this purpose. Application of MS Excel in organic chemistry could be further explored to produce more effective and meaningful 3D simulation to enhance the study of organic chemistry. It is hoped that meaningful understanding will be enhanced by sophisticated visualizations of molecules and their properties; simulation of chemical phenomena and processes at the molecular level with interactively and the ability to perform virtual experiments through MS Excel spreadsheet program. In Malaysia, this will certainly create further interest in exploring MS Excel's pedagogical potential in the teaching and learning of chemistry.

With the limitations mentioned above, the result of the study may not be valid to generalize the results to apply to the whole population of Lower Six students who take chemistry and undergraduate students in Malaysia. Hence, other similar studies involving a bigger sample from different locations of the country are needed.

5.2 CONCLUSIONS

This study illustrates how MS Excel can be utilized by teachers and lecturers to create effective and interactive educational environment in the teaching and learning of chemistry at secondary school and institution of higher learning level.

With elementary knowledge of MS Excel, several effective workbooks on chemistry topics were written as teaching aids and tested in schools as well as a few institutions of higher learning. Positive responses and feedback from both teachers and students involved in the field study are very encouraging. Thus, these spreadsheet packages are expected to promote further interest in exploring the potential of MS Excel in pedagogical aspect. Such an approach, if widely adopted, it will be of great benefit to teachers and students in the teaching and learning of chemistry.

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Appendix A

Experiment Manual

STPM CHEMISTRY STUDENT'S MANUAL

Experiment 9

Topic Reaction Kinetics

Purpose To investigate the hydrolysis of methyl ethanoate

Materials **KA 1** is 0.5 moldm^{-3} hydrochloric acid
KA 2 is aqueous sodium hydroxide of concentration 4.0 gdm^{-3}
KA 3 is methyl ethanoate
Distilled water

Procedure:

(a) Using a measuring cylinder, place 100 cm^3 of **KA 1** into a 250 cm^3 conical flask. Using a smaller measuring cylinder, add 5 cm^3 of **KA 3** into the 250 cm^3 conical flask. When about half of the **KA 3** have been added, start the stopwatch and shake the flask carefully for a while.
Then pipette immediately 5.0 cm^3 of solution from this 250 cm^3 conical flask and transfer the sample to a 250 cm^3 titration flask containing 100 cm^3 of ice water. Note the time when half of the sample in the pipette has been transferred. When all of the 5.0 cm^3 in transferred, add one or two drops of pehnolpthalein and titrate this solution immediately with solution **KA 2**. Record your results in the table below.

(b) Repeat the procedure in the second paragraph above for sample 2, 3, and 4 withdrawn from the 250 cm^3 conical flask in the specific time intervals of 10, 20, and 30 minutes respectively. Recond all your results in the table below.

(c) Repeat procedure (a) in the first paragraph but substitute solution **KA 1** with distilled water to prepare sample 5. Repeat the procedure in the second paragraph for sample 5 after 30 minutes have elapsed. You are advised to continue writing your report while waiting for the 30 minutes to end.

Results:

(d) Record and complete your readings in the table below.

Sample	**1**	**2**	**3**	**4**	**5**
Time of transferring sample/ minute					
Final reading / cm^3					
Initial reading / cm^3					
Volume of **KA 2** / cm^3					

Questions:

1. Write a balanced equation for the hydrolysis of methyl ethanoate.

2. What is the purpose of titrating the sample of reaction mixture with KA 2?

3. Plot a graph showing the concentration of methyl ethanoate varies with time and a graph of ln [CH_3COOCH_3] versus time.

4. Determine the order of reaction and the value of **k**. Calculate $\mathbf{t}_{½}$.

5. Why was the sample of reaction mixture added to 100 cm^3 of ice water before titration ?

6. Based on the results of the experiments for samples 4 and 5, state the role of hydrochloric acid in the experiments.

Appendix B

<u>User Manual To Prepare Graph</u>

Name : ___________________
Form 6 (   )

Learning objective: 1.Deduce the order of reaction from concentration-time graphs.
2.Determine the value of k and calculate $t_{1/2}$ for both the first and second order reaction.
3.Explain qualitatively the relationship between concentration and rate of reaction.

Instructions:

1. Each group of students (Group of two) is given a diskette which contain program
   created using Microsoft Excel.
2. You have to use Microsoft Excel program to plot graph from experiment data.
3. Analyze and discuses among friends the output of the chart.
4. Answer all the questions given.

Procedure A : To investigate the hydrolysis of methyl ethanoate

a. Open Microsoft Excel program and click open file – Chemical Kinetics [Worksheet 1]
b. Key in the data collected from experiment into the table accordingly.
c. Highlight the data to be used to form a chart of concentration of methyl ethanoate versus time [cells A11 to A17 and cells E11 to E17]
d. Click "Insert" on menu bar, choose "Chart".
e. From chart wizard, choose 'XY (Scatter)', then choose smooth line with dot from chart sub-type on the right. Click "Next".
f. You will see a graph on the screen. Click "Next" again.
g. Type in the chart title, label of (X) axis and label of (Y) axis. Then click "Next".
h. Choose the chart location to be placed "as object in sheet".
i. Click "Finish". The graph will appear in the worksheet.
j. Repeat from step 3 to plot a graph of ln[CH_3COOCH_3] versus time. [Highlight cells A11 to A17 and cells F11 to F17]
k. When the graph is ready, move the cursor to the graph. Right click the mouse button and choose "Add Trendline".
l. From the "Add Trendline" menu, choose the linear trend type. You will see a darken straight line formed.
m. Then, double click at the "Trendline". From the format trendline menu, choose option, then choose "Display equation on chart" and click "OK"
n. Determine the k value from equation.
o. Calculate the value of $t_{1/2}$.

Procedure B : To investigate the decomposition of nitrogen dioxide

a. Open Microsoft Excel program and click open file- Chemical Kinetics [Worksheet 2]
b. Key in the data as given below into the worksheet.

Time/s	0	60	120	180	240	300	360
$[NO_2]$/M	0.01	0.00683	0.00518	0.00418	0.00350	0.00301	0.00264

c. Highlight the data [cells A9 to A15 and cells B9 to B15]
d. Click “Insert” on menu bar, choose “Chart”.
e. From chart wizard, choose ‘XY (Scatter)’, then choose smooth line with dot from chart sub-type on the right. Click “Next”.
f. You will see a graph on the screen. Click “Next” again.
g. Type in the chart title, label of (X) axis and label of (Y) axis. Then click “Next”.
h. Choose the chart location to be placed “as object in sheet”.
i. Click “Finish”. The graph will appear in the worksheet.
j. Repeat from step 3 to plot graph of ln$[NO_2]$ versus time [Highlight cells A9 to A15 and cells C9 to C15] and graph 1/$[NO_2]$ versus time [Highlight cells A9 to A15 and cells D9 to D15].
k. When the graph 1/$[NO_2]$ versus time is ready, move the cursor to the graph. Right click the mouse button and choose “Add Trendline”.
l. From the “Add Trendline” menu, choose the linear trend type. You will see a darken straight line formed.
m. Then, double click at the “Trendline”. From the format trendline menu, choose option, then choose “Display equation on chart” and click “OK”
n. Determine the k value from equation.
o. Calculate the value of $t_{1/2}$.

Appendix C

Full VBA code to run the combo box in “sheet 2” worksheet in “Period Three Elements” workbook.

```
Private Sub ComboBox1_Click()

Select Case ComboBox1.Value
Case "Atomic Radius"
Sheets("Atomic Radius").Select
Case "First Ionization Energy"
Sheets("1st Ionization Energy").Select
Case "Melting Point"
Sheets("Melting Point").Select
Case "Boiling Point"
Sheets("Boiling Point").Select
Case "Electronegativity"
Sheets("Electronegativity").Select
Case "Atomic radius and Melting point"
Sheets("Atomic radius and Melting point").Select
Case "Atomic radius & First Ionization Energy"
Sheets("Atomic radius & 1st I.E").Select
Case "Sodium"
Sheets("sodium").Select
Case "Magnesium"
Sheets("Magnesium").Select
Case "Aluminium"
Sheets("Aluminium").Select
Case "Silicon"
Sheets("Silicon").Select
Case "Phosphorus"
Sheets("Phosphorus").Select
Case "Sulphur"
Sheets("Sulphur").Select
Case "Chlorine"
Sheets("Chlorine").Select
Case "Argon"
Sheets("Argon").Select
Case "Reaction of elements with water"
Sheets("Reaction with water").Select
Case "Reaction of elements with oxygen"
Sheets("Reaction with oxygen").Select
End Select
End Sub
```

Appendix D

Full VBA code to run the task for showing explanation to the questions set in "Atomic Radius" worksheet, "1st Ionization Energy" worksheet, "Boiling Point" worksheet and "Electronegativity" worksheet in "Period Three Elements" workbook.

```
Sub Atomicradius_click()
MsgBox ("Atomic radius decreases from Na to Ar. The nuclear charge increases and the
added electron goes into same quantum shell. The screening effect remains constant.
The force of attraction between electron charge cloud and the increasing nuclear charge
increases. Therefore, size of atom decreases.")
End Sub

Sub First_ionization_energy_Click()
MsgBox ("1st ionization energy increases across the period from left to right (From Na
to Ar). Atomic radius decreases whilst the charge of the nucleus increases, and the
screening effect is almost constant. The force of attraction between the nucleus and the
outer electrons keeps increasing resulting in ionization energy increasing across the
period.")
End Sub

Sub Meltingpoint_click()
MsgBox ("The melting points and boiling point rise from Na to Si, then fall sharply to P.
After rising slightly at S, they drop again from Cl to Ar. Na, Mg and Al exhibit metallic
bonding where each positively charged metal ion is attracted to a sea of delocalised
electrons. The greater the number of electrons involved, the stronger the metallic
bonding. Since Na contributes one electron, Mg two and Al three electrons for bonding,
the strength of the metallic bonding in these metals are increasing in the order
Na<Mg<Al. Hence the melting points also increase in the order Na<Mg<Al.")

MsgBox ("Si has a giant molecular structure. the Si atoms are held together in a solid
lattice by a network of strong covalent bonds. A lot of heat energy is needed to break
these bonds. Hence, Si has a very high melting point and boiling point.")

MsgBox ("P, S, Cl and Ar have simple molecular structures. Although the covalent
bonds between the atoms within these moleculars are strong, the van der Waals forces
of attraction between these molecules are weak. Therefore, these molecules are easily
separated and have low melting points and boiling point. The larger the molecules and
the greater the number of electrons per molecule, the greater would be the strength of
the van der Waals forces. Since the order of size for these molecules is Ar<Cl<P<S,
therefore, the melting point and boiling point of these elements also vary in the order
Ar<Cl<P<S.")
End Sub

Sub Electronegativity_click()
MsgBox ("The electronegativity increases from Na to Cl. Size of atom decrease but the
nuclear charge increases. Thus effective nuclear charge increases. The bonded elecrons
in a covalent bond will be attracted more strongly to the nucleus of atom; thus
electronegativity increases from Na to Cl.")
End Sub
```

Appendix E

Full VBA code to run the task for showing explanation to the reaction between period three elements with oxygen in “Period Three Elements” workbook.

```
Sub sodiumoxygen()
MsgBox "Sodium is the most reactive element in Period 3. It burns vigorously in oxygen with a bright yellow flame to produce sodium oxide, a white solid. Sodium is so reactive that it is usually kept under paraffin oil."
End Sub

Sub magnesiumoxygen()
MsgBox "Magnesium burns in oxygen with a brilliant white flame to produce magnesium oxide, a white solid."
End Sub

Sub aluminiumoxygen()
MsgBox "Aluminium burns in oxygen with a brilliant white light to produce aluminium oxide, a white solid."
End Sub

Sub siliconoxygen()
MsgBox "Silicon burns in oxygen at red heat to produce silicon(IV)oxide, a white solid."
End Sub

Sub phosphorusoxygen()
MsgBox "Phosphorus exists as 2 allotropes: white and red phosphorus. White phosphorus burns in oxygen at about 40 degree celcius to form phosphorus(V)oxide. In limited supply of oxygen, a liquid phosphorus(III)oxide is formed. Red phosphorus burns in oxygen at about 300 degree celcius to form phosphorus(V)oxide."
End Sub

Sub sulphuroxygen()
MsgBox "When heated in oxygen, sulphur first melts, then burns with a blue flame to form mainly sulphur(IV)oxide or sulphur dioxide. The sulphur dioxide can further combine with oxygen in the presence of vanadium(V)oxide as catalyst at 450 degree celcius to form sulphur(VI)oxide or sulphur trioxide."
End Sub
```

Appendix F

Full VBA code to run the task for “Add Item” button in qualitative analysis worksheet.

```
Private Sub CommandButton2_Click()
Me.ListBox1.AddItem "Pb2+", 0
Me.ListBox1.AddItem "Cu2+", 1
Me.ListBox1.AddItem "Ni2+", 2
Me.ListBox1.AddItem "Mn2+", 3
Me.ListBox1.AddItem "Fe2+", 4
Me.ListBox1.AddItem "Fe3+", 5
Me.ListBox1.AddItem "Al3+", 6
Me.ListBox1.AddItem "Cr3+", 7
Me.ListBox1.AddItem "Zn2+", 8
Me.ListBox1.AddItem "Ba2+", 9
Me.ListBox1.AddItem "Ca2+", 10
Me.ListBox1.AddItem "Mg2+", 11
Me.ListBox1.AddItem "NH4 +", 12

Me.ListBox2.AddItem "Cl-", 0
Me.ListBox2.AddItem "Br-", 1
Me.ListBox2.AddItem "I-", 2
Me.ListBox2.AddItem "S2-(in HCl)", 3
Me.ListBox2.AddItem "OH-", 4
Me.ListBox2.AddItem "CO32-", 5
Me.ListBox2.AddItem "[Fe(CN)6]3-", 6
Me.ListBox2.AddItem "[Fe(CN)6]4-", 7
Me.ListBox2.AddItem "[HPO4]2-", 8
Me.ListBox2.AddItem "CrO42-", 9
Me.ListBox2.AddItem "SO42-", 10
Me.ListBox2.AddItem "CH3COO-", 11
Me.ListBox2.AddItem "C2O42-", 12
Me.ListBox2.AddItem "SCN-", 13
End Sub
```

Appendix G

Full VBA code to run the task for “Result” button in qualitative analysis worksheet.

```
Private Sub CommandButton1_Click()
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 0 Then
Me.Label1.Caption = "White precipitate soluble when heated;recrystalises on cooling"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 2 Then
Me.Label1.Caption = "Yellow precipitate soluble when heated;recrystalises on cooling"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 3 Then
Me.Label1.Caption = "Black precipitate form"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "White precipitate soluble in excess of NaOH(aq)"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "White precipitate"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 7 Then
Me.Label1.Caption = "White precipitate"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "White precipitate"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 9 Then
Me.Label1.Caption = "Yellow precipitate soluble in HNO3(aq)"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 10 Then
Me.Label1.Caption = "White precipitate soluble in (NH4)2C2O4"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 12 Then
Me.Label1.Caption = "White precipitate soluble in HNO3"
End If
If Me.ListBox1.ListIndex = 0 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
```

```
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 2 Then
Me.Label1.Caption = "White precipitate in brown solution"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 3 Then
Me.Label1.Caption = "Black precipitate form"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "Blue precipitate insoluble in excess of NaOH(aq), becomes black
on heating"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "Blue precipitate becomes black on heating"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 7 Then
Me.Label1.Caption = "Reddish brown precipitate soluble in excess NH3(aq)to form
blue solution"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "Blue precipitate form"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 9 Then
Me.Label1.Caption = "Brown precipitate soluble in acids"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 1 And Me.ListBox2.ListIndex = 13 Then
Me.Label1.Caption = "Black precipitate form"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
```

```
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "Green precipitate insoluble in excess of NaOH(aq)"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "Green precipitate form"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 7 Then
Me.Label1.Caption = "Green precipitate form"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "Green precipitate form"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 9 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 2 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "White precipitate turns to brown/buff"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "Yellowish brown precipitate form"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
```

```
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 7 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "Yellowish brown precipitate becomes brown when heated"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 9 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 3 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "Dirty green precipitate insoluble in excess of NaOH(aq)"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "Dirty green precipitate form"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 6 Then
Me.Label1.Caption = "Dark blue precipitate form"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 7 Then
Me.Label1.Caption = "Blue precipitate form"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 8 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 9 Then
Me.Label1.Caption = "Brown precipitate soluble in acids"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 10 Then
```

```
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 4 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 2 Then
Me.Label1.Caption = "Yellow/Brown solution or black precipitate"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "Brown precipitate insoluble in excess of NaOH(aq)"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "Brown precipitate form"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 6 Then
Me.Label1.Caption = "Brown solution form"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 7 Then
Me.Label1.Caption = "Dark blue precipitate form"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "Yellowish-white precipitate soluble in mineral acids, insoluble in
CH3COOH"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 9 Then
Me.Label1.Caption = "Reddish brown precipitate soluble in acids"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 11 Then
Me.Label1.Caption = "Reddish-brown solution; brown precipitate on heating"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 5 And Me.ListBox2.ListIndex = 13 Then
```

```
Me.Label1.Caption = "Blood red colouration"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "White precipitate soluble in excess of NaOH(aq)"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "White precipitate form"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 7 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "White precipitate soluble in mineral acids and NaOH; insoluble
in CH3COOH"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 9 Then
Me.Label1.Caption = "Yellow precipitate soluble in mineral acids"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 11 Then
Me.Label1.Caption = "No precipitate; white precipitate when boiled"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 6 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 2 Then
```

```
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "Greyish-green precipitate soluble in excess of NaOH(aq)to form green solution"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "Greyish-green precipitate form"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 7 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "Green precipitate soluble in mineral acids"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 9 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 7 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "White precipitate soluble in excess of NaOH(aq)"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 5 Then
```

```
Me.Label1.Caption = "White precipitate form"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 6 Then
Me.Label1.Caption = "Orange brown precipitate form"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 7 Then
Me.Label1.Caption = "White precipitate soluble in alkalis; insoluble in mineral acids"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "White precipitate soluble in NaOH,NH4Cl and mineral acids"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 9 Then
Me.Label1.Caption = "Yellow precipitate soluble in acids"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 8 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "White precipitate in concentrated solution of NaOH"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "White precipitate form"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 7 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "White precipitate soluble in HNO3 and HCl"
```

```
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 9 Then
Me.Label1.Caption = "Yellow precipitate soluble in mineral acids"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 10 Then
Me.Label1.Caption = "White precipitate form"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 12 Then
Me.Label1.Caption = "White precipitate soluble in hot CH3COOH"
End If
If Me.ListBox1.ListIndex = 9 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "White precipitate insoluble in excess of NaOH(aq)"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "White precipitate form"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 7 Then
Me.Label1.Caption = "White precipitate form in excess of [Fe(CN)6]4-"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "White precipitate soluble in acids"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 9 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
```

```
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 12 Then
Me.Label1.Caption = "White precipitate insoluble in CH3COOH"
End If
If Me.ListBox1.ListIndex = 10 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "White precipitate insoluble in excess of NaOH(aq); soluble in
NH4Cl"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "White precipitate insoluble in excess of Na2CO3(aq); soluble in
NH4Cl"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 7 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 8 Then
Me.Label1.Caption = "White precipitate soluble in mineral acids"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 9 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 11 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 0 Then
MsgBox "No Observation"
```

```
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 1 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 2 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 3 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 4 Then
Me.Label1.Caption = "Gas with pungent smell evolved when heated"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 5 Then
Me.Label1.Caption = "Gas with pungent smell evolved when heated"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 6 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 7 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 8 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 9 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 10 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 11 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 12 Then
MsgBox "No Observation"
End If
If Me.ListBox1.ListIndex = 12 And Me.ListBox2.ListIndex = 13 Then
MsgBox "No Observation"
End If
End Sub
```

Appendix H

Full VBA code to run the task for "Observation" button in QA Simulation 1 worksheet.

```
Private Sub CommandButton1_Click()
If Range("B9").Value = 1 And Range("C9").Value = 1 Then
TextBox1 = "a)White precipitate soluble when heated;recrystalises on cooling"
TextBox2 = "b)Yellow precipitate soluble when heated;recrystalises on cooling"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate soluble when heated;recrystalises on cooling"
TextBox2 = "b)Yellow precipitate soluble when heated;recrystalises on cooling"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate soluble when heated;recrystalises on cooling"
TextBox2 = "b)Yellow precipitate soluble when heated;recrystalises on cooling"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 4 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)Black precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 5 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)White precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
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End If

If Range("B9").Value = 1 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 10 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow precipitate soluble in HNO3(aq)"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in (NH4)2C2O4"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 13 Then
TextBox1 = "a)White precipitate soluble in HNO3(aq)"
TextBox2 = "b)Yellow precipitate soluble in HNO3(aq)"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 1 And Range("C9").Value = 14 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 1 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate in brown solution"
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TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 4 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Black precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 5 Then
TextBox1 = "a)Blue precipitate insoluble in excess, becomes black on heating"
TextBox2 = "b)Blue precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 6 Then
TextBox1 = "a)Blue precipitate becomes black on heating"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 7 Then
TextBox1 = "a)Blue precipitate becomes black on heating"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 8 Then
TextBox1 = "a)Reddish brown precipitate soluble in excess NH3(aq)to form blue
solution"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 9 Then
TextBox1 = "a)Reddish brown precipitate"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 10 Then
TextBox1 = "a)Brown precipitate soluble in acids"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 11 Then
TextBox1 = "a)Brown precipitate soluble in acids"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If
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If Range("B9").Value = 2 And Range("C9").Value = 12 Then
TextBox1 = "a)Blue precipitate becomes black on heating"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 13 Then
TextBox1 = "a)Blue precipitate becomes black on heating"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 2 And Range("C9").Value = 14 Then
TextBox1 = "a)Black precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 1 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Green precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 2 Then
TextBox1 = "a)Green precipitate insoluble in excess"
TextBox2 = "b)Green precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 3 Then
TextBox1 = "a)Green precipitate insoluble in excess"
TextBox2 = "b)Green precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 4 Then
TextBox1 = "a)Green precipitate insoluble in excess"
TextBox2 = "b)Green precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 5 Then
TextBox1 = "a)Green precipitate insoluble in excess"
TextBox2 = "b)Green precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 6 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
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End If

If Range("B9").Value = 3 And Range("C9").Value = 7 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 8 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 9 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 10 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 11 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 12 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 13 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 3 And Range("C9").Value = 14 Then
TextBox1 = "a)Green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 1 Then
TextBox1 = "a)Brown precipitate form"
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TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 4 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 5 Then
TextBox1 = "a)White precipitate turns to brown/buff"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellowish brown precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellowish brown precipitate becomes brown when heated"
TextBox3 = "c)No Observation"
End If
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If Range("B9").Value = 4 And Range("C9").Value = 10 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 13 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 4 And Range("C9").Value = 14 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 1 Then
TextBox1 = "a)Blue precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 2 Then
TextBox1 = "a)Blue precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 3 Then
TextBox1 = "a)Blue precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 4 Then
TextBox1 = "a)Blue precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
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End If

If Range("B9").Value = 5 And Range("C9").Value = 5 Then
TextBox1 = "a)Blue precipitate form"
TextBox2 = "b)Dirty green precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 6 Then
TextBox1 = "a)Dirty green precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If
If Range("B9").Value = 5 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Dark blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If
If Range("B9").Value = 5 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 10 Then
TextBox1 = "a)Brown precipitate soluble in acids"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 5 And Range("C9").Value = 13 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
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End If

If Range("B9").Value = 5 And Range("C9").Value = 14 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 1 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Brown precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Brown precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow/Brown solution or black precipitate"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 4 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow/Brown solution or black precipitate"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 5 Then
TextBox1 = "a)Brown precipitate insoluble in excess"
TextBox2 = "b)Yellow solution"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 6 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 7 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)Brown solution form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 8 Then
TextBox1 = "a)Brown precipitate form"
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TextBox2 = "b)Dark blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 9 Then
TextBox1 = "a)Yellowish-white precipitate soluble in mineral acids, insoluble in CH3COOH"
TextBox2 = "b)Dark blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 10 Then
TextBox1 = "a)Reddish brown precipitate soluble in acids"
TextBox2 = "b)Dark blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 11 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)Dark blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 12 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)Reddish-brown solution; brown precipitate on heating"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 13 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)Dark blue precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 6 And Range("C9").Value = 14 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)Blood red colouration"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 1 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 2 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If
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If Range("B9").Value = 7 And Range("C9").Value = 3 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 4 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 5 Then
TextBox1 = "a)Brown precipitate form"
TextBox2 = "b)White precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate soluble in mineral acids and NaOH; insoluble in
CH3COOH"
TextBox2 = "b)Yellow precipitate soluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 10 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Yellow precipitate soluble in mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate soluble in excess"
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TextBox2 = "b)Yellow precipitate soluble in mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)No precipitate; white precipitate when boiled"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 13 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Brown precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 7 And Range("C9").Value = 14 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 1 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 4 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 5 Then
TextBox1 = "a)Greyish-green precipitate soluble in excess to form green solution"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If
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If Range("B9").Value = 8 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate soluble in mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 10 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 13 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 8 And Range("C9").Value = 14 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Greyish-green precipitate form"
TextBox3 = "c)No Observation"
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End If

If Range("B9").Value = 9 And Range("C9").Value = 1 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 4 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 5 Then
TextBox1 = "a)White precipitate soluble in excess"
TextBox2 = "b)Green precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 7 Then
TextBox1 = "a)Orange brown precipitate form"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 8 Then
TextBox1 = "a)Orange brown precipitate form"
TextBox2 = "b)White precipitate soluble in alkalis; insoluble in mineral acids"
TextBox3 = "c)No Observation"
End If
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If Range("B9").Value = 9 And Range("C9").Value = 9 Then
TextBox1 = "a)Orange brown precipitate form"
TextBox2 = "b)White precipitate soluble in NaOH,NH4Cl and mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 10 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH,NH4Cl and mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 11 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 12 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 13 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 9 And Range("C9").Value = 14 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 1 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 2 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If
```

```
If Range("B9").Value = 10 And Range("C9").Value = 3 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 4 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate soluble in NaOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 5 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate in concentrated solution"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 6 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 7 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 8 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate soluble in HNO3 and HCl"
TextBox2 = "b)White precipitate insoluble in acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 10 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If
```

```
If Range("B9").Value = 10 And Range("C9").Value = 11 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate form when add with dilute H2SO4 and CaSO4"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 12 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate form"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 13 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate soluble in hot CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 10 And Range("C9").Value = 14 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate soluble in hot CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 1 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate soluble in hot CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 2 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate soluble in hot CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 3 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate soluble in hot CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 4 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate soluble in hot CH3COOH"
TextBox3 = "c)No Observation"
End If
```

```
If Range("B9").Value = 11 And Range("C9").Value = 5 Then
TextBox1 = "a)Yellow precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate form"
TextBox2 = "b)Yellow precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate form in excess reagent"
TextBox2 = "b)Yellow precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)Yellow precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 10 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)Yellow precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)Yellow precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)Yellow precipitate insoluble in excess"
TextBox3 = "c)No Observation"
End If
```

```
If Range("B9").Value = 11 And Range("C9").Value = 13 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 11 And Range("C9").Value = 14 Then
TextBox1 = "a)Yellow precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 1 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 4 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 5 Then
TextBox1 = "a)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox2 = "b)White precipitate soluble in CH3COOH"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If
```

```
If Range("B9").Value = 12 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate soluble in acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 10 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 13 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 12 And Range("C9").Value = 14 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in excess; soluble in NH4Cl"
TextBox3 = "c)No Observation"
End If
```

```
If Range("B9").Value = 13 And Range("C9").Value = 1 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 2 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 3 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 4 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)White precipitate insoluble in mineral acids"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 5 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 6 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 7 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 8 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If
```

```
If Range("B9").Value = 13 And Range("C9").Value = 9 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 10 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 11 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 12 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 13 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If

If Range("B9").Value = 13 And Range("C9").Value = 14 Then
TextBox1 = "a)White precipitate soluble in mineral acids"
TextBox2 = "b)Gas with pungent smell evolved when heated"
TextBox3 = "c)No Observation"
End If
End Sub
```

Appendix I

Full VBA code to run the task for "Check Answer" button in QA Simulation 1 worksheet.

```
Private Sub CommandButton3_Click()

If Range("B9").Value = 1 And Range("C9").Value = 1 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 1 And Range("C9").Value = 2 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 1 And Range("C9").Value = 3 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 1 And Range("C9").Value = 4 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 1 And Range("C9").Value = 5 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 1 And Range("C9").Value = 6 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 1 And Range("C9").Value = 7 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 1 And Range("C9").Value = 8 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 1 And Range("C9").Value = 9 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 1 And Range("C9").Value = 10 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 1 And Range("C9").Value = 11 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 1 And Range("C9").Value = 12 Then
```

```
MsgBox "Answer is c"
End If
If Range("B9").Value = 1 And Range("C9").Value = 13 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 1 And Range("C9").Value = 14 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 2 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 2 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 2 And Range("C9").Value = 3 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 2 And Range("C9").Value = 4 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 2 And Range("C9").Value = 5 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 2 And Range("C9").Value = 6 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 2 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 2 And Range("C9").Value = 8 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 2 And Range("C9").Value = 9 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 2 And Range("C9").Value = 10 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 2 And Range("C9").Value = 11 Then
```

```
MsgBox "Answer is c"
End If
If Range("B9").Value = 2 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 2 And Range("C9").Value = 13 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 2 And Range("C9").Value = 14 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 3 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 3 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 3 And Range("C9").Value = 3 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 3 And Range("C9").Value = 4 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 3 And Range("C9").Value = 5 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 3 And Range("C9").Value = 6 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 3 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 3 And Range("C9").Value = 8 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 3 And Range("C9").Value = 9 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 3 And Range("C9").Value = 10 Then
```

```
MsgBox "Answer is c"

End If

If Range("B9").Value = 3 And Range("C9").Value = 11 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 3 And Range("C9").Value = 12 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 3 And Range("C9").Value = 13 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 3 And Range("C9").Value = 14 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 1 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 2 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 3 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 4 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 5 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 4 And Range("C9").Value = 6 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 4 And Range("C9").Value = 7 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 8 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 9 Then
```

```
MsgBox "Answer is b"

End If

If Range("B9").Value = 4 And Range("C9").Value = 10 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 11 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 12 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 13 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 4 And Range("C9").Value = 14 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 5 And Range("C9").Value = 1 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 5 And Range("C9").Value = 2 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 5 And Range("C9").Value = 3 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 5 And Range("C9").Value = 4 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 5 And Range("C9").Value = 5 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 5 And Range("C9").Value = 6 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 5 And Range("C9").Value = 7 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 5 And Range("C9").Value = 8 Then
```

```
MsgBox "Answer is b"
End If
If Range("B9").Value = 5 And Range("C9").Value = 9 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 5 And Range("C9").Value = 10 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 5 And Range("C9").Value = 11 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 5 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 5 And Range("C9").Value = 13 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 5 And Range("C9").Value = 14 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 6 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 6 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 6 And Range("C9").Value = 3 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 6 And Range("C9").Value = 4 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 6 And Range("C9").Value = 5 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 6 And Range("C9").Value = 6 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 6 And Range("C9").Value = 7 Then
```

```
MsgBox "Answer is b"

End If

If Range("B9").Value = 6 And Range("C9").Value = 8 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 6 And Range("C9").Value = 9 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 6 And Range("C9").Value = 10 Then
MsgBox "Answer is a"

End If

If Range("B9").Value = 6 And Range("C9").Value = 11 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 6 And Range("C9").Value = 12 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 6 And Range("C9").Value = 13 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 6 And Range("C9").Value = 14 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 7 And Range("C9").Value = 1 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 7 And Range("C9").Value = 2 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 7 And Range("C9").Value = 3 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 7 And Range("C9").Value = 4 Then
MsgBox "Answer is c"

End If

If Range("B9").Value = 7 And Range("C9").Value = 5 Then
MsgBox "Answer is b"

End If

If Range("B9").Value = 7 And Range("C9").Value = 6 Then
```

```
MsgBox "Answer is a"
End If
If Range("B9").Value = 7 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 7 And Range("C9").Value = 8 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 7 And Range("C9").Value = 9 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 7 And Range("C9").Value = 10 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 7 And Range("C9").Value = 11 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 7 And Range("C9").Value = 12 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 7 And Range("C9").Value = 13 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 7 And Range("C9").Value = 14 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 3 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 4 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 5 Then
```

```
MsgBox "Answer is a"
End If
If Range("B9").Value = 8 And Range("C9").Value = 6 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 8 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 8 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 9 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 8 And Range("C9").Value = 10 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 11 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 13 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 8 And Range("C9").Value = 14 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 3 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 4 Then
```

```
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 5 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 9 And Range("C9").Value = 6 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 9 And Range("C9").Value = 7 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 9 And Range("C9").Value = 8 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 9 And Range("C9").Value = 9 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 9 And Range("C9").Value = 10 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 9 And Range("C9").Value = 11 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 13 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 9 And Range("C9").Value = 14 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 3 Then
```

```
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 4 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 5 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 10 And Range("C9").Value = 6 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 10 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 8 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 9 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 10 And Range("C9").Value = 10 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 10 And Range("C9").Value = 11 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 10 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 10 And Range("C9").Value = 13 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 10 And Range("C9").Value = 14 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 2 Then
```

```
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 3 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 4 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 5 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 11 And Range("C9").Value = 6 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 11 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 8 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 11 And Range("C9").Value = 9 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 11 And Range("C9").Value = 10 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 11 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 11 And Range("C9").Value = 13 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 11 And Range("C9").Value = 14 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 1 Then
```

```
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 3 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 4 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 5 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 12 And Range("C9").Value = 6 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 12 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 8 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 9 Then
MsgBox "Answer is a"
End If
If Range("B9").Value = 12 And Range("C9").Value = 10 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 11 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 13 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 12 And Range("C9").Value = 14 Then
```

```
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 1 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 2 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 3 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 4 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 5 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 13 And Range("C9").Value = 6 Then
MsgBox "Answer is b"
End If
If Range("B9").Value = 13 And Range("C9").Value = 7 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 8 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 9 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 10 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 11 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 12 Then
MsgBox "Answer is c"
End If
If Range("B9").Value = 13 And Range("C9").Value = 13 Then
```

```
MsgBox "Answer is c"

End If

If Range("B9").Value = 13 And Range("C9").Value = 14 Then
MsgBox "Answer is c"

End If

End Sub
```

Appendix J

	Cl^-	Br^-	I^-	CH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Fe^{3+}	No observation	No observation	Brown solution	Brown precipitate insoluble in excess of NaOH(aq)	Brown precipitate form.	Brown precipitate insoluble in excess	Brown solution	Dark blue precipitate form.	Yellowish white precipitate soluble in mineral acids; insoluble in CH_3COOH.	Reddish brown precipitate soluble in acid.	No observation	Reddish brown solution; brown precipitate on heating.	No observation	Blood red colouration.	CH_3COO^-
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Al^{3+}	No observation	No observation	No observation	White precipitate soluble in excess of NaOH(aq).	White precipitate form.	White precipitate insoluble in excess.	No observation	No observation	White precipitate soluble in mineral acid and NaOH in soluble in CH_3COOH.	Yellow precipitate soluble in mineral acid.	No observation	No precipitation	No observation	No observation	$[C_2O_4]^{2-}$
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Cr^{3+}	No observation	No observation	No observation	Greyish - green precipitate soluble in excess of NaOH(aq) to form green solution.	Greyish - green precipitate form.	Greyish - green precipitate soluble in excess to form purple solution.	No observation	No observation	Green precipitate soluble in mineral acids.	No observation	No observation	No observation	No observation	No observation	SCN^-
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Ca^{2+}	No observation	No observation	No observation	White precipitate insoluble in excess of NaOH(aq).	White precipitate form.	No observation	No observation	White precipitate form in excess of $[Fe(CN)_6]^{4-}$	White precipitate insoluble in acids.	No observation	No observation	No observation	White precipitate insoluble in CH_3 COOH.	No observation	
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Mg^{2+}	No observation	No observation	No observation	White precipitate insoluble in excess of NaOH(aq), soluble in NH_4Cl.	White precipitate insoluble in excess soluble in NH_4Cl.	White precipitate insoluble in excess soluble in NH_4Cl.	No observation	No observation	White precipitate soluble in mineral acids.	No observation	No observation	No observation	No observation	No observation	

	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	$[Fe(CN)_6]^{3-}$
Pb^{2+}	White precipitate soluble when heated ; recrystalises on cooling.	White precipitate soluble when heated crystal when cooled.	Yellow precipitate soluble in hot water ; yellow crystal when cooled.	White precipitate soluble in excess of NaOH(aq).	White precipitate form.	White precipitate insoluble in excess.	No observation	White precipitate form.	White precipitate form.	Yellow precipitate soluble in HNO_3 (aq)	White precipitate form.	No observation	White precipitate soluble in HNO_3	White precipitate form.	$[Fe(CN)_6]^{4-}$
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Cu^{2+}	No observation	No observation	White precipitate in brown solution.	Blue precipitate insoluble in excess becomes black on heating	Blue precipitate form.	Blue precipitate soluble in excess to form deep blue solution. Soluble in NH_4Cl	Yellowish brown precipitate	Reddish brown precipitate soluble in excessNH_3(aq) to form blue solution.	Blue precipitate from.	Brown precipitate soluble in acids.	No observation	Blue precipitate soluble in excess.	White precipitate form.	Black precipitate form.	$[HPO_4]^{2-}$
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Ni^{2+}	No observation	No observation	No observation	Green precipitate insoluble in excess of NaOH(aq).	Green precipitate form.	Green precipitate soluble in excess to form light blue solution. Soluble in NH_4Cl.	Brown precipitate form.	Green precipitate form.	Green precipitate form.	No observation	No observation	No observation	No observation	No observation	$[CrO_4]^{2-}$
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	
Mn^{2+}	No observation	No observation	No observation	White precipitate turns to brown/buff.	Yellowish white precipitate	White precipitato turns to brown/buff. Soluble in NH_4Cl.	Brown precipitate form.	Yellowish white precipitate	Yellowish white precipitate becomes brown when heated	No observation	No observation	No observation	No observation	No observation	$[SO_4]^{2-}$

	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	Cl^-
X $[Ba^{2+}]$	No Observation	No Observation	No Observation	White precipitate in concentrated solution of NaOH.	White precipitate form	No Observation	No Observation	No Observation	White precipitate soluble in HNO3 and HCl	Yellow precipitate soluble in mineral acid	White precipitate form	No Observation	White precipitate form	No Observation	Br^-
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	I^-
Y $[Fe^{2+}]$	No Observation	No Observation	No Observation	Dirty green precipitate insoluble in excess of NaOH(aq)	Dirty green precipitate form	Dirty green precipitate insoluble in excess of (NH_3)aq, soluble in NH_4Cl	Dark blue precipitate form	Blue precipitate form	White precipitate form.	Brown precipitate soluble in acid	No Observation	No Observation	Light yellow precipitate form	Form brown solution	OH^-
	Cl^-	Br^-	I^-	OH^-	$[CO_3]^{2-}$	$NH_3(aq)$	$[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{4-}$	$[HPO_4]^{2-}$	$[CrO_4]^{2-}$	$[SO_4]^{2-}$	CH_3COO^-	$[C_2O_4]^{2-}$	SCN^-	$[CO_3]^{2-}$
Z $[Zn^{2+}]$	No Observation	No Observation	No Observation	White precipitate soluble in excess of NaOH(aq)	White precipitate form	White precipitate soluble in excess of $NH_3(aq)$	Orange brown precipitate form	White precipitate soluble in alkali;insoluble in mineral acid	White precipitate soluble in NaOH, NH_4Cl and mineral acid	Yellow precipitate soluble in acids	No Observation	No Observation	No Observation	No Observation	$NH_3(aq)$

Appendix K

List of Video Clip

1. video clip 1_reaction between Pb^{2+} and anions
2. video clip 2_reaction between Cu^{2+} and anions
3. video clip 3_reaction between Ni^{2+} and anions
4. video clip 4_reaction between Mn^{2+} and anions
5. video clip 5_reaction between Fe^{2+} and anions
6. video clip 6_reaction between Fe^{3+} and anions
7. video clip 7_reaction between Al^{3+} and anions
8. video clip 8_reaction between Cr^{3+} and anions
9. video clip 9_reaction between Zn^{2+} and anions
10. video clip 10_reaction between Ba^{2+} and anions
11. video clip 11_reaction between Ca^{2+} and anions
12. video clip 12_reaction between Mg^{2+} and anions

Appendix L

```
Private Sub CommandButton1_Click()
Application.ScreenUpdating = False
Range("A8:C68").Select
    Selection.Copy
    ActiveWindow.ScrollRow = 2
    ActiveWindow.ScrollRow = 10
    ActiveWindow.ScrollRow = 26
    ActiveWindow.ScrollRow = 44
    ActiveWindow.ScrollRow = 60
    ActiveWindow.ScrollRow = 62
    ActiveWindow.ScrollRow = 63
    ActiveWindow.ScrollRow = 64
    ActiveWindow.ScrollRow = 65
    ActiveWindow.ScrollRow = 69
    ActiveWindow.ScrollRow = 73
    ActiveWindow.ScrollRow = 75
    ActiveWindow.ScrollRow = 77
    ActiveWindow.ScrollRow = 89
    ActiveWindow.ScrollRow = 96
    ActiveWindow.ScrollRow = 103
    ActiveWindow.ScrollRow = 105
    Range("F115").Select
    ActiveSheet.Paste
    ActiveWindow.ScrollRow = 104
    ActiveWindow.ScrollRow = 87
    ActiveWindow.ScrollRow = 67
    ActiveWindow.ScrollRow = 48
    ActiveWindow.ScrollRow = 44
    ActiveWindow.ScrollRow = 41
    ActiveWindow.ScrollRow = 22
    ActiveWindow.ScrollRow = 11
    ActiveWindow.ScrollRow = 4
    ActiveWindow.ScrollRow = 2
    ActiveWindow.ScrollRow = 1
    Range("F14:H175").Select
    Application.CutCopyMode = False
    Selection.Copy
    Range("J14").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Application.CutCopyMode = False
    Selection.Sort Key1:=Range("K15"), Order1:=xlAscending, Header:=xlGuess, _
        OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom, _
        DataOption1:=xlSortNormal
    Application.ScreenUpdating = True
    Range("a7").Select

End Sub
Private Sub CommandButton2_Click()
TextBox1.Value = ""
```

```
TextBox2.Value = ""
For i = 1 To 4
rname = "n" & i + 5
Range(rname).Value = ""
Next i
End Sub

Private Sub TextBox1_Change()
Dim cmp
cmp = TextBox1.Value
If IsNumeric(cmp) Then
   If CDbl(cmp) > 0.0001 Then
     Range("n6") = CDbl(cmp)
     Range("n8") = ""
   Else
     Range("n6") = ""
       Range("n8") = CDbl(cmp)
End If
End If
End Sub

Private Sub TextBox2_Change()
Dim cmp
cmp = TextBox2.Value
If IsNumeric(cmp) Then
   If CDbl(cmp) > 0.0001 Then
     Range("n7") = CDbl(cmp)
     Range("n9") = ""
   Else
     Range("n7") = ""
       Range("n9") = CDbl(cmp)
End If
End If
End Sub
Private Sub TextBox3_Change()
End Sub
Private Sub CommandButton1_Click()
Application.ScreenUpdating = False
 Range("B8:C33").Select
   Selection.Copy
   ActiveWindow.ScrollRow = 5
   ActiveWindow.ScrollRow = 13
   ActiveWindow.ScrollRow = 25
   ActiveWindow.ScrollRow = 37
   ActiveWindow.ScrollRow = 48
   ActiveWindow.ScrollRow = 60
   ActiveWindow.ScrollRow = 69
   ActiveWindow.ScrollRow = 71
   ActiveWindow.ScrollRow = 73
   ActiveWindow.ScrollRow = 74
   ActiveWindow.ScrollRow = 75
   ActiveWindow.ScrollRow = 78
```

```
ActiveWindow.ScrollRow = 85
ActiveWindow.ScrollRow = 91
ActiveWindow.ScrollRow = 92
ActiveWindow.ScrollRow = 93
ActiveWindow.ScrollRow = 95
ActiveWindow.ScrollRow = 98
ActiveWindow.ScrollRow = 99
ActiveWindow.ScrollRow = 100
ActiveWindow.ScrollRow = 101
ActiveWindow.ScrollRow = 102
Range("G114").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
ActiveWindow.ScrollRow = 101
ActiveWindow.ScrollRow = 99
ActiveWindow.ScrollRow = 93
ActiveWindow.ScrollRow = 87
ActiveWindow.ScrollRow = 80
ActiveWindow.ScrollRow = 72
ActiveWindow.ScrollRow = 64
ActiveWindow.ScrollRow = 49
ActiveWindow.ScrollRow = 42
ActiveWindow.ScrollRow = 33
ActiveWindow.ScrollRow = 28
ActiveWindow.ScrollRow = 24
ActiveWindow.ScrollRow = 18
ActiveWindow.ScrollRow = 9
ActiveWindow.ScrollRow = 3
ActiveWindow.ScrollRow = 1
Range("F12:H139").Select
Application.CutCopyMode = False
Selection.Copy
Range("J12").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
Application.CutCopyMode = False
Selection.Sort Key1:=Range("K13"), Order1:=xlAscending, Header:=xlGuess, _
    OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom, _
    DataOption1:=xlSortNormal
ActiveWindow.ScrollRow = 2
ActiveWindow.ScrollRow = 3
ActiveWindow.ScrollRow = 4
ActiveWindow.ScrollRow = 5
ActiveWindow.ScrollRow = 6
ActiveWindow.ScrollRow = 7
ActiveWindow.ScrollRow = 11
ActiveWindow.ScrollRow = 12
ActiveWindow.ScrollRow = 16
ActiveWindow.ScrollRow = 20
ActiveWindow.ScrollRow = 22
ActiveWindow.ScrollRow = 23
ActiveWindow.ScrollRow = 25
```

```
    ActiveWindow.ScrollRow = 26
    ActiveWindow.ScrollRow = 27
    ActiveWindow.ScrollRow = 28
    ActiveWindow.ScrollRow = 29
    ActiveWindow.ScrollRow = 31
    ActiveWindow.ScrollRow = 35
    ActiveWindow.ScrollRow = 36
    ActiveWindow.ScrollRow = 38
    ActiveWindow.ScrollRow = 40
    ActiveWindow.ScrollRow = 41
    ActiveWindow.ScrollRow = 44
    ActiveWindow.ScrollRow = 48
    ActiveWindow.ScrollRow = 50
    ActiveWindow.ScrollRow = 53
    ActiveWindow.ScrollRow = 59
    ActiveWindow.ScrollRow = 68
    ActiveWindow.ScrollRow = 75
    ActiveWindow.ScrollRow = 83
    ActiveWindow.ScrollRow = 87
    ActiveWindow.ScrollRow = 92
    ActiveWindow.ScrollRow = 94
    ActiveWindow.ScrollRow = 99
    ActiveWindow.ScrollRow = 102
    ActiveWindow.ScrollRow = 103
    ActiveWindow.ScrollRow = 105
    ActiveWindow.ScrollRow = 106
    ActiveWindow.ScrollRow = 107
    ActiveWindow.ScrollRow = 108
    ActiveWindow.ScrollRow = 109
    ActiveWindow.ScrollRow = 110
    ActiveWindow.ScrollRow = 111
    ActiveWindow.ScrollRow = 110
    ActiveWindow.ScrollRow = 109
    ActiveWindow.ScrollRow = 108
    ActiveWindow.ScrollRow = 107
    ActiveWindow.ScrollRow = 98
    ActiveWindow.ScrollRow = 89
    ActiveWindow.ScrollRow = 79
    ActiveWindow.ScrollRow = 63
    ActiveWindow.ScrollRow = 46
    ActiveWindow.ScrollRow = 33
    ActiveWindow.ScrollRow = 23
    ActiveWindow.ScrollRow = 6
    ActiveWindow.ScrollRow = 1
    Range("a7").Select
    Application.ScreenUpdating = True
End Sub
Private Sub OptionButton3_Click()
End Sub
Private Sub OptionButton4_Click()
End Sub
```

Appendix M

```
Private Sub CommandButton1_Click()
Application.ScreenUpdating = False
Range("A8:C68").Select
    Selection.Copy
    ActiveWindow.ScrollRow = 2
    ActiveWindow.ScrollRow = 10
    ActiveWindow.ScrollRow = 26
    ActiveWindow.ScrollRow = 44
    ActiveWindow.ScrollRow = 60
    ActiveWindow.ScrollRow = 62
    ActiveWindow.ScrollRow = 63
    ActiveWindow.ScrollRow = 64
    ActiveWindow.ScrollRow = 65
    ActiveWindow.ScrollRow = 69
    ActiveWindow.ScrollRow = 73
    ActiveWindow.ScrollRow = 75
    ActiveWindow.ScrollRow = 77
    ActiveWindow.ScrollRow = 89
    ActiveWindow.ScrollRow = 96
    ActiveWindow.ScrollRow = 103
    ActiveWindow.ScrollRow = 105
    Range("F115").Select
    ActiveSheet.Paste
    ActiveWindow.ScrollRow = 104
    ActiveWindow.ScrollRow = 87
    ActiveWindow.ScrollRow = 67
    ActiveWindow.ScrollRow = 48
    ActiveWindow.ScrollRow = 44
    ActiveWindow.ScrollRow = 41
    ActiveWindow.ScrollRow = 22
    ActiveWindow.ScrollRow = 11
    ActiveWindow.ScrollRow = 4
    ActiveWindow.ScrollRow = 2
    ActiveWindow.ScrollRow = 1
    Range("F14:H175").Select
    Application.CutCopyMode = False
    Selection.Copy
    Range("J14").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks
_        :=False, Transpose:=False
    Application.CutCopyMode = False
    Selection.Sort Key1:=Range("K15"), Order1:=xlAscending, Header:=xlGuess, _
OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom, _
        DataOption1:=xlSortNormal
    Application.ScreenUpdating = True
    Range("a7").Select

End Sub
```

```
Private Sub CommandButton2_Click()
TextBox1.Value = ""
TextBox2.Value = ""
For i = 1 To 4
rname = "n" & i + 5
Range(rname).Value = ""
Next i
End Sub

Private Sub TextBox1_Change()
Dim cmp
cmp = TextBox1.Value
If IsNumeric(cmp) Then
   If CDbl(cmp) > 0.0001 Then
     Range("n6") = CDbl(cmp)
     Range("n8") = ""
   Else
     Range("n6") = ""
       Range("n8") = CDbl(cmp)
End If
End If
End Sub

Private Sub TextBox2_Change()
Dim cmp
cmp = TextBox2.Value
If IsNumeric(cmp) Then
   If CDbl(cmp) > 0.0001 Then
     Range("n7") = CDbl(cmp)
     Range("n9") = ""
   Else
     Range("n7") = ""
       Range("n9") = CDbl(cmp)
End If
End If
End Sub

Private Sub TextBox3_Change()

End Sub
```

Appendix N

Evaluation Form For Teaching Kinetics Chemistry Using MS Excel Program
[Student]

Part A : Repondent Background

Instruction : Please tick **'√'** in the blank provided

1. Gender — Male [ ] Female [ ]

2. Race — Malay [ ] Chinese [ ]
   India [ ] Others [ ] (Please state)

3. Gred for chemistry In SPM

1	
2	
3	
4	
5	
6	
7	
8	
9	

4. Level of computer knowledge

Very poor	
Poor	
Moderate	
Good	
Very good	

5. Ddo you have personal computer at home

Yes	
No	

6. Have you attended any Computer course before? If "Yes" Please state the course You have attended

Yes	
No	

____

7. Have you ever use computer
To solve any problem or task
Given by your teacher?
If your answer is "Yes", Please
state what program have you used

Yes	
No	

____

____

PART B:

No	**Items**	**Yes**	**No**	**If your answer is "No", Please states your reason**
1	I like to use Excel worksheets during my learning process			
2	I don't have difficulty to use the Excel worksheets			
3	I become more hardworking and put in more effort after using computer during chemistry lessons			
4	Using the Excel worksheets can save a lot of time to solve chemistry problems			
5	It is easier to evaluate interactive graph using the Excel worksheets			
6	Through Excel worksheets, charts can be presented accurately in a short time			
7	It is more convenient and easier to plot graph of concentration over time using the Excel worksheets			
8	I feel very interested and enjoy my chemistry lessons with the Excel worksheets			
9	I remember lessons better after using the Excel worksheets			
10	Excel worksheets has many advantages which can help in the teaching and learning of chemistry			
11	The use of Excel worksheets should be encouraged to a wider area of chemistry			
12	Using Excel worksheets in the teaching and learning can encourage discussion among the students and with the teacher			
13	I think Excel worksheets are not suitable to use in chemistry learning			
14	The language and menu in Excel worksheets are easy to understand an user friendly			
15	I have no experience in Excel worksheets, I am afraid to use it in learning chemistry			

Appendix O

Evaluation Form For Teaching Kinetic Chemistry Using MS Excel Program
[Teacher]

Part A : Personal Background

1 Gender :
2 Race :
3 Option :
4 Name of school/institut:
5 Experience of teaching chemistry :

Part B

Bil	Item	Yes	No	If "No", state your reason
1	Student use the worksheets actively.			
2	Excel worksheets is attractive.			
3	Excel worksheets motivates students towards the lesson.			
4	Learning through Excel worksheets stimulate student to think.			
5	Learning through Excel worksheets encourage collaborative discussion among students and also between teacher and students.			
6	These worksheets can be used as reference for revision.			
7	Content of worksheets fulfill the objective of lesson.			
8	Language used in Excel worksheets easy to understand.			
9	Facts presented with interactive feature can deliver the lesson effectively.			
10	Other comment on this program:(Please state below)			

Appendix P

Evaluation Form For Teaching/Learning Spectroscopy
Using MS Excel Spreadsheet
[Students]

Part A: Respondent's Background

Instruction : Please tick ' / ' at the appropriate box provided.

1. Gender Male ☐ Female ☐

2. Race Malay ☐ Chinese ☐
   India ☐ Others ☐

3. Level of computer knowledge

   Very poor ☐
   Poor ☐
   Moderate ☐
   Good ☐
   Very good ☐

4. Do you have a personal computer or laptop?

   Yes ☐ No ☐

5. Have you attended any computer courses before ?

   Yes ☐ No ☐

   If your answer is "Yes", please state the name of the courses you have attended.

   ____

6. Have you ever used computers to solve problems or learning tasks given by your lecturers ?

   Yes ☐ No ☐

   If your answer is "Yes", please tick the program which you use frequently.

MS Word	
MS PowerPoint	
MS Excel	
MS Access	

Other (Please state) ______________________________

Part B:

Instruction : Please tick ‘ / ‘ at the appropriate box provided.

No.	Question	Yes	No
1.	I am surprised to see that EXCEL can be used to learn/teach spectroscopy		
2.	The simulation worksheet is well designed and user friendly		
3.	The simulation worksheet renders visualization of vibration-rotation spectroscopy concept more concretely.		
4.	The worksheet is flexible enough to allow me to explore the important ideas behind rotational and vibrational spectroscopy		
5.	Simulation of pure rotational spectra for various diatomic molecules in the worksheet allows me to better understand how the different parameters in the rotational equation effect the appearance of the spectrum		
6.	Spreadsheet simulation of the vibrational-rotational spectrum allows me to understand clearly that vibrational transitions of a molecule is accompanied by fine rotational transitions.		
7.	The idea of rigid and non-rigid rotor is made clear via this simulation worksheet		
8.	I can understand better the ideas behind rotational and vibrational spectroscopy via the interactive graph animation in the worksheet compared to traditional learning methods.		
9.	Use of EXCEL in learning vibrational and rotational spectroscopy is more convenient and fun compared to learning the concepts from books.		
10.	The use of MS Excel in learning/teaching chemistry should be widely encouraged in schools and universities.		

Appendix Q

BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
KEMENTERIAN PELAJARAN MALAYSIA
ARAS 1-4, BLOK E-8
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA.

Telefon : 03-88846591
Faks : 03-88846579

Ruj. Kami : **KP(BPPDP)603/5/JLD.07(444)**
Tarikh : **08 Julai 2008**

Lee Sui Chin
31, Jalan Jelita
Taman Suliana
70400 Seremban
Negeri Sembilan

Tuan/Puan,

Kelulusan Untuk Menjalankan Kajian Di Sekolah, Institut Perguruan, Jabatan Pelajaran Negeri Dan Bahagian-Bahagian Di Bawah Kementerian Pelajaran Malaysia

Adalah saya dengan hormatnya diarah memaklumkan bahawa permohonan tuan /puan untuk menjalankan kajian bertajuk :

" Excel For Chemistry: Use In Teaching And Learning " diluluskan.

2. Kelulusan ini adalah berdasarkan kepada cadangan penyelidikan dan instrumen kajian yang tuan/puan kemukakan ke Bahagian ini. **Kebenaran bagi menggunakan sampel kajian perlu diperolehi dari Ketua Bahagian/Pengarah Pelajaran Negeri yang berkenaan.**

3. Sila tuan/puan kemukakan ke Bahagian ini senaskah laporan akhir kajian setelah selesai kelak. Tuan/Puan juga diingatkan supaya **mendapat kebenaran terlebih dahulu** daripada Bahagian ini sekiranya sebahagian atau sepenuhnya dapatan kajian tersebut hendak dibentangkan di mana-mana forum atau seminar atau diumumkan kepada media massa.

Sekian untuk makluman dan tindakan tuan/puan selanjut nya. Terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

(DR. SOON SENG THAH)
Ketua Penolong Pengarah
b.p. Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pelajaran Malaysia

Zul/surat kelulusan/08

JABATAN PELAJARAN JOHOR,
JALAN TUN ABDUL RAZAK,
80604 JOHOR BAHRU,
JOHOR DARUL TA'ZIM

Telefon:
Pengarah : 07-2361787
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: 07-2378319
Peperiksaan : 07-2361979
No. Fax : 07-2369084
e_mail : jpnjohor@joh.moe.gov.my.

Ruj. Kami : JPNJ/31/1128/Jld.43 (23)
Tarikh : 12 Ogos 2008

Lee Sui Chin
31, Jalan Jelita,
Taman Suliana,
70400 Seremban,
Negeri Sembilan.

Tuan,

<u>Kelulusan Untuk Menjalankan Kajian Di Sekolah, Institut Perguruan, Jabatan Pelajaran Negeri Dan Bahagian-Bahagian Di Bawah Kementerian Pelajaran Malaysia.</u>

Dengan hormatnya surat daripada KPM bil KP(BPPDP)603/5/Jld.07(444) bertarikh 08 Julai 2008 berkaitan permohonan tuan adalah dirujuk.

2. Sukacita dimaklumkan bahawa Jabatan ini tiada apa-apa halangan bagi membenarkan tuan / puan menjalankan kajian ke sekolah-sekolah **Kerajaan dan Swasta Negeri Johor** bertajuk :

" Excel For Chemistry : Use In Teaching And Learning "

3. Sila hubungi Pengetua / Guru Besar sekolah-sekolah berkenaan bagi mendapatkan maklumat dan tindakan selanjutnya.

4. Sila bawa surat ini semasa membuat kajian.

Sekian, terima kasih.

" BERKHIDMAT UNTUK NEGARA "

Saya yang menurut perintah,

(MOHD. HASSIM BIN SUDIMAN)
Penolong Pendaftar Sekolah dan Guru
Jabatan Pelajaran Negeri Johor.
Ketua Pendaftar Sekolah dan Guru
Kementerian Pelajaran Malaysia.

Kajian/Zulkefli – pg.1

جابتن ڤلاجرن نڬري سمبيلن دارالخصوص

JABATAN PELAJARAN NEGERI
NEGERI SEMBILAN DARUL KHUSUS

JALAN DATO' HAMZAH KARUNG BERKUNCI No. 6
70990 SEREMBAN, NEGERI SEMBILAN DARUL KHUSUS.

Tel : 06-7653100
Fax : 06-7639969

Ruj. Tuan :

Ruj. Kami : JPNS(PPS)2/4/2/1/2008( )

Tarikh : 24 Julai 2008

Lee Sui Chin
No 31 Jalan Jelita
Taman Suliana
70400 Seremban
Negeri Sembilan Darul Khusus

Tuan/Puan,

Kebenaran Menjalankan Kajian Ke Sekolah-Sekolah Di Negeri Sembilan Darul Khusus Di Bawah Kementerian Pelajaran Malaysia

Saya dengan hormatnya di arah memaklumkan bahawa permohonan tuan/puan untuk menjalankan kajian bertajuk:-

" Excel For Chemistry : Use In Teaching And Learning "

telah diluluskan

2. Tuan/Puan hendaklah berjumpa terus dengan Pengetua sekolah berkenaan untuk meminta persetujuan dan membincangkan kajian tersebut seperti berikut:

NAMA SEKOLAH DI LAMPIRKAN

3. Dimaklumkan bahawa kebenaran ini diberi berdasarkan surat kelulusan dari pihak Kementerian Pelajaran Malaysia, Bahagian Perancangan Dan Penyelidikan Dasar Pelajaran, nombor rujukan KP(BPPDP)603/5/Jld.07(444) bertarikh 08 Julai 2008
.

...2/

JABATAN PELAJARAN MELAKA
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Pengarah : 06-2323782
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Pejabat Am : 06-2323776/777/778/779
fax : 06-2320500

Rujukan Fail : JPM.SPS.UPP.100 -11/3 (16)
Tarikh : 30 Julai 2008

Lee Sui Chin
31, Jalan Jelita
Taman Suliana
70400 Seremban
Negeri Sembilan

Tuan / Puan,

KEBENARAN UNTUK MENJALANKAN KAJIAN DI SEKOLAH, MAKTAB PERGURUAN, JABATAN PELAJARAN NEGERI DAN BAHAGIAN-BAHAGIAN DI BAWAH KEMENTERIAN PELAJARAN MALAYSIA

Adalah saya diarah merujuk surat tuan/puan bertarikh 21 Julai 2008 dan surat dari Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, Kementerian Pelajaran Malaysia, KP(BPPDP)603/5/Jld.07(444) bertarikh 08 Julai 2008 mengenai perkara di atas.

2. Sukacita dimaklumkan bahawa Jabatan ini tiada halangan bagi tuan/puan menjalankan kajian seperti yang dinyatakan. Walau bagaimanapun tuan/puan adalah dinasihatkan menghubungi Pengetua/Guru Besar sekolah berkenaan terlebih dahulu untuk berbincang dan mendapatkan persetujuan.

Sekian dimaklumkan, terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

HJ. ZUBIR BIN MOHD.NOR
Ketua Unit Perhubungan Dan Pendaftaran
Jabatan Pelajaran Melaka
B.p Pengarah Pelajaran Melaka

s.k
1. Pengetua, SMK Gajah Berang
2. Pengetua, SMK Tinggi Melaka

Kajian universiti.sps.upp/mno

Appendix R

Frequency Table (Students)

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	253	41.3	41.3	41.3
	Female	359	58.7	58.7	100.0
	Total	612	100.0	100.0	

Race

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Malay	56	9.2	9.2	9.2
	Chinese	450	73.5	73.5	82.7
	India	103	16.8	16.8	99.5
	Others	3	.5	.5	100.0
	Total	612	100.0	100.0	

Grade for chemistry in SPM

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A1	121	19.8	19.8	19.8
	A2	115	18.8	18.8	38.6
	C3	123	20.1	20.1	58.7
	C4	76	12.4	12.4	71.1
	C5	92	15.0	15.0	86.1
	C6	52	8.5	8.5	94.6
	P7	30	4.9	4.9	99.5
	P8	3	.5	.5	100.0
	Total	612	100.0	100.0	

Level of computer knowledge

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very poor	21	3.4	3.4	3.4
	Poor	60	9.8	9.8	13.2
	Moderate	400	65.4	65.4	78.6
	Good	113	18.5	18.5	97.1
	Very good	18	2.9	2.9	100.0
	Total	612	100.0	100.0	

Do you have a personal computer at home?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	497	81.2	81.2	81.2
	No	115	18.8	18.8	100.0
	Total	612	100.0	100.0	

Have you attended any computer course before?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	96	15.7	15.7	15.7
	No	515	84.2	84.2	99.8
	3	1	.2	.2	100.0
	Total	612	100.0	100.0	

Have you ever use computer to solve any problem or task given by your teacher?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	291	47.5	47.5	47.5
	No	321	52.5	52.5	100.0
	Total	612	100.0	100.0	

I like to use Excel worksheets during my learning process

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	492	80.4	80.4	80.4
	No	120	19.6	19.6	100.0
	Total	612	100.0	100.0	

I don't have difficulty in using the Excel worksheets

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	483	78.9	78.9	78.9
	No	129	21.1	21.1	100.0
	Total	612	100.0	100.0	

I become more hardworking and put in more effort after using the computer during my chemistry lessons

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	436	71.2	71.2	71.2
	No	176	28.8	28.8	100.0
	Total	612	100.0	100.0	

Using the Excel worksheets can save a lot of time in solving chemistry problems

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	528	86.3	86.3	86.3
	No	84	13.7	13.7	100.0
	Total	612	100.0	100.0	

It is easier to evaluate interactive graph using the Excel worksheets

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	573	93.6	93.6	93.6
	No	39	6.4	6.4	100.0
	Total	612	100.0	100.0	

Through Excel worksheets, charts can be presented accurately in a short time

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	582	95.1	95.1	95.1
	No	30	4.9	4.9	100.0
	Total	612	100.0	100.0	

It is more convenient and easier to plot graph of concentration over time using the Excel worksheets

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	577	94.3	94.3	94.3
	No	35	5.7	5.7	100.0
	Total	612	100.0	100.0	

I feel very interested and enjoy my chemistry lessons with the Excel worksheets

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	507	82.8	82.8	82.8
	No	105	17.2	17.2	100.0
	Total	612	100.0	100.0	

I remember lessons better after using the Excel worksheets

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	422	69.0	69.0	69.0
	No	190	31.0	31.0	100.0
	Total	612	100.0	100.0	

Excel worksheets has many advantages which can help in the teaching and learning process of chemistry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	546	89.2	89.2	89.2
	No	65	10.6	10.6	99.8
	11	1	.2	.2	100.0
	Total	612	100.0	100.0	

The use of Excel worksheets should be encouraged to a wider area of chemistry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	566	92.5	92.5	92.5
	No	46	7.5	7.5	100.0
	Total	612	100.0	100.0	

Using Excel worksheets in the teaching and learning can encourage discussion among the students and with the teacher

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	529	86.4	86.4	86.4
	No	83	13.6	13.6	100.0
	Total	612	100.0	100.0	

I think Excel worksheets are not suitable to use in chemistry learning

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	190	31.0	31.0	31.0
	No	422	69.0	69.0	100.0
	Total	612	100.0	100.0	

The language and menu in Excel worksheets are easy to understand and user friendly

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	571	93.3	93.3	93.3
	No	41	6.7	6.7	100.0
	Total	612	100.0	100.0	

I have no experience in using Excel worksheets, I am afraid to use it in learning chemistry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	218	35.6	35.6	35.6
	No	394	64.4	64.4	100.0
	Total	612	100.0	100.0	

School name

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SMK King George V	90	14.7	14.7	14.7
	SMK Tunku Ampuan Durah	64	10.5	10.5	25.2
	SMK Seri Ampangan	22	3.6	3.6	28.8
	SMK Dato Mohd Said Nilai	10	1.6	1.6	30.4
	SMK Tunku Besar Tampin	35	5.7	5.7	36.1
	SMK Datuk Mansur Bahau	16	2.6	2.6	38.7
	SMK Tuanku Muhammad Kuala Pilah	10	1.6	1.6	40.4
	SMK Tinggi Muar	85	13.9	13.9	54.2
	SMK Dato Sri Amar Muar	40	6.5	6.5	60.8
	SMK Tinggi Port Dickson	31	5.1	5.1	65.8
	SMK St Paul	109	17.8	17.8	83.7
	SMK Gajah Behrang Melaka	100	16.3	16.3	100.0
	Total	612	100.0	100.0	

Appendix S

Frequency Table (Teachers)

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	8	33.3	33.3	33.3
	Female	16	66.7	66.7	100.0
	Total	24	100.0	100.0	

Race

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Malay	14	58.3	58.3	58.3
	Chinese	10	41.7	41.7	100.0
	Total	24	100.0	100.0	

Option of subject

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Chemistry	19	79.2	79.2	79.2
	Physics	1	4.2	4.2	83.3
	Science	1	4.2	4.2	87.5
	Biology/Chemistry	1	4.2	4.2	91.7
	Mathematics/Chemistry	2	8.3	8.3	100.0
	Total	24	100.0	100.0	

Name of school

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SMK King George V	3	12.5	12.5	12.5
	SMK Ampuan Durah	3	12.5	12.5	25.0
	SMK Sri Ampangan	1	4.2	4.2	29.2
	SMK Dato Mohd Said Nilai	1	4.2	4.2	33.3
	SMK Tunku besar Tampin	2	8.3	8.3	41.7
	SMK Datuk Mansor Bahau	1	4.2	4.2	45.8
	SMK Tuanku Muhammad Kuala Pilah	1	4.2	4.2	50.0
	SMK Tinggi Muar	1	4.2	4.2	54.2
	SMK Dato Sri Amar Diraja Muar	3	12.5	12.5	66.7
	SMK Tinggi Port Dickson	1	4.2	4.2	70.8
	SMK St Paul	3	12.5	12.5	83.3
	12	4	16.7	16.7	100.0
	Total	24	100.0	100.0	

Student use the worksheets actively

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	23	95.8	95.8	95.8
	No	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Excel worksheets are attrative

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	24	100.0	100.0	100.0

Excel worksheets motivates students towards the lesson

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	23	95.8	95.8	95.8
	No	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Learning through Excel worksheets stimulate student to think

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	21	87.5	87.5	87.5
	No	3	12.5	12.5	100.0
	Total	24	100.0	100.0	

Learning through Excel worksheets encourage collaborative discussion among students and also between teacher and student

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	21	87.5	87.5	87.5
	No	3	12.5	12.5	100.0
	Total	24	100.0	100.0	

These worksheets can be used as a reference for revision

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	19	79.2	79.2	79.2
	No	5	20.8	20.8	100.0
	Total	24	100.0	100.0	

Content of worksheets fulfill the objective of lesson

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	23	95.8	95.8	95.8
	No	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Language used in Excel worksheets easy to understand

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	23	95.8	95.8	95.8
	No	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Facts presented with interactive features can deliver the lesson effectively

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	22	91.7	91.7	91.7
	No	2	8.3	8.3	100.0
	Total	24	100.0	100.0	

Appendix T

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
secondarystu_perception * Gender	612	100.0%	0	.0%	612	100.0%

secondarystu_perception * Gender Crosstabulation

			Gender		Total
			Male	Female	
secondarystu_perception	15	Count	33	50	83
		Expected Count	34.3	48.7	83.0
		Std. Residual	-.2	.2	
	16	Count	12	29	41
		Expected Count	16.9	24.1	41.0
		Std. Residual	-1.2	1.0	
	17	Count	87	134	221
		Expected Count	91.4	129.6	221.0
		Std. Residual	-.5	.4	
	18	Count	29	49	78
		Expected Count	32.2	45.8	78.0
		Std. Residual	-.6	.5	
	19	Count	14	30	44
		Expected Count	18.2	25.8	44.0
		Std. Residual	-1.0	.8	
	20	Count	15	20	35
		Expected Count	14.5	20.5	35.0
		Std. Residual	.1	-.1	
	21	Count	18	17	35
		Expected Count	14.5	20.5	35.0
		Std. Residual	.9	-.8	
	22	Count	12	11	23
		Expected Count	9.5	13.5	23.0
		Std. Residual	.8	-.7	
	23	Count	8	7	15
		Expected Count	6.2	8.8	15.0
		Std. Residual	.7	-.6	
	24	Count	5	5	10
		Expected Count	4.1	5.9	10.0
		Std. Residual	.4	-.4	
	25	Count	10	1	11
		Expected Count	4.5	6.5	11.0
		Std. Residual	2.6	-2.1	
	26	Count	3	2	5

		Expected Count	2.1	2.9	5.0
		Std. Residual	.6	-.5	
	27	Count	3	0	3
		Expected Count	1.2	1.8	3.0
		Std. Residual	1.6	-1.3	
	28	Count	1	2	3
		Expected Count	1.2	1.8	3.0
		Std. Residual	-.2	.2	
	29	Count	1	1	2
		Expected Count	.8	1.2	2.0
		Std. Residual	.2	-.2	
	30	Count	2	1	3
		Expected Count	1.2	1.8	3.0
		Std. Residual	.7	-.6	
Total		Count	253	359	612
		Expected Count	253.0	359.0	612.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	25.976(a)	15	.038
Likelihood Ratio	27.975	15	.022
Linear-by-Linear Association	12.374	1	.000
N of Valid Cases	612		

a 12 cells (37.5%) have expected count less than 5. The minimum expected count is .83.

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
secondarystu_perception * Race	612	100.0%	0	.0%	612	100.0%

secondarystu_perception * Race Crosstabulation

			Race				Total
			Malay	Chinese	Indian	Others	
secondarystu_perception	15	Count	10	59	14	0	83
		Expected Count	7.5	61.2	14.0	.4	83.0
		Std. Residual	.9	-.3	.0	-.6	
	16	Count	4	31	6	0	41
		Expected Count	3.7	30.2	6.9	.2	41.0

		Std. Residual	.2	.1	-.3	-.4	
	17	Count	18	158	44	1	221
		Expected Count	19.9	162.9	37.2	1.1	221.0
		Std. Residual	-.4	-.4	1.1	-.1	
	18	Count	12	50	14	2	78
		Expected Count	7.0	57.5	13.1	.4	78.0
		Std. Residual	1.9	-1.0	.2	2.6	
	19	Count	2	33	9	0	44
		Expected Count	4.0	32.4	7.4	.2	44.0
		Std. Residual	-1.0	.1	.6	-.5	
	20	Count	3	25	7	0	35
		Expected Count	3.1	25.8	5.9	.2	35.0
		Std. Residual	-.1	-.2	.5	-.4	
	21	Count	2	30	3	0	35
		Expected Count	3.1	25.8	5.9	.2	35.0
		Std. Residual	-.6	.8	-1.2	-.4	
	22	Count	1	22	0	0	23
		Expected Count	2.1	16.9	3.9	.1	23.0
		Std. Residual	-.7	1.2	-2.0	-.3	
	23	Count	1	13	1	0	15
		Expected Count	1.3	11.1	2.5	.1	15.0
		Std. Residual	-.3	.6	-1.0	-.3	
	24	Count	0	9	1	0	10
		Expected Count	.9	7.4	1.7	.0	10.0
		Std. Residual	-.9	.6	-.5	-.2	
	25	Count	2	9	0	0	11
		Expected Count	1.0	8.1	1.9	.1	11.0
		Std. Residual	1.0	.3	-1.4	-.2	
	26	Count	0	4	1	0	5
		Expected Count	.4	3.7	.8	.0	5.0
		Std. Residual	-.7	.2	.2	-.2	
	27	Count	0	3	0	0	3
		Expected Count	.3	2.2	.5	.0	3.0
		Std. Residual	-.5	.5	-.7	-.1	
	28	Count	0	2	1	0	3
		Expected Count	.3	2.2	.5	.0	3.0
		Std. Residual	-.5	-.1	.7	-.1	
	29	Count	0	1	1	0	2
		Expected Count	.2	1.5	.3	.0	2.0
		Std. Residual	-.4	-.4	1.1	-.1	
	30	Count	0	2	1	0	3
		Expected Count	.3	2.2	.5	.0	3.0
		Std. Residual	-.5	-.1	.7	-.1	
Total		Count	55	451	103	3	612
		Expected Count	55.0	451.0	103.0	3.0	612.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	36.275(a)	45	.820
Likelihood Ratio	42.073	45	.597
Linear-by-Linear Association	.051	1	.821
N of Valid Cases	612		

a 43 cells (67.2%) have expected count less than 5. The minimum expected count is .01.

Appendix U

Frequency Table

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	11	16.2	16.2	16.2
	Female	57	83.8	83.8	100.0
	Total	68	100.0	100.0	

Race

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Malay	64	94.1	94.1	94.1
	Chinese	3	4.4	4.4	98.5
	Indian	1	1.5	1.5	100.0
	Total	68	100.0	100.0	

Level of computer knowledge

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Poor	2	2.9	2.9	2.9
	Moderate	53	77.9	77.9	80.9
	Good	12	17.6	17.6	98.5
	Very good	1	1.5	1.5	100.0
	Total	68	100.0	100.0	

Do you have a personal computer or laptop?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	68	100.0	100.0	100.0

Have you attended any computer courses before?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	35	51.5	51.5	51.5
	No	33	48.5	48.5	100.0
	Total	68	100.0	100.0	

Have you ever used computer to solve problem or learning tasks given by your lectures?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	58	85.3	85.3	85.3
	No	10	14.7	14.7	100.0
	Total	68	100.0	100.0	

Computer program frequently use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MS Word	6	8.8	10.3	10.3
	MS PowerPoint	1	1.5	1.7	12.1
	MS Excel	16	23.5	27.6	39.7
	MS Word, MS PowerPoint & MS Excel	35	51.5	60.3	100.0
	Total	58	85.3	100.0	
Missing	System	10	14.7		
Total		68	100.0		

I am surprised to see that EXCEL can be used to learn/teach spectroscopy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	58	85.3	85.3	85.3
	No	10	14.7	14.7	100.0
	Total	68	100.0	100.0	

The simulation worksheet is well designed and user friendly

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	63	92.6	92.6	92.6
	No	5	7.4	7.4	100.0
	Total	68	100.0	100.0	

The simulation worksheet renders visualization of vibration-rotation spectroscopy concept more concretely

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	60	88.2	88.2	88.2
	No	8	11.8	11.8	100.0
	Total	68	100.0	100.0	

The worksheet is flexible enough to allow me to explore the important ideas behind rotational and vibrational spectroscopy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	55	80.9	80.9	80.9
	No	13	19.1	19.1	100.0
	Total	68	100.0	100.0	

Simulation of pure rotational spectra for various diatomic molecules in the worksheet allows me to better understand how the different parameters in the ratational equation effect the appearance of the spectrum

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	59	86.8	86.8	86.8
	No	9	13.2	13.2	100.0
	Total	68	100.0	100.0	

Spreadsheet simulation of the vibrational-rotational spectrum allow me to understand clearly that vibrational transitions of a molecule is accompanied by fine rotational transition

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	49	72.1	72.1	72.1
	No	19	27.9	27.9	100.0
	Total	68	100.0	100.0	

The idea of rigid and non-rigid rotor is made clear via this simulation worksheet

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	57	83.8	83.8	83.8
	No	11	16.2	16.2	100.0
	Total	68	100.0	100.0	

I can understand better the idea behind rotational and vibrational spectroscopy via the interactive graph animation in the worksheet compared to traditional learning methods

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	51	75.0	75.0	75.0
	No	17	25.0	25.0	100.0
	Total	68	100.0	100.0	

Use of EXCEL in learning vibrational and rotational spectroscopy is more convenient and fun compared to learning the concepts from books

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	58	85.3	85.3	85.3
	No	10	14.7	14.7	100.0
	Total	68	100.0	100.0	

The use of MS Excel in learning/teaching chemistry should be widely encouraged in school and universities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	65	95.6	95.6	95.6
	No	3	4.4	4.4	100.0
	Total	68	100.0	100.0	

Appendix V

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
unistudent_perception * Gender	68	100.0%	0	.0%	68	100.0%

unistudent_perception * Gender Crosstabulation

			Gender		
			Male	Female	Total
unistudent_perception	10	Count	2	24	26
		Expected Count	4.2	21.8	26.0
		Std. Residual	-1.1	.5	
	11	Count	3	8	11
		Expected Count	1.8	9.2	11.0
		Std. Residual	.9	-.4	
	12	Count	3	11	14
		Expected Count	2.3	11.7	14.0
		Std. Residual	.5	-.2	
	13	Count	1	7	8
		Expected Count	1.3	6.7	8.0
		Std. Residual	-.3	.1	
	14	Count	1	4	5
		Expected Count	.8	4.2	5.0
		Std. Residual	.2	-.1	
	15	Count	0	2	2
		Expected Count	.3	1.7	2.0
		Std. Residual	-.6	.2	
	16	Count	1	1	2
		Expected Count	.3	1.7	2.0
		Std. Residual	1.2	-.5	
Total		Count	11	57	68
		Expected Count	11.0	57.0	68.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.871(a)	6	.560
Likelihood Ratio	4.846	6	.564
Linear-by-Linear Association	1.022	1	.312
N of Valid Cases	68		

a 10 cells (71.4%) have expected count less than 5. The minimum expected count is .32.